CHAPTER 4 ENVIRONMENTAL IMPACTS OF CONSTRUCTION

Chapter 4 presents the potential environmental impacts of construction and preconstruction activities for the Clinch River (CR) Small Modular Reactor (SMR) Project, which will include the construction and operation of two or more SMRs at the Clinch River Nuclear (CRN) Site.

As defined in Title 10 of the Code of Federal Regulations (10 CFR) 50.10, "construction" includes activities related to installation of structures, systems, and components related to safety, security, fire protection, or onsite emergency facilities. "Preconstruction" activities include site exploration, preparation for construction (including clearing, grading, and establishment of temporary roads), excavation, and erection of temporary construction support buildings.

As discussed in Section 3.9, the project schedule indicates that completion of preconstruction and construction activities for two or more SMRs would require approximately 6 years (yr). Preconstruction activities will occur over a period of approximately 1 yr and construction activities will continue for an additional approximately 4 to 5 yr.

In accordance with 10 CFR Part 51, impacts are analyzed, and a significance level of potential impact to each resource (i.e., SMALL, MODERATE, or LARGE) is assigned consistent with the criteria that U.S. Nuclear Regulatory Commission (NRC) established in 10 CFR Part 51, Appendix B, Table B-1, Footnote 3. Unless the impact is identified as beneficial, the impact is adverse. In the case of “SMALL,” the impact may be negligible. The definitions of significance are as follows:

SMALL — Environmental effects are not detectable or are so minor that they neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the NRC has concluded that those impacts that do not exceed permissible levels in the NRC’s regulations are considered SMALL.

MODERATE — Environmental effects are sufficient to alter noticeably, but not to destabilize important attributes of the resource.

LARGE — Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

This chapter is divided into seven sections:

- Land Use Impacts (Section 4.1)
- Water-Related Impacts (Section 4.2)
- Ecological Impacts (Section 4.3)
- Socioeconomic Impacts (Section 4.4)
- Radiation Exposure to Construction Workers (Section 4.5)

- Measures and Controls to Limit Adverse Impacts During Construction (Section 4.6)
- Cumulative Impacts Related to Construction Activities (Section 4.7)

These sections present the potential environmental impacts of construction of the CR SMR Project. Impacts are analyzed and a significance level of potential impact to each resource is assigned. In addition, this section presents ways to avoid, minimize, or mitigate adverse impacts of CR SMR Project construction to the maximum extent practical. For the purposes of this Environmental Report, the site, vicinity, and region are defined in Chapter 2.

4.1 LAND USE IMPACTS

The following subsections describe the impacts on land use and historic and cultural resources at the Clinch River Nuclear (CRN) Site and within the 6-mile (mi) vicinity associated with the Clinch River (CR) Small Modular Reactor (SMR) Project. Subsection 4.1.1 describes the effects on the CRN Site and the 6-mi vicinity. Subsection 4.1.3 describes the effects of construction on historic properties and cultural resources.

4.1.1 The Site and Vicinity

The following subsections describe the effects of preconstruction and construction activities on land use at the CRN Site and in the 6-mi vicinity. As described in Section 2.2, the CRN Site is approximately 935 acres (ac). As described in Section 3.1, approximately 30 ac of land off the CRN Site will be permanently impacted by roadway improvements and refurbishment of a barge terminal. Approximately 15 ac of land will be temporarily impacted by construction in the Barge/Traffic Area, which is off the CRN Site. An additional approximately 210 ac of land off the CRN Site will be temporarily impacted by construction of a 69-kilovolt (kV) underground transmission line within the existing Bull Run – Watts Bar 500-kV transmission line right-of-way (ROW). These improvements will occur within the 6-mi site vicinity.

4.1.1.1 The Site

The majority of the CRN Site currently consists of undeveloped areas as described in Subsection 2.2.1.1 and Table 2.2-1. Subsection 2.2.1.1 describes the current conditions at the CRN Site and past land uses and disturbances at the CRN Site, primarily associated with the Clinch River Breeder Reactor Project (CRBRP). Approximately 240 ac of the CRN Site were disturbed during site preparation for the CRBRP (Reference 4.1-1).

The surrogate plant for the Clinch River SMR project is described in Chapter 3. Figure 4.1-1 depicts the CRN Site layout during the construction process and shows the land cover of the areas that will be permanently and temporarily cleared during construction. Section 3.9 describes the construction activities that will occur on and in the vicinity of the CRN Site. The surrogate plant will permanently disturb approximately 327 ac of the CRN Site. An additional 167 ac will be temporarily disturbed during construction for use as laydown areas for staging materials, assembling project components, and installation of the onsite portion of the 69 kV underground transmission line. Table 4.1-1 lists the numbers of acres of each land use type which will be temporarily disturbed and permanently converted. Subsection 4.3.1.2 provides discussion regarding the impacts to wetlands.

Prime farmland at the CRN Site is discussed in Subsection 2.2.1.1. A Farmland Conversion Impact Rating (Form AD-1006) was completed by TVA in consultation with the USDA's Natural Resources Conservation Service to quantify the potential impacts to prime farmland. The impact rating considers the acreage of prime farmland to be converted, the relative abundance of prime farmland in the surrounding county, and other criteria such as distance from urban support services and built-up areas, potential effects of conversion on the local agricultural economy, and compatibility with existing agricultural use. Sites with a total score of at least 160 have the potential to adversely affect prime farmland. The impact rating score for the CRN Site was 102 points (Environmental Report Appendix A). Therefore, the impact of the CR SMR Project on the relative value of farmland would be SMALL.

As stated in Subsection 2.2.1.1, there are no known mineral resources within or adjacent to the CRN Site that are being exploited or are of any known value. The only known mineral resource located within the CRN Site is limestone, which is not currently being exploited. There would be no adverse impacts on mineral resources from preconstruction and construction activities at the CRN Site.

Site preconstruction and construction activities that affect land use on the CRN Site and the associated areas off the CRN Site (i.e., Barge/Traffic Area and underground transmission line ROW) include clearing, grubbing, grading and excavating, stockpiling soils, and onsite disposal of construction-related debris. Materials excavated on the CRN Site would be stockpiled and/or used as fill onsite. Tennessee Valley Authority (TVA) expects to construct and operate an onsite landfill for construction, site clearing, and grading debris. The construction/demolition landfill would be sized to accommodate the anticipated materials and would be located in the permanently cleared laydown area north of the main plant area. The landfill would be constructed in accordance with relevant permits and licenses. No hazardous or municipal waste would be disposed of in this landfill. The landfill would be closed at the end of the construction period. Therefore, land use impacts associated with the onsite landfill would be SMALL.

Prior to commencement of earth-moving activities, appropriate permits and authorizations including coverage under the Tennessee Individual National Pollution Discharge Elimination System (NPDES) Permit for Construction Stormwater Discharges will be obtained and appropriate environmental control measures will be implemented. A site-specific Stormwater Pollution Prevention Plan (SWPPP) will be developed as a part of the permit application to prevent erosion, minimize the discharge of sediments with stormwater, prevent spills and address operation, maintenance, sampling, and reporting using site-specific details and best management practices (BMPs). The BMPs will be implemented in accordance with existing TVA best management practices and may include one or more of the methods described in the State of Tennessee Erosion and Sediment Control Handbook (Reference 4.1-2). Approval under the Construction Stormwater Permit will be in place before site preparation and preconstruction activities commence. Therefore, impacts associated with stormwater are considered to be SMALL.

Construction materials will be shipped to the CRN Site and construction debris and associated waste not placed in the onsite disposal pit will be removed from the Site via road, rail, and/or barge. Bear Creek Road and the U.S. Department of Energy (DOE) road near the Rail Offload Area will be modified to handle heavy haul traffic. The CRN Site Access Road will also be modified to handle heavy haul traffic into the CRN Site. River Road will be improved to handle regular patrol traffic. The DOE former K-25 Power House Area rail siding near the CRN Site, the

Rail Offload Area will be refurbished and stabilized for deliveries. The DOE former K-25 Barge Loading Area between Tennessee State Highway (TN) 58 and the CRN Site entrance will also be refurbished for deliveries. Alternatively, a new barge slip may be constructed. No dredging is anticipated to be required for the barge terminal. These road and barge improvements will occur within the CRN Site vicinity and are discussed in Subsection 4.1.1.2. Impacts to land use associated with roadway modifications on the CRN Site would be SMALL.

Transmission lines are discussed in Subsection 2.2.3 and Section 3.7. The 161 kV transmission line on the CRN Site will be relocated, as shown in Figure 3.7-1. The new location will be within the area designated as permanently disturbed on Figure 4.1-1. Changes to land use due to construction along the transmission corridor will include the removal of trees in the new ROW and the re-clearing of the existing transmission line ROWs. Additional information on transmission corridors is discussed in Section 5.6. Impacts to land use associated with construction of the new onsite 161 kV transmission line corridor would be SMALL.

Areas that are temporarily disturbed during preconstruction and construction activities will be rehabilitated and restored to a condition similar to their present land cover. Permanently disturbed locations will either be part of the plant itself or will be stabilized and contoured in accordance with plant design specifications and in compliance with applicable safety and permit requirements, regulations, and standard practices. As described previously, stormwater will be managed and controlled in accordance with a site-specific SWPPP. The impact on erosion and sedimentation on surface waters at the CRN Site and in the vicinity would be SMALL.

The Clinch River arm of the Watts Bar Reservoir surrounds the CRN Site on three sides. The Clinch River arm of the Watts Bar Reservoir in this area is not designated as a national wild or scenic river (Reference 4.1-3). As described in Subsection 2.5.2, currently limited hunting has been allowed on the CRN Site under a revised agreement between DOE and the Tennessee Wildlife Resources Agency (TWRA) that incorporated the CRN Site into the Oak Ridge Wildlife Management Area managed-hunt program for deer and wild turkey. After the commencement of construction activities on the CRN Site, hunting will no longer be allowed on the CRN Site. Additional information discussing recreational opportunities is provided in Subsection 2.5.2.5.

Zoning ordinances in Roane County and the City of Oak Ridge, Tennessee, are discussed in Subsections 2.2.1.2 and 2.5.2.4. The majority of the CRN Site is designated as Zone 2 – Project Operations. A strip along the reservoir shoreline is designated Zone 3 – Sensitive Resource Management. The Grassy Creek HPA (adjacent to the CRN Site) is also designated Zone 3 – Sensitive Resource Management/Natural Area. (Reference 4.1-4) The CR SMR project will attempt to follow all zone designations in its site planning. Should implementation of the CR SMR Project at the CRN Site conflict with existing zone allocations, TVA will follow its reservoir land management process to request modification of the CRN Site zones as appropriate. Impacts on land use associated with zoning would be SMALL.

There are no national wild and scenic rivers or recreational opportunities located on the CRN Site, and there are no zoning conflicts that affect the Site. Impacts on recreational types of land use would be SMALL.

Contacted tribes and tribal lands are discussed in Subsection 2.5.3.2. No concerns regarding the construction on the CRN Site have been received from the contacted tribes. As a result, the effects on tribal lands would be SMALL.

As discussed in Section 2.9, there are no related federal project activities within the CRN Site which will affect construction or operation. Therefore, effects on land within the CRN Site due to related projects would be SMALL.

4.1.1.2 The Vicinity

The vicinity of the CRN Site is defined as the area within a 6-mi radius of the center point of the surrogate plant. Land use in the vicinity of the CRN Site is described in detail in Subsection 2.2.1.2, summarized in Table 2.2-1, and shown in Figure 2.2-4. Land use outside the CRN Site but within the 6-mi radius is discussed in this subsection.

As part of the preconstruction and construction activities for the CR SMR Project, land off the CRN Site will be impacted by roadway improvements and refurbishment of a barge terminal in the Barge/Traffic Area, which extends from the CRN Site entrance northwest to encompass the ramp on the west side of TN 58 at Bear Creek Road (Figure 4.1-1). Approximately 30 ac of land in the Barge/Traffic Area will be permanently impacted, and approximately 15 ac of land will be temporarily impacted by the improvements in this area. Table 4.1-1 provides the numbers of acres of each land use type which will be temporarily disturbed and permanently converted by construction activities in the Barge/Traffic Area. Subsection 4.3.1.2 provides additional discussion regarding the impacts to wetlands.

As discussed in Subsection 4.1.1.1, there are no first-class or prime farmland soils within the Barge/Traffic Area and underground transmission line ROW. Therefore, the impact of the CR SMR Project on the relative value of farmland in the CRN Site vicinity will be SMALL.

As discussed in Subsection 4.1.1.1, the only known mineral resource within or adjacent to the CRN Site vicinity is limestone, which is not currently being exploited. Impacts of construction on mineral resources in the CRN Site vicinity would therefore be SMALL.

The road and highway system in Roane, Loudon, Anderson, and Knox counties is shown in Figure 2.5.2-1 and discussed in Subsection 2.5.2.2. Information pertaining to the effects of construction workers on the local road and highway system is presented in Subsections 4.4.2.3. Modifications to the existing ramp from TN 58 to Bear Creek road and construction of a new ramp connecting TN 58 to Bear Creek Road on the east side of TN 58 as part of the CR SMR Project is anticipated. This road and the ramps are shown in Figure 3.1-1. No bridge work will be anticipated as part of the CR SMR Project. Refurbishment of a barge terminal on the Clinch

River arm of the Watts Bar Reservoir is anticipated to allow the transport of heavy equipment and reactor components to the CRN Site. The impact on local roadways and waterborne transportation facilities would be MODERATE.

Figure 2.1-1 shows railways within the CRN Site region and Figure 2.1-2 shows railways within the 6 mi vicinity. Norfolk Southern rail lines are located approximately 7.5 mi northwest and 9 mi southeast of the CRN Site. The line to the southeast runs through Knoxville, Tennessee, connecting Chattanooga, Tennessee, with Johnson City and Kingsport, Tennessee. The nearest rail spur (Energy Solutions Heritage Railroad) is located 2.5 mi north-northwest of the CRN Site center point. This rail line will be utilized to transport materials in support of construction. The impact of construction on the rail line would be SMALL.

Transmission lines are discussed in Subsection 2.2.3 and Section 3.7. Service lines provide electrical power to the CRN Site for construction. A new 69 kV underground transmission line will be constructed from the CRN Site to the Bethel Valley substation within the existing 500 kV transmission line ROW as shown in Figure 3.7-2. Changes to land use due to construction along the transmission corridors could include the re-clearing of existing transmission line ROWs. Additional information on transmission corridors is discussed in Section 5.6. Impacts to land use associated with construction of the transmission line corridor would be SMALL.

Numerous locations within the CRN Site vicinity provide recreational opportunities; these facilities are discussed in Subsection 2.5.2.5.2. Offsite construction areas are limited in extent and do not intersect with any of these recreational areas or facilities. Therefore, impacts of construction on these recreational areas and facilities would be SMALL.

The Clinch River arm of the Watts Bar Reservoir is not designated a national wild and scenic river in the CRN Site vicinity, nor are any of the other rivers in the CRN Site vicinity (Reference 4.1-3). Thus, there will be no effects from construction on any national wild and scenic rivers in the vicinity of the CRN Site. Additional information about the Clinch River arm of the Watts Bar Reservoir can be found in Section 2.3.

Section 2.9 discusses the related federal project activities within the CRN Site vicinity which will affect preconstruction and construction activities. Impacts on other federal project activities from construction are considered to be SMALL.

4.1.2 Transmission Corridors and Offsite Areas

Transmission lines are discussed in Subsection 2.2.3 and Section 3.7. Impacts associated with onsite transmission line changes and the new underground 69 kV transmission line are described in Subsections 4.1.1.1 and 4.1.1.2 respectively. As described in Section 3.7, several offsite transmission lines in the region will be uprated. Changes to offsite land use due to construction along the transmission corridors will include the re-clearing of the existing transmission line ROWs. Additional information on transmission corridors is discussed in

Section 5.6. Impacts to offsite land use associated with uprating transmission lines would be SMALL.

As discussed in Subsection 2.2.3, fill material will be required for the CRN Site. In addition to potentially using borrow material from the CRN Site, offsite borrow sources may be used. The volume of fill material and selection of the source for fill material will be dependent on the backfill plan and the required material properties identified by analyses performed in support of the combined license application (COLA). Material excavated from portions of the CRN Site will be evaluated in accordance with the backfill plan to determine whether the material provides characteristics and quantities needed for use as fill on the site. If additional fill material is needed from offsite, the borrow source(s) will be selected based on the properties and quantities of fill material available at the potential source locations. The soil quality at each potential borrow site will be required to meet the criteria for acceptability for use as fill material at the CRN Site. Nine possible offsite borrow areas have been identified and are shown in Figure 2.2-8. The total acreage of these nine potential borrow sites is 227 ac. The combined volume of fill material present in the disturbed and fully permitted offsite borrow areas is anticipated to meet the volume of fill that would be needed for the CR SMR Project. Therefore, it is unlikely that any existing borrow areas would need to be expanded beyond currently permitted boundaries or that any new borrow areas would need to be opened to accommodate the CR SMR Project.

If material excavated on the CRN Site is not suitable for fill, it will be disposed of in accordance with TVA's waste management program and regulatory requirements or, if appropriate, in the onsite landfill. In Tennessee, borrow areas are subject to permitting under the State Stormwater Pollution Prevention regulations, Aquatic Resource Alteration Regulations depending upon proximity to aquatic resources, and state mining regulations, if applicable, depending upon the material to be excavated. Each of these state permitting programs includes environmental protection requirements that must be met during operation of the borrow area facilities. Based on compliance with these permitting programs and the expected availability of sufficient borrow material from existing borrow sites, land use impacts associated with the potential use of borrow areas would be SMALL.

4.1.3 Historic Properties

This subsection focuses on the potential for the CR SMR Project construction to affect historic properties within the CRN Site, within 0.5-mi of the CRN Site (including the Barge/Traffic Area), at the Melton Hill Dam, and within 0.5 mi of the Melton Hill Dam. Archaeological sites and aboveground historic properties are among the properties that can be considered for listing on the National Register of Historic Places (NRHP). They are the principal historic properties of concern with regard to effects from CRN Site construction, along with traditional cultural properties. (Subsection 2.5.3, Tables 2.5.3-1 and 2.5.3-2, and Figures 2.5.3-1 and 2.5.3-2 present the site numbers, locations, and NRHP status of relevant historic properties within the 10-mi radius of the CRN Site center point, which includes the Melton Hill Dam.) Direct effects from CR SMR Project construction to historic properties are possible within the CR SMR Project area of potential effect (CR SMR Project APE). The CR SMR Project APE is described in Subsection 2.5.3.

As described in Subsection 2.5.3, no NRHP-listed properties are located on or immediately adjacent to the CRN Site or the Barge/Traffic Area. One NRHP eligible National Register Historic District (NRHD) is located within the CR SMR Project APE. Fifty-nine recorded archaeological sites, four isolated finds, one non-site locality, and one cemetery have been identified within or immediately adjacent to the CR SMR Project APE. Of these sites, one is considered eligible for listing on the NRHP; 16 are considered potentially eligible for the NRHP; and 42 are considered not eligible for the NRHP. Ten of the eligible and potentially eligible sites are avoidable. Within the CRN Site, sites 40RE0107, 40RE0595, 40RE0549, 40RE0104, and 40RE0105 will potentially be impacted by CR SMR Project preconstruction and construction activities. In the Barge/Traffic Area, sites 40RE138 and 40RE233, may be affected by CR SMR Project preconstruction and construction activities. Within the CR SMR Project APE, the Melton Hill Dam will potentially be impacted by CR SMR Project preconstruction and construction activities.

To avoid, minimize, and mitigate potential effects to historic properties, TVA has executed a Programmatic Agreement (PA) pursuant to 36 CFR 800.14(b)(3), the signatories are: TVA and the Tennessee State Historic Preservation Officer (SHPO). Invited concurring parties are the Eastern Band of the Cherokee Indians and the United Keetoowah Band of the Cherokee Indians in Oklahoma. The PA records the terms and conditions agreed upon to resolve potential adverse effects of the undertaking. It provides for modifications to the CR SMR Project APE, evaluating the NRHP eligibility of unevaluated resources (archaeological sites and historic architectural resources), evaluating project effects to resources, and resolution of adverse effects. The current PA is in effect until construction of the SMR project is complete or the undertaking is otherwise terminated (Reference 4.1-5). The following paragraphs describe the stipulations in the PA to avoid, minimize, and mitigate potential effects to historic properties within the CR SMR Project APE.

As stipulated in the PA, the CR SMR Project APE will remain as defined unless TVA determines, in consultation with the Tennessee SHPO, that final project plans warrant revisions to better delineate the area in which there is a potential for effects on historic properties. If project plans result in activities that would disturb soils or sediments to depths greater than the maximum depth investigated previously during the archaeological surveys of the CR SMR Project APE (approximately 80 centimeters/31 inches), in areas with potential for deeply buried cultural deposits, the CR SMR Project APE would be enlarged in the vertical dimension in those areas to include deposits not previously investigated that could be affected by the undertaking. Should the CR SMR Project APE be revised in either the vertical and/or horizontal direction, TVA would undertake any additional steps necessary to identify historic properties within the revised CR SMR Project APE. Such steps could include additional Phase I surveys. (Reference 4.1-5)

TVA, in consultation with the Signatories of the PA, shall seek ways to avoid adverse effects to properties determined eligible for inclusion in the NRHP whenever economically prudent and technically feasible. To the extent practical, TVA will:

- Avoid locating any project elements within the identified boundaries of NRHP-eligible historic properties
- Mark or delineate sensitive archaeological areas and define any special conditions placed on such areas located within the CR SMR Project APE on the plans to be used during construction
- Avoid locating any transmission line structure, substation, building, or infrastructure within the viewshed of any NRHP-eligible historic architectural resource (Reference 4.1-5)

After the SMR technology is selected and the facility layout is finalized, Phase II (site evaluation) consultations with the Tennessee SHPO, and federally recognized Native American tribes that attach religious and cultural significance to the historic property affected by the undertaking, will be conducted for any undetermined potentially eligible or eligible sites that cannot be avoided. After the investigation, if the TVA and the Tennessee SHPO agree that the property meets NRHP criteria, the property shall be considered eligible for inclusion in the NRHP. TVA would, then, continue to seek ways to avoid adverse effects to the property. If the property is found not eligible for the NRHP, TVA shall notify the Signatories of the PA and make the documentation available for public inspection pursuant to 36 CFR 800.4(d)(1). Provisions for resolving disagreements on eligibility are provided in the PA. (Reference 4.1-5) A final assessment of effects on such properties identified as “potentially eligible” or of “undertermined” eligibility for the NRHP, and any required mitigation, are dependent on the outcome of the Phase II testing, in consultation with the Tennessee SHPO and federally recognized Native American tribes that attach religious and cultural significance to the historic property.

If TVA, in consultation with the Signatories of the PA, determines that avoidance of NRHP-eligible properties is not possible, TVA shall notify and invite the Advisory Council on Historic Preservation to participate with the Signatories of the PA in establishing a course of action for minimization and mitigation of effects on such properties. TVA will consult with the Signatories of the PA to minimize effects to the extent realistically possible. If both avoidance and minimization are not possible, TVA will develop treatment measures for mitigation of adverse effects. TVA shall consult with the Signatories to reach agreement on appropriate mitigation measures. For NRHP-eligible archaeological sites, mitigation shall consist of data recovery. TVA will develop a Data Recovery Plan, written by a qualified professional archaeologist, that meets Secretary of the Interior standards. The Data Recovery Plan shall be developed consistent with the applicable provisions in 36 CFR 800.5 and 800.16, the standards set forth in Archeology and Historic Preservation: Secretary of Interior’s Standards and Guidelines, and the standards set forth in the Tenness SHPO Standards and Guidelines for Archaeological Resource Management Studies (March 2009 revision). TVA will distribute the Data Recovery Plan to the Signatories for concurrence. The Data Recovery Plan shall specify, at a minimum:

- The property, properties, or portions of properties where data recovery is to be carried out
- Any property, properties, or portions of properties that will be destroyed without data recovery
- The research questions to be addressed through data recovery, with an explanation of their relevance and importance
- The field and laboratory methods to be used, with an explanation of their relevance to the research questions
- The methods to be used in analysis, data management, and dissemination of data
- A schedule for implementation of the above parts of the Plan
- The curation facility selected by TVA, in consultation with the Tennessee SHPO, and the procedures for curation of the recovered materials and records consistent with the curation standards prescribed in 36 CFR Part 79 (except for human remains)
- Procedures for the treatment of any human remains discovered within the CR SMR Project APE as a consequence of implementation of the Data Recovery Plan
- Proposed methods for involving the interested public in data recovery and for disseminating results of the work to the interested public
- A proposed schedule for the submission of progress reports to the Tennessee SHPO (Reference 4.1-5)

In the event of potential impacts to historic architectural properties (historic district, site, building, structure, or object), mitigation would be developed in consultation with the Signatories of the PA. Mitigation measures could include, but are not limited to:

- Vegetation screening
- Historic American Building Survey (HABS) or Historic American Engineering Record (HAER) equivalent documentation
- Preparation of a Tennessee Historical and Architectural Resource form
- National Register of Historic Places nomination
- Interpretative panels presenting summary historical information about the resource in a location accessible for public viewing
- Presentation of historical research paper at a public meeting or professional conference (Reference 4.1-5)

TVA will adhere to and comply with the stipulations of the PA. Because there is the potential for undiscovered resources and human remains and because the extent of effects to those undiscovered resources is unknown, impacts to historic properties as a result of preconstruction and construction activites associated with the CR SMR Project would be SMALL to

MODERATE. Implementation of the mitigation measures as stipulated in the PA would minimize the potential for LARGE impacts to historic properties.

4.1.3.1 Prehistoric and Historic Archaeological Sites

Archaeological sites may be adversely affected by the construction of the CR SMR Project. As described previously, final assessment of effects to archaeological sites within the CR SMR Project APE and any required mitigation are dependent on the outcome of the Phase II testing/reporting conducted in consultation with the SHPO and federally recognized Native American tribes that attach religious and cultural significance to the historic property. Project effects to archaeological sites determined in consultation to be eligible for listing in the NRHP would be treated pursuant to mitigation measures developed in consultation with the consulting parties. As described previously, because there are the potential for undiscovered resources and human remains and because the extent of effects to those undiscovered resources is unknown, impacts to archaeological sites as a result of preconstruction and construction activites associated with the CR SMR Project would be SMALL to MODERATE. Implementation of the mitigation measures as stiupated in the PA would minimize the potential for LARGE impacts to archaeological sites.

With preconstruction and construction activities, there is the possibility for the inadvertent discovery of previously unknown archaeological resources or human remains. The PA describes the measures that will be implemented in the event of such discoveries. Should previously unknown archaeological resources be discovered, sites will be protected and stabilized to prevent any further disturbance. Ground-disturbing work will stop within a 50-foot (ft) radius of the discovery. TVA, in consultation with the SHPO and federally recognized Native American tribes that attach religious and cultural significance to the property affected by the undertaking, would develop and implement a discovery plan to make an informed NRHP eligibility determination. TVA would continue to fulfill all stipulations of the PA and its obligations under Section 106. Ground-disturbing work would not resume at the previously unknown site until completion of the NRHP determination and PA signatory consultation. (Reference 4.1-5)

In the event of discovery of human remains as a result of preconstruction and/or construction activities, TVA will implement the following measures. TVA will:

- Ensure that the treatment of any human remains complies with all state and federal laws concerning archaeological sites and treatment of human remains
- Immediately cease all-ground disturbing activities within a 10-ft radius of the burial
- Notify the Roane County Coroner and the Tennessee SHPO within 24 hours (hr)
- Notify the Signatories of the PA and potentially culturally affiliated federally-recognized tribal governments within 72 hr and invite them to comment on any plans developed to treat the human remains

- Ensure that the remains are treated in a manner consistent with the Advisory Council on Historic Preservation's *Policy Statement Regarding Treatment of Burial Sites, Human Remains, and Funerary Objects* (2007) and will be conducted in accordance with the applicable provisions of Tennessee Code Annotated (T.C.A.) 46-4-101 et seq. (*Termination of Use of Land as a Cemetery*); T.C.A. 11-6-116 (*Excavation of Areas Containing Native American Indian Remains*); T.C.A. 11-6-119 (*Reburial of Human Remains or Native American Burial Objects Following Discovery or Confiscation*); and Tennessee Rules and Regulations Chapter 0400-9-1 (*Native American Indian Cemetery Removal and Reburial*) (Reference 4.1-5)

4.1.3.2 Historic Structures

As discussed in Subsection 2.5.3.7.2, one eligible nominated NRHD, the Melton Hill Hydroelectric Project/Melton Hill Dam was identified within the CR SMR Project APE. As described in Subsection 3.4.2.5, TVA has identified the potential need for a future minor modification to the flow of the Clinch River in the CR SMR Project vicinity. An increase in flow of up to 400 cubic feet per second (cfs) may be needed to regulate water temperatures in the Clinch River arm of the Watts Bar Reservoir during times of low water levels, depending on the reactor design ultimately selected for the site. The magnitude of the change would be small compared to the average unregulated flow of 4520 cfs at Melton Hill Dam, approximately 3.5 river miles upstream of the intake location. TVA is considering a number of alternatives for providing this additional flow. Some of the alternatives could require changes at Melton Hill Dam. Project designs would not be proposed until a reactor design is selected. The Melton Hill Dam (including the spillway) is a contributing structure to the Melton Hill Hydroelectric Project nominated NRHD. TVA will adhere to and comply with the stipulations of the PA with respect to modifications of the Melton Hill Dam. Therefore, impacts to historic structures as a result of preconstruction and construction activities associated with the CR SMR Project would be SMALL to MODERATE. Implementation of the mitigation measures as stipulated in the PA would minimize the potential for LARGE impacts to historic structures.

4.1.3.3 Cemeteries

One cemetery, the Hensley Cemetery, exists on the CRN Site. As discussed in Subsection 2.5.3.9, this cemetery is not eligible for the NRHP. TVA has determined that this cemetery will remain in place onsite and that families will be able access the cemetery (Reference 4.1-6). Therefore, impacts to the Hensley Cemetery would be SMALL.

4.1.3.4 Traditional Cultural Properties

As discussed in Subsection 2.5.3.10, no traditional cultural properties have been identified in consultation with federally recognized Native American tribes that attach religious and cultural significance to an archaeological historic property, or any other interested parties on the CRN Site, or within a 0.5-mi radius from the CRN Site.

4.1.4 References

Reference 4.1-1. U.S. Department of Energy, "Clinch River Breeder Reactor Plant Project Site Redress Plan," March, 1984.

Reference 4.1-2. Tennessee Department of Environment and Conservation, "Tennessee Erosion & Sediment Control Handbook - Fourth Edition," August, 2012.

Reference 4.1-3. National Park Service, Tennessee Segments of the National River Inventory, Website: http://www.nps.gov/ncrc/programs/rtca/nri/states/tn.html, January 18, 2007.

Reference 4.1-4. Tennessee Valley Authority, "Final Environmental Impact Statement Watts Bar Reservoir Land Management Plan Loudon, Meigs, Rhea, and Roane Counties, Tennessee," February, 2009.

Reference 4.1-5. Tennessee Valley Authority and Tennessee State Historic Preservation Officer, "Programmatic Agreement between the Tennessee Valley Authority and the Tennessee State Historic Preservation Office regarding the management of historic properties affected by the Clinch River SMR Project," July 20, 2016.

Reference 4.1-6. AECOM, "Final Clinch River Site Land Use and Recreation Technical Report - Revision 2," Greenville, SC, Tennessee Valley Authority, October, 2014.

Table 4.1-1 (Sheet 1 of 2)
Land Cover Types to be Disturbed by Development on the CRN Site

Land Cover Type	Approximate Acreage Affected	Percentage of Disturbed Areas	Total Acreage on the CRN Site	Percent of Land Cover Type Distrubed on the CRN Site
CRN Site - Temporarily Disturbed Areas				
Barren Land (Rock/Sand/Clay)	6	4	20	30
Cultivated Crops	0	0	8	0
Deciduous Forest	55	33	320	17
Developed, High Intensity	0	0	1	0
Developed, Medium Intensity	0	0	6	0
Developed, Low Intensity	0	0	19	0
Developed, Open Space	0	0	42	0
Emergent Herbaceous Wetlands	0	0	0	0
Evergreen Forest	13	8	67	19
Grassland/Herbaceous	7	4	26	27
Mixed Forest	6	4	62	10
Open Water	0	0	16	0
Pasture/Hay	64	38	245	26
Shrub/Scrub	11	6	20	55
Woody Wetlands	5	3	83	6
Total:	167	100	935	NA
CRN Site - Permanently Disturbed Areas				
Barren Land (Rock/Sand/Clay)	14	4	20	70
Cultivated Crops	7	2	8	88
Deciduous Forest	78	24	320	24
Developed, High Intensity	0	0	1	0
Developed, Medium Intensity	4	1	6	67
Developed, Low Intensity	14	4	19	74
Developed, Open Space	17	5	42	40
Emergent Herbaceous Wetlands	0	0	0	0
Evergreen Forest	14	4	67	21
Grassland/Herbaceous	16	5	26	62
Mixed Forest	14	4	62	23
Open Water	1	1	16	6
Pasture/Hay	122	37	245	50
Shrub/Scrub	4	2	20	20
Woody Wetlands	22	7	83	27
Total:	327	100	935	NA

Table 4.1-1 (Sheet 2 of 2)
Land Cover Types to be Affected by Development on the CRN Site

Land Cover Type	Approximate Acreage Affected	Percentage of Affected Areas	Total Acreage in the Barge/Traffic Area	Percent of Land Cover Type Affected in the Barge/Traffic Area
Barge/Traffic Area - Temporarily Disturbed Areas				
Barren Land (Rock/Sand/Clay)	0	0	1	0
Cultivated Crops	1	7	4	25
Deciduous Forest	10	66	102	10
Developed, High Intensity	0	0	2	0
Developed, Medium Intensity	4	27	16	25
Developed, Low Intensity	0	0	21	0
Developed, Open Space	0	0	4	0
Emergent Herbaceous Wetlands	0	0	2	0
Evergreen Forest	0	0	7	0
Grassland/Herbaceous	0	0	1	0
Mixed Forest	0	0	0	0
Open Water	0	0	9	0
Pasture/Hay	0	0	28	0
Shrub/Scrub	0	0	0	0
Woody Wetlands	0	0	9	0
Total:	15	100	203	NA
Barge/Traffic Area - Permanently Disturbed Areas				
Barren Land (Rock/Sand/Clay)	0	0	1	0
Cultivated Crops	2	7	4	50
Deciduous Forest	7	24	102	7
Developed, High Intensity	0	0	2	0
Developed, Medium Intensity	6	20	16	38
Developed, Low Intensity	7	24	21	33
Developed, Open Space	3	10	4	75
Emergent Herbaceous Wetlands	0	0	2	0
Evergreen Forest	1	2	7	14
Grassland/Herbaceous	0	0	1	0
Mixed Forest	0	0	0	0
Open Water	0	0	9	0
Pasture/Hay	3	11	28	11
Shrub/Scrub	0	0	0	0
Woody Wetlands	1	2	9	11
Total	30	100	203	NA

Note: NA = Not applicable

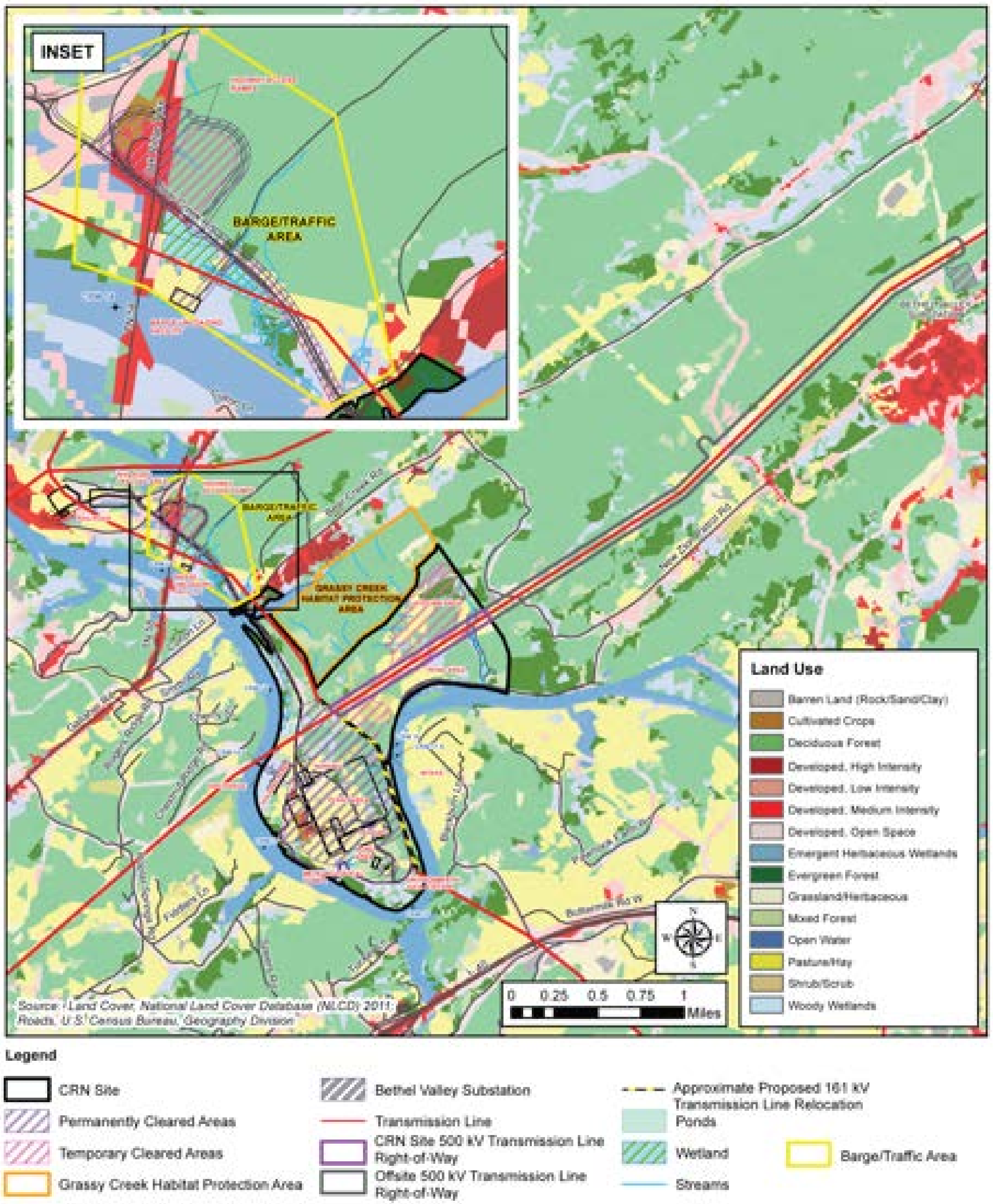

Figure 4.1-1. Areas to be Cleared and Land Cover Disturbed on the CRN Site Vicinity

4.2 WATER-RELATED IMPACTS

This section describes water-related impacts that could result from construction and preconstruction activities for the Clinch River (CR) Small Modular Reactor (SMR) Project. Subsection 4.2.1 addresses hydrologic alterations, Subsections 4.2.2 and 4.2.3 address water use impacts and water quality impacts, respectively.

Potential water-related impacts from construction of a nuclear power plant could include:

- Direct physical alteration of local streams and wetlands
- Indirect physical alteration of receiving surface water bodies, especially streams, due to increased runoff volumes and rates during construction or diversions of runoff
- Alteration of surface water quality as a result of erosion and sedimentation
- Discharges of pollutants associated with construction activities
- Changes in groundwater flow patterns from dewatering and soil retention management practices
- Downgradient groundwater quality changes from spills of fuels and lubricants used in construction equipment
- Increased groundwater use during construction

The following subsections describe the anticipated construction-related impacts to both surface water and groundwater resources.

4.2.1 Hydrological Alterations

This subsection identifies and describes the hydrological alterations that could result from construction of SMRs at the Clinch River Nuclear (CRN) Site. The following preconstruction and construction activities have the potential to impact the hydrology at the CRN Site:

- Clearing land and installing infrastructure such as roads and stormwater conveyance and retention systems
- Raising the surface grade
- Constructing new buildings and structures (reactor containment structure, turbine building, cooling towers, electrical substation, sub-grade piping and systems), roads, rails, parking lots
- Constructing transmission towers
- Constructing cooling water intake and discharge structures on the shoreline and into the reservoir
- Placing the diffuser in the reservoir

- Disturbing currently vegetated areas and wetlands for construction laydown areas, concrete batch plants, sands/gravel stockpiles and construction-phase parking areas
- Dewatering foundation excavations during construction
- Improving rail siding and barge terminal

4.2.1.1 Surface Water

Surface water could potentially be impacted by land-based construction activities such as building and infrastructure construction or water-based construction activities such as barge terminal improvements and excavations along the shoreline in the intake and discharge areas. The potential surface water hydrological impacts of these activities would be SMALL as described below.

4.2.1.1.1 Land-Based Construction

Land-based preconstruction and construction activities for Tennessee Valley Authority (TVA) projects, including site grading, access road improvements, transmission line installation, power block excavation, and building construction, are conducted in accordance with all applicable federal, state and local regulations, and TVA procedures.

As discussed in Subsection 4.1.1.1, anticipated construction and preconstruction activities on the CRN Site include clearing, grubbing, grading and excavating, and stockpiling soils. Materials excavated on the CRN Site are to be stockpiled and/or used as fill onsite. Prior to commencement of earth-moving activities, TVA obtains all appropriate permits and authorizations and appropriate environmental control measures are implemented. As part of the application for a National Pollutant Discharge Elimination System (NPDES) permit, TVA will submit a Notice of Intent (NOI) for Construction Activity Stormwater Discharges and an associated Stormwater Pollution Prevention Plan (SWPPP) to the Tennessee Department of Environment and Conservation (TDEC). SWPPPs are implemented to minimize the discharge of sediments and other pollutants with stormwater. The NPDES permit will be obtained before any construction activities take place.

In addition to the Clinch River arm of the Watts Bar Reservoir, there are four perennial streams, one intermittent stream, and 19 ephemeral streams/wet-weather conveyances (WWCs) on the CRN Site (Figure 2.4.1-2; (Reference 4.2-1)). The current footprint of the land-based construction likely would directly impact one small perennial stream (S01) and 11 WWCs. Stream S01 and six of these WWCs are within the footprint of the areas to be permanently developed and would be removed. Portions of five WWCs are within the area in the northeast portion of the CRN Site to be temporarily developed then revegetated and restored following completion of construction.

In order to minimize the potential surface water impacts, soil stockpiles and disturbed areas are stabilized using best management practices (BMPs) in accordance with design specifications.

Revegetation activities required by applicable soil erosion and sediment control permits would be conducted in accordance with site maintenance and safety requirements. As stated in Subsection 3.9.2.1, drainage control measures for the spoils piles may include berms, riprap, sedimentation filters, and detention ponds. Land-based construction-related discharges would be managed in accordance with the CRN Site's SWPPP and NPDES permit for discharges of stormwater associated with construction activities. BMPs and engineered site drainage structures are used to control run-off. Existing and additional stormwater retention ponds would moderate the increased runoff from impervious structures and surfaces and allow infiltration to reduce runoff directly into the reservoir. This would limit stormwater flow rates into the reservoir and associated increases in stormwater discharges during high intensity precipitation events. Assuming the implementation of effective stormwater controls and given the small size of the single perennial stream that would be lost, effects on hydrology are expected to be so minor that they neither destabilize nor noticeably alter any important attribute of the surface water resources of the area. Therefore, the hydrological impacts on surface water from land-based construction would be SMALL.

4.2.1.1.2 Water-Based Construction

As discussed in Subsection 3.9.2.11, no dredging would be required for the project. However, there would be underwater excavation required along the shoreline, for construction of the intake structure. In addition, underwater excavation would be required to bury the diffuser pipe at the discharge. The Lower Clinch River sediments are listed as impaired for mercury, polychlorinated biphenyl (PCBs), and chlordane. Additional legacy contamination present in the portion of the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site includes radionuclides from U.S. Department of Energy (DOE) activities.

As shown in Table 1.2-2, a Clean Water Act Section 404 permit for disturbance of wetlands and navigable waters, and a Rivers and Harbors Act Section 10 permit for construction within navigable waters, are among the authorizations and permits that will be obtained, if applicable. In addition to obtaining and complying with the conditions of these permits, TVA is party to an Interagency Agreement, along with the U.S. Army Corps of Engineers (USACE), DOE, TDEC, and the U. S. Environmental Protection Agency (EPA), to coordinate review of permitting and other use authorization activities which could result in the disturbance, re-suspension, removal, and/or disposal of contaminated sediments in the reservoir. The agreement, signed in 1991, defines how each agency coordinates with the others to review proposed activities to determine their potential to disturb contaminated sediments. (Reference 4.2-5) TDEC requires monitoring of sediment in the area(s) where disturbance of sediment is proposed. In addition, Section 404 and Section 10 permit conditions intended to ensure that activities which disturb sediments do not further degrade surface water quality will be followed. Any sediment removed may also contain manmade radionuclides; therefore coordination of the disposition of the sediment with DOE is also anticipated.

Burial of diffusers and construction of intake and discharge structures may cause localized changes in surface water flow patterns. However, water-based construction of the intake structure is expected to be limited to an area along the shoreline, and burial of the diffuser pipe would involve only temporary modification of the river bottom. These activities would not be expected to destabilize the surface water resource. Therefore, the overall hydrological impacts on surface water from water-based construction would be SMALL.

4.2.1.2 Groundwater

Potential hydraulic alterations to groundwater that may result from preconstruction and construction activities include those associated with dewatering.

As discussed in Subsection 2.3.2.2.4, temporary dewatering would be required to maintain a dry excavation for the construction of the foundations for the CR SMR Project structures. It is anticipated that dewatering would be accomplished using similar techniques as were used during the Clinch River Breeder Reactor Project (CRBRP), including installation of horizontal gravity drains in the excavated rock faces and pumping from sumps located around the perimeter of the excavation and at the base of the excavation. These dewatering methods are localized to the power block area excavation and to the areas immediately in the vicinity of the power block excavations. All de-watering flows would be routed to one of the stormwater retention ponds (either existing or planned to be installed as part of initial construction). Once dewatering is no longer needed, the water table is expected to return to static conditions.

During the CRBRP, results of the test grouting program and bedrock verification program investigated the depth of weathering in bedrock. These investigations concluded that the foundations would be anchored in solid, unweathered bedrock and there would be no risk of subsidence. (Reference 4.2-2) Therefore, dewatering is not anticipated to create subsidence in adjoining areas and impacts from the dewatering of the excavation would be SMALL.

4.2.2 Water-Use Impacts

This subsection describes the potential impacts of water use during preconstruction and construction activities.

4.2.2.1 Surface Water

Surface water may be used during the preconstruction and construction phases of the project for activities such as dust suppression. A conservative estimate of the volume of surface water to be used for dust suppression is 5000 gallons per day (gpd). The minimum daily flow rate of the Clinch River arm of the Watts Bar Reservoir past the CRN Site (release rate from the Melton Hill Dam) is more than 179,000 gallons per minute (gpm). Withdrawal and consumption of 5000 gpd (or 3.5 gpm) of surface water for dust suppression would be less than 0.002 percent of the daily flow rate. The City of Oak Ridge would provide potable water during construction activities. The City of Oak Ridge obtains potable water from the Melton Hill Reservoir (Reference 4.2-3). Therefore, the impacts from surface water use during preconstruction and construction would be SMALL.

4.2.2.2 Groundwater

There are no planned uses of groundwater during construction activities; therefore the hydrologic impacts from groundwater use would be SMALL.

4.2.3 Water Quality Impacts

Various impacts to water quality may occur as a result of preconstruction and construction activities. These potential impacts include: increased soil erosion and/or sediment transport, changes in stormwater flow, and changes in water quality parameters such as pH and temperature. The following subsections discuss the potential effects of construction activities on surface water and groundwater quality.

4.2.3.1 Surface Water

Impacts to surface water quality can occur as the result of chemical spills, dewatering, and soil erosion due to ground disturbance during construction. Additionally, accidental discharges of construction-related chemicals such as fuel, oil or grease can occur. As stated in Subsection 2.3.1.1 and shown on Figure 2.3.1-1, water bodies near the CRN Site that discharge to the Clinch River arm of the Watts Bar Reservoir include Caney Creek, Poplar Springs Creek, and Grassy Creek. Caney Creek and Poplar Springs Creek enter the Clinch River arm of the Watts Bar Reservoir on the shore opposite the CRN Site; Grassy Creek enters from the northwestern corner of the CRN Site. As discussed in Subsection 4.1.1.1, the CR SMR Project would permanently disturb 327 acres (ac) on the CRN Site and 30 ac offsite for road, rail, and barge terminal improvements. An additional 167 ac on the CRN Site would be temporarily disturbed during construction for use as laydown areas for staging materials and assembling project components, as well as installation of the onsite portion of the 69-kV underground transmission line within the existing ROW of the 500-kV transmission line. Approximately 15 ac offsite would be temporarily disturbed during construction of road and rail improvements and barge terminal refurbishment. Up to an additional 210 ac offsite would be temporarily disturbed for installation of the offsite portion of the 69-kV underground transmission line. Table 4.1-1 lists separately the acreage of each land cover type which would be temporarily disturbed and permanently converted within the CRN Site and the Barge/Traffic Area.

As discussed in Subsection 4.2.1.1.1, compliance with federal, state, and local requirements minimizes potential impacts, construction and preconstruction activities. Surface water monitoring requirements for the preconstruction and construction phases are developed as part of the permit application for a NPDES permit for stormwater discharges issued by the TDEC. Prior to initiation of construction, a completed and signed NOI for Construction Activity - Stormwater Discharges will be submitted to TDEC, and the NPDES permit will be obtained. A site-specific SWPPP will be developed and submitted with the NOI. In addition, compliance with the terms of applicable Section 404 and Section 10 permits, and coordination with the USACE, DOE, TDEC, and EPA on these permits, is expected to minimize the amount of disturbance of contaminated sediments.

Given that construction-related discharges would be managed in accordance with the CRN Site's SWPPP and NPDES permit for stormwater discharges, BMPs would be followed during construction, and permit and coordination requirements for disturbance of contaminated sediments would be followed, the impacts of construction on surface water quality would be SMALL.

4.2.3.2 Groundwater

Dewatering of the power block area usually occurs within a limited area during the duration of the construction of the below grade nuclear island structures and foundations. Drainage sumps installed at the bottom of the excavation pump surface drainage and/or accumulated groundwater to an established and, if necessary, permitted release point. However, these activities will not have any permanent effect at the CRN Site because of the following:

- The extent of the dewatering effects on groundwater levels is expected to be limited to about 150 ft from the edge of the excavation, based on the pumping test data, and is not expected to impact existing or future offsite groundwater users; and
- Streams, pond, and wetlands present on the CRN Site are not expected to be impacted by excavation dewatering. The closest such feature, excluding wetlands planned for removal, is approximately 500 ft away from the limits of the power block area, whereas excavation dewatering within the power block area is expected to have a radius of influence of approximately 150 ft. Therefore, no impact on groundwater levels and on groundwater discharge to springs, streams, ponds, and wetlands is expected.

Also during construction, gasoline, diesel fuel, hydraulic lubricants, and other similar products are used for construction equipment. Controls are described in Integrated Pollution Prevention Plans. BMPs are also employed during construction to minimize potential discharges to the environment. Construction dewatering is managed in accordance with TVA BMP procedures and Construction Stormwater Permits which may include design considerations described in Practice 7.21 of the State of Tennessee Erosion and Sediment Control Handbook, depending upon the volume of water involved (Reference 4.2-4).

In the unlikely event small amounts of contaminants are released into the environment, they would have only a small, localized, temporary impact on the water table aquifer. In conclusion, because engineering controls which prevent or minimize the release of harmful effluents would be used, and effluent concentrations would be maintained at levels below permitted limits established to be protective of water quality and aquatic life, any impacts to groundwater quality would be SMALL and would not warrant mitigation beyond those described in this subsection or required by a permit.

4.2.4 References

Reference 4.2-1. Howard, Charles S., Henderson, Andrew R., and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Evaluation of Aquatic Habitats and Protected Aquatic Animals Technical Report - Revision 4," Tennessee Valley Authority, November 20, 2015.

Reference 4.2-2. Project Management Corporation, "Clinch River Breeder Reactor Plant Environmental Report Volume V," 1982.

Reference 4.2-3. City of Oak Ridge, Tennessee, "Annual Water Quality Report 2014," TN0000522, 2014.

Reference 4.2-4. Tennessee Department of Environment and Conservation, "Tennessee Erosion & Sediment Control Handbook - Fourth Edition," August, 2012.

Reference 4.2-5. Tennessee Valley Authority, "Interagency Agreement (Memoranda of Agreement [MOA]) Watts Bar Reservoir Permit Coordination," February 1991.

4.3 ECOLOGICAL IMPACTS

This section describes the potential effects on terrestrial and aquatic ecological resources from preconstruction and construction activities for the Clinch River (CR) Small Modular Reactor (SMR) Project, which includes the construction and operation of two or more SMRs at the Clinch River Nuclear (CRN) Site. For the purposes of this assessment, the plant parameter envelope was used as the source of bounding values for the new plant.

As discussed in Section 3.9, the anticipated project schedule indicates that completion of preconstruction and construction activities for two or more SMRs would require approximately 5 years (yr). Preconstruction activities would occur over a period of approximately 1 yr and construction activities would continue for an additional approximately 4 to 5 yr. Ecological impacts from construction are likely to occur principally during preconstruction, when existing habitats would be removed in many areas of the CRN Site to prepare for the installation of both temporary and permanent facilities.

Preconstruction and construction activities associated with the CR SMR Project have the potential to affect terrestrial and aquatic ecosystems occurring on and adjacent to the CRN Site. These resources include upland and wetland habitats, streams and ponds, and the ecological communities they support. Preconstruction activities such as land clearing, grading, excavation, and filling have the greatest potential to result in substantial effects on ecosystems.

The extent of the areas on the CRN Site that would be affected by these activities was estimated conservatively such that it would encompass the range of possible requirements associated with the various SMR design options under consideration. Therefore, the potentially affected areas evaluated represent an upper bound estimate, and the actual areas disturbed may be somewhat smaller. Figure 4.3-1 shows the general layout of facility, laydown and storage areas, with the proposed cleared areas superimposed on the land cover types currently present on the CRN Site. It is estimated that up to approximately 494 acres (ac) of the CRN Site would be affected by preconstruction and construction activities, including approximately 327 ac that would be permanently covered by the facility or otherwise developed and 167 ac that would be affected temporarily during construction.

In addition to the areas on the CRN Site that would be affected by preconstruction and construction, additional areas that would be affected are located off the CRN Site within an existing transmission line right-of-way (ROW) and the Barge/Traffic Area. The Barge/Traffic Area extends northwest from the CRN Site entrance to Tennessee State Highway (TN) 58. The Barge/Traffic Area encompasses locations that would be affected by the development of the barge facility and its haul road, the construction of road/intersection improvements to facilitate the flow of traffic, and the hauling of heavy loads into and out of the CRN Site. Development plans for the CRN Site and adjacent areas are shown in Figure 3.1-2. The only new transmission line proposed to be built off the CRN Site is a 69-kilovolt (kV) underground line to be installed within the existing 500-kV ROW from the CRN Site to the Bethel Valley substation, located approximately 5 miles (mi) northeast of the CRN Site. The preconstruction activities involved in installing the 69-kV underground line are expected to occur principally within the ROW. Modifications to other segments of the existing transmission system also are planned, but new ROWs would not be developed.

4.3.1 Impacts to Terrestrial Ecosystems

The terrestrial ecosystem of the CRN Site is described in detail in Subsection 2.4.1, including both upland and wetland habitats and the ecological communities and important species they support. Subsection 2.4.1 also briefly describes these features for areas off the CRN Site, including the Barge/Traffic Area. Subsection 4.3.1 evaluates the potential effects of preconstruction and construction activities on the terrestrial ecosystems that occur on the CRN Site, the Barge/Traffic Area, and in the proposed 69-kV underground line installation area.

4.3.1.1 Upland Habitats

Dominant vegetation communities and other land cover types on the CRN Site are described in Subsection 2.4.1. Figure 4.3-1 depicts the areas to be temporarily or permanently disturbed by proposed preconstruction and construction activities on the CRN Site and the Barge/Traffic Area overlaid on the current vegetation communities and land cover types. The communities on the CRN Site most affected by construction-related activities would be, in order of decreasing acreage affected, herbaceous/grassland, mixed evergreen/deciduous forest, deciduous forest, and evergreen forest. Table 4.3-1 shows the estimated acreage of each type of vegetation community or land use potentially disturbed by development on the approximately 935-ac CRN Site, the approximate percentage of each type that would be disturbed temporarily and permanently, and the percentage of each type that would be disturbed on the CRN Site overall. Table 4.1-1 shows the estimated acreage of each land cover type in the Barge/Traffic Area. More than 90 percent of the Barge/Traffic Area is covered by deciduous forest, and the remainder is covered by herbaceous vegetation (Reference 4.3-1).

Preconstruction and construction activities would comply with federal and state regulations, permit requirements, established best management practices (BMPs), and Tennessee Valley Authority (TVA) procedures and guidelines. An initial preconstruction activity, land clearing, would involve the cutting and removal of trees and other vegetation. Clearing operations would be conducted in accordance with TVA BMPs and in a manner that will prevent any unnecessary damage to the remaining natural vegetation, will protect wetlands and streams, and will prevent soil erosion (Reference 4.3-12). If clearing of trees is required, TVA would evaluate the potential for the trees to provide roosting habitat for listed bat species. Depending on the amount and type of clearing to be done and the potential for the trees to provide bat habitat, bat surveys may be conducted and the timing of clearing activities may be scheduled to avoid seasons when bats are present. In areas such as transmission line ROWs that need to be kept cleared of vegetation, mechanical (mowing, hand trimming) and chemical clearing (herbicides) may be used. As described in Section 4.2, BMPs for erosion control and stormwater management would be employed during preconstruction and construction to minimize the potential for erosion, sediment deposition, and dust. These BMPs would substantially reduce the potential for such processes to directly disturb or indirectly impact nearby plant communities outside the footprint of development.

The upland plant communities that would be permanently disturbed by the construction of facilities on the CRN Site comprise predominantly mixed evergreen-deciduous, deciduous, and evergreen forest (162 ac) and herbaceous/grassland (152 ac) habitats (Table 4.3-1), which are common in the vicinity. The total acreages of these forest and herbaceous communities that would be permanently lost to development would be 54 percent and 75 percent, respectively, of the areas these communities now cover on the CRN Site (Table 4.3-1). These acreages are a minor component of the expanse of such communities within the vicinity and the region. (The Oak Ridge Reservation (ORR), which adjoins the CRN Site to the east, north, and west, encompasses more than 33,100 acres of federally owned land. Most of the ORR is a relatively undisturbed ecosystem of nearly continuous forest within a surrounding region that is more fragmented by agriculture and development. The ORR is a large area of relatively unfragmented eastern deciduous and mixed forest communities, as well as semi-natural grasslands and forest edges, which provide a diversity of habitats for a great variety of wildlife. (Reference 4.3-2)

Riparian habitats on the CRN Site and the Barge/Traffic Area, consisting principally of forest in the floodplain of the Clinch River arm of the Watts Bar Reservoir and immediately adjacent to streams and wetlands, would be mostly avoided by development. Construction of the intake and discharge structures would require the removal of vegetation from the narrow riparian zone on the shoreline of the reservoir within the footprint of each structure, along the small stream and wetland where the intake pipeline would be installed, and around the margin of the wetland (W001) within the discharge pipeline corridor. Relatively small areas would be affected by the installation of these structures across these narrow riparian zones. The plants potentially affected, described in Subsection 2.4.1.1.1, and are not rare or unusual in the region. Natural riparian vegetation previously was removed during historical development of the barge facility, and improvements to that existing facility would not require substantial additional clearing of shoreline vegetation.

Some of the areas disturbed on the CRN Site (approximately 167 ac or 34 percent of the total disturbed area) would be for temporary, construction-related facilities, material laydown areas, and installation of the onsite portion of the 69-kV underground transmission line (Table 4.3-1). Installation of the offsite portion of the 69-kV underground line within the existing ROW from the CRN Site to the Bethel Valley substation also may temporarily disturb up to 210 ac of mainly herbaceous/grassland community. The areas cleared for temporary uses may be revegetated or otherwise restored after construction completion using native or non-invasive species. Over time, some of these areas likely would undergo succession and gradually transition from herbaceous/grassland to forest habitat. Other areas may be replanted in trees, and some areas where open spaces need to be maintained may be permanently converted from forest to herbaceous/grassland vegetation. Thus, the functional value of the former forest communities would not be restored in these converted areas.

Terrestrial vegetation communities and other land cover types on the Barge/Traffic Area east of TN 58 are described in Subsection 2.4.1. Deciduous forest is the upland plant community that predominantly would be affected by construction in the Barge/Traffic Area. As shown in Table 4.1-1, approximately 45 ac in the Barge/Traffic Area would be temporarily or permanently disturbed by the planned improvements. Of that 45 ac, approximately 20 ac (44 percent) are currently developed and 25 ac (56 percent) are undeveloped and potentially could be impacted. A 17-ac area of predominantly deciduous forest is a minor component of the expanse of this common community within the vicinity and the region. Furthermore, some of the undeveloped areas that could be disturbed (approximately 15 ac, or 33 percent, of the total cleared area) would be disturbed temporarily and may be revegetated or otherwise restored after completion of the Barge/Traffic Area improvements. Temporarily disturbed areas adjacent to the planned traffic improvements may be permanently converted from forest to herbaceous/grassland vegetation to maintain open space near roadways.

Thus, effects from preconstruction and construction activities on terrestrial plant communities and upland habitats at the CRN Site and in the adjacent Barge/Traffic Area would be SMALL in both the short and long-term.

4.3.1.2 Wetland Habitats

Wetland communities on the CRN Site are described in Subsection 2.4.1.2 and mapped in Figure 2.4.1-2 based on field surveys and wetland identifications performed by TVA. Figure 4.3-1 shows the wetlands that would be affected by construction and preconstruction activities. Facilities are planned and sited to avoid impacts and minimize effects on wetlands to the extent practicable. TVA's BMP manual includes a requirement that site construction plans include a 50-ft wetland buffer, and project managers integrate these buffers into construction plans (1242 Muncy 2012). Most wetlands would be avoided and unaffected. Of the 12 wetlands on the CRN Site, only four small wetlands would need to be removed because they are within the footprint of facilities: Wetland 001 (0.67 ac) is in the planned ROW for the discharge pipeline from the holding pond to the reservoir, Wetland 002 (0.13 ac) is in the planned power block area, Wetland 012 (0.13 ac) is in the planned power block and parking areas, and Wetland 008 (0.23 ac) is in the planned ROW for the makeup water pipeline from the cooling water intake structure. Thus, only 1.2 ac of the 15.54 ac of wetlands on the CRN Site (Table 2.4.1-3) are expected to be lost due to filling for construction. The functions of wetland areas impacted by filling would be lost. Other wetlands not directly affected would be protected from the indirect effects of preconstruction and construction activities by the use of BMPs to prevent erosion and the transport of sediment to wetlands via stormwater. Preconstruction and construction activities would comply with federal and state BMPs for erosion control and stormwater management, thereby largely eliminating the potential for those processes to directly disturb or indirectly impact nearby wetland communities outside the footprint of development.

As discussed in Subsection 4.2.3.2, dewatering of groundwater within a limited area in the power block area is likely during construction of the below-grade nuclear island structures and foundations. Drainage sumps installed at the bottom of the excavation would pump surface drainage and/or accumulated groundwater to an established and, if necessary, permitted release point. These activities could have an effect on the surrounding water table. Wetlands W003 (0.18 ac), W004 (0.24 ac), and W007 (0.17 ac) are the only wetlands not otherwise affected by construction that are sufficiently close to the power block area that they potentially could be affected by alterations in groundwater flow. All three of these small wetlands are located immediately adjacent to the reservoir, and assessments of these wetlands did not identify groundwater as a source of their hydrology. The hydrology of two wetlands (W005 and W008) located near the power block area is affected by groundwater discharge. (Reference 4.3-3) Wetland 008 would be removed due to intake pipeline construction. The hydrology of W005 is affected by the Clinch River arm of the Watts Bar Reservoir and an intermittent stream and is unlikely to be noticeably affected by temporary groundwater dewatering in the power block construction area more than 800 feet (ft) away (Reference 4.3-3). As indicated by the wetland descriptions in Subsections 2.3.1.1.1.6 and 2.4.1.2, these three wetlands and the other wetlands on the CRN Site and in the Barge/Traffic Area are predominantly associated with surface water (streams or the reservoir); thus, they would not be substantially affected by alterations in groundwater levels.

Wetlands located off the CRN Site in the Barge/Traffic Area are discussed in Subsection 2.4.1.2 and mapped in Figure 2.4.1-2. The wetland survey identified four wetlands totaling 10.06 ac along the south side of Bear Creek Road between TN 58 and the CRN Site entrance: W013 (3.73 ac), W014 (3.05 ac), W015 (1.95 ac), and W017 (1.33 ac). Wetlands W013 and W014 are on each side of the haul road connecting the barge facility to Bear Creek Road. Based on the proximity of these wetlands to Bear Creek Road and the haul road and the planned widening of these roads, there is a potential that the margins of these wetlands would be impacted by road improvements, which may require forest removal and filling in marginal areas. It is estimated that the total 10-ac area of these four wetlands approximately 5 percent (0.5 ac) would be impacted by road construction. In addition, a small, 0.11-ac wetland (Wetland W016) is located immediately adjacent to the planned intersection of a new CRN Site access road to be constructed on the east side of TN 58. This wetland likely would be impacted by preconstruction activities, which may require filling. The extent to which these five wetlands are affected will be determined by the roadway design finalized during the combined license application (COLA) stage and specific plans developed for these areas. Wetlands are not present in the underground transmission line ROW located off the CRN Site.

The U.S. Army Corps of Engineers (USACE) determines whether individual wetlands are within its jurisdiction and provides guidance regarding permitting of wetland impacts and compensatory mitigation. If impacts to wetlands are unavoidable, mitigation likely would be required in accordance with USACE guidelines. During a September 2013 site visit, USACE personnel determined that all but two of the 12 wetlands on the CRN Site are under federal jurisdiction. Of the two wetlands that are not under federal jurisdiction, one is an isolated wetland under state jurisdiction (W002), and one may be non-jurisdictional and associated with historic site grading activities (W012). The jurisdictional status of W012 and the wetlands in the Barge/Traffic Area have not yet been determined by the USACE. The total area of wetlands impacted by preconstruction activities on and off the CRN Site potentially would be approximately 2 ac, so impacts on wetlands would be SMALL and would likely be further reduced by mitigation.

4.3.1.3 Important Terrestrial Habitats

As discussed in Subsection 2.4.1.3, important terrestrial habitats comprise natural areas as well as habitats that have been identified by government agencies as unique, rare, or a priority for protection, including managed areas and ecologically significant sites. Such habitats adjoining the CRN Site include the Grassy Creek Habitat Protection Area (HPA) as well as natural areas, managed areas, and other designated areas on the ORR. Preconstruction and construction activities on the CRN Site would be separated from these habitats by undeveloped buffers resulting in SMALL impacts. The implementation of BMPs would further minimize the potential for effects on habitats beyond the areas directly disturbed.

Development off the CRN Site in the Barge/Traffic Area would occur within the ORR. Two small natural areas have been designated in the vicinity of the Barge/Traffic Area: the 7-ac East Tennessee Technology Park (ETTP) Filtration Plant Wetland, located across Bear Creek Road from the CRN Site entrance, and the 17-ac K-25 Beaver Pond Complex, located west of the TN 58 intersection and south of the ETTP (Reference 4.3-4). Neither these areas nor other ORR natural areas, managed areas, or other designated areas would be within the footprint of preconstruction or construction activities or otherwise adversely affected by these activities.

4.3.1.4 Wildlife

Terrestrial wildlife species identified on the CRN Site, other areas of the CR Property, and the Barge/Traffic Area are described in Subsection 2.4.1.4. The native species observed are characteristic of the region and the habitats described in Subsection 2.4.1. Preconstruction and construction activities on the CRN Site and the Barge/Traffic Area would have both short-term and long-term effects on these wildlife species. The removal of upland plant communities described in Subsection 4.3.1.1 would eliminate wildlife habitat permanently in the areas where permanent facilities are constructed and temporarily in some areas to be used only during the construction period and later revegetated, such as the areas in the eastern part of the CRN Site to be used for construction material laydown and storage of equipment and supplies.

As discussed in Subsection 4.3.1.1 and shown in Figure 4.3-1, the areas of the CRN Site and the Barge/Traffic Area to be directly affected by preconstruction disturbance currently are covered by forest and herbaceous/grassland habitats. None of these habitats are unique in the region, and the permanent loss of approximately 357 ac (327 ac on the CRN Site plus 30 ac on the Barge/Traffic Area) to the building of facilities would not noticeably reduce the local abundance and diversity of wildlife in the surrounding vicinity. Much of the approximately 182 ac to be cleared for temporary use (167 ac on the CRN Site plus 15 ac on the Barge/Traffic Area) is expected to be restored and returned to habitat after the construction phase. Removal of forest from the peninsula would not affect forest fragmentation any further than it already has been affected by previous work on the CRBRP. The CR SMR Project would result in removing the forested areas described in Subsection 4.3.1.1 from use by species currently occupying those areas, but all of these species would have access to adjacent suitable habitat. Proposed clearing on the Barge/Traffic Area would be small and would not permanently preclude species access and movement to suitable adjacent habitat.

A forested riparian zone would be retained along most of the shoreline of the reservoir, and the clearing that would occur in the interior portions of the peninsula would not result in forest fragmentation or impede the movements of terrestrial wildlife. Similar riparian habitat for wildlife is extensively available along reservoirs and other water bodies in the region, and the loss of small segments at the intake and discharge structures would not affect populations of wildlife that utilize riparian habitats.

During the preconstruction activities for the CR SMR Project, disturbance, displacement, and mortality of individual animals likely would occur as heavy equipment is used for clearing, grading, and excavation. Mobile animals, including birds, larger mammals, and some reptiles, can avoid such disturbances and move to safer areas. However, small, less-mobile animals, such as amphibians, turtles, and small mammals, are likely to be at much greater risk of mortality. Although wildlife displaced by clearing activities can find refuge in undisturbed habitats in the vicinity, temporary reductions in population could occur as a result of increased predation and competition in these habitats. These effects from clearing, grading, excavation, and building of facilities also would occur on a smaller scale in localized portions of areas located off the CRN Site, including the Barge/Traffic Area and the Watts Bar NP – Bull Run FP 500-kV transmission line ROW. Effects within the ROW would be particularly limited because burial of the transmission line would be a temporary disturbance within an existing ROW in which vegetation is maintained and habitat is disturbed.

Birds can be affected by collisions with transmission towers or other tall structures, such as towers and construction cranes. However, the CRN Site is not within a major migratory flyway and is surrounded by higher terrain with tall trees. Evaluation of avian impacts by the U. S. Nuclear Regulatory Commission (NRC), summarized in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, determined that the effects of avian collisions with existing structures at nuclear power plants have been small. The mechanical draft cooling towers to be constructed for the cooling system for the CR SMR Project would not be as tall as natural draft cooling towers, which have been found by NRC to cause only low levels of bird mortality due to collisions, and would pose little risk to migrating birds (Reference 4.3-5). Based on the findings at other facilities and the lack of concentrated numbers of birds at the CRN Site, avian collisions with man-made structures during preconstruction and construction are predicted to have a negligible effect on avian mortality and populations.

Subsection 4.4.1.1, describes noise that can result from preconstruction and construction activities and factors that influence noise effects, such as frequency, intensity, duration, location, and timing. As discussed in that section, construction-related noise is attenuated by natural factors such as vegetation, topography, and temperature, and it quickly decreases over relatively short distances. The majority of the preconstruction and construction activities occurring on the CRN Site would generate noise levels below 65 A-weighted decibels (dBA) at the Site Boundary. Some infrequent or night-time construction activities could generate temporary noise levels at or above 60 to 90 dB at a distance of 100 ft from the equipment; however, the noise level should be attenuated to below 65 dBA at the Site Boundary. The threshold noise level at which birds and small mammals are frightened or startled is 80 to 85 dBA (Reference 4.3-6). This noise level is not expected to occur beyond the Site Boundary.

Prediction of the effects of noise on wildlife is limited by the paucity of information linking sound levels to effects on species. A study by the Federal Highway Administration that summarized information from the available literature on the effects of noise on wildlife populations indicated that birds have been studied more than other wildlife. The review found that some studies indicated that bird numbers and breeding were adversely affected by proximity to roads and their associated noise, while other studies found the opposite effect, with reports of many bird species using roadside habitats despite the noise. The sensitivity of birds seems to vary by species, with some species being affected, some being not affected, and others being more common even near noisy interstate highways. For mammals, the review found that studies indicate large mammals may avoid noise, but the effect seems to be small to moderate, and small mammals occur in significant numbers in highway ROWs and do not seem to be adversely affected by road noise. (Reference 4.3-7) Thus, more sensitive species may be temporarily displaced to more distant habitats during periods of elevated construction noise, while more tolerant species likely would remain nearby.

Based on the predicted lack of noise exceeding 80 to 85 dB in habitat areas beyond the Site Boundary, the similarity of construction and highway noise levels, the rapid attenuation of noise expected to occur beyond the construction areas, and the habituation and limited sensitivity of many wildlife species to the noise levels likely to occur in habitat areas, impacts of noise from preconstruction and construction activities on wildlife are expected to be negligible. The loss of approximately 494 ac of habitat at the CRN Site (327 ac permanently disturbed plus 167 ac temporarily disturbed) and 45 ac in the Barge/Traffic Area (30 ac permanently disturbed plus 15 ac temporarily disturbed) would result in mortality or temporary displacement of wildlife in those areas; however, this acreage would be a small component of the accessible, undeveloped habitat in the vicinity to which animals can disperse with minimal effects on populations. In addition, noise avoidance and collisions with structures also would have a negligible impact on wildlife populations in the vicinity. Overall, impacts on terrestrial wildlife from preconstruction and construction would be SMALL.

4.3.1.5 Important Terrestrial Species

Subsection 2.4.1.5 describes the important terrestrial species that potentially can be affected by preconstruction and construction activities, including federally or state-listed species and commercially or recreationally valuable species. Table 2.4.1-5 identifies terrestrial and wetland species with federal or state status and recorded occurrences in Roane County, Tennessee. As discussed in Subsection 2.4.1.5.1, no federally listed or candidate species of plants were found on the Clinch River Property, which includes the CRN Site and the adjoining Grassy Creek Habitat Protection Area, or in the Barge/Traffic Area during TVA botanical surveys, and habitats suitable for such species were not found to be present. However, three federally listed bat species were found by TVA surveys to forage on the Clinch River Property and the Barge/Traffic Area: the gray bat (endangered), Indiana bat (endangered), and northern long-eared bat (threatened). All three of these bats hibernate in caves during the winter. During the rest of the year, including the period when young are born, the gray bat roosts in caves and the Indiana bat and northern long-eared bat roost in trees. Given the absence of caves on the CRN Site and the Barge/Traffic Area, gray bat roosts would not be affected by preconstruction or construction activities. TVA performed surveys to identify suitable summer roosting habitat for the Indiana bat and northern long-eared bat within forested areas of the Clinch River Property and found potential roosting habitat of moderate to high quality on the northern half of the property. However, no occupied roost trees were documented, which made difficult any estimate of the numbers of individual bats that may roost or forage on the Clinch River Property or the CRN Site.

Preconstruction clearing of forest and herbaceous/grassland habitats would reduce foraging habitat available to all three listed bat species on the CRN Site and the Barge/Traffic Area, including forest, edge, and riparian foraging habitats. However, the habitat types that would be affected are common in the vicinity, and bats are highly mobile and capable of utilizing other, similar foraging habitats nearby. Clearing of forested areas of the CRN Site and the Barge/Traffic Area potentially could result in the removal of roost trees for the Indiana bat and northern long-eared bat. The extensive forests on the ORR and elsewhere in the vicinity provide numerous potential roost trees that could be used as alternatives to any roost trees removed from the CRN Site. There is a potential for bat injury or mortality if an occupied roost tree were inadvertently removed during the warmer months. However, surveys of specific areas to be cleared could identify roost trees if present and allow them to be avoided, and removal of trees during the winter would preclude the possibility of direct effects on roosting bats. As part of TVA’s consultation with the U.S Fish and Wildlife Service (USFWS) under Section 7 of the Endangered Species Act, the USFWS may identify measures such as these to be employed in minimizing potential take of these listed bat species. Based on the limited dependence of these bats on the CRN Site and the Barge/Traffic Area for foraging habitat, the low likelihood of occupied roosting trees on the CRN Site and the Barge/Traffic Area, and the ability to avoid direct effects on bats in occupied roosting trees if present, the potential for construction and preconstruction impacts on the gray bat, Indiana bat, or northern long-eared bat would be SMALL.

The description of state-listed species in Subsection 2.4.1.5.2 identified two state-status species that have been observed on the Clinch River Property (in addition to the federally listed gray bat and Indiana bat discussed above): the sharp-shinned hawk and bald eagle. A bald eagle also was observed flying over the Barge/Traffic Area. Both of these raptors have a state status of “in need of management.” Marginally suitable habitat is available for the sharp-shinned hawk within the upland habitat in the northern half of the Clinch River Property, principally the Grassy Creek

HPA. The closest documented bald eagle nest is approximately 8 mi from the CRN Site on Watts Bar Reservoir. Both the hawk and the eagle are highly mobile and neither is known to nest on the Clinch River Property. The preconstruction clearing of forest habitat on the CRN Site and the Barge/Traffic Area would have a minor effect on the amount of potential habitat available to both species in the area, and the potential for preconstruction and construction impacts on the sharp-shinned hawk or bald eagle would be SMALL.

As discussed in Subsection 2.4.1.5.3, commercially or recreationally valuable terrestrial species on the CRN Site and the Barge/Traffic Area are game species such as deer, turkey, and waterfowl. Impacts to these species would be SMALL as described above for other wildlife.

Invasive terrestrial species, such as those discussed in Subsection 2.4.1.5.4, already are present at the CRN Site, on the Barge/Traffic Area, and in transmission line ROWs. With use of established TVA BMPs, preconstruction and construction activities associated with the CR SMR Project would not contribute to the spread of exotic or invasive species or increase their impacts on native species. Thus, impacts related to invasive species from the CR SMR project would be SMALL.

4.3.1.6 Transmission Corridors

As discussed in Subsections 2.4.1.6 and 3.7.3, two transmission corridors cross the CRN Site (Figure 2.2-1). The Kingston – Fort Loudoun #1 line is a 161-kV transmission line that crosses the CRN Site from the southeastern tip of the peninsula to the northwestern corner of the CRN Site near the entrance gate. The Watts Bar NP– Bull Run FP line is a 500-kV transmission line that crosses the reservoir and the western boundary of the CRN Site, extends northeast across the widest part of the CRN Site, and continues past the Bethel Valley substation, which is located approximately 5 mi northeast of the Site.

An approximately 1.2-mi segment of the 161-kV line within the CRN Site would be re-routed from its current alignment to make room for construction of the power island. The new 161-kV ROW likely would extend north from the reservoir parallel to the shoreline before turning northwest and connecting to the existing ROW slightly northwest of where it crosses the 500-kV ROW. The re-located segment from near the reservoir to where the ROW turns northwest near the cooling water intake would require clearing of deciduous and mixed evergreen/deciduous forest within the ROW. In addition, relocation of this segment of the 161-kV transmission line is likely to displace an osprey nest that has been built on a tower in this area.

The only new transmission line proposed for construction off the CRN Site is a 69-kV underground line to be installed within the 500-kV ROW between the CRN Site and the Bethel Valley substation. The preconstruction activities involved in installing the 69-kV underground line are expected to occur principally within the ROW. However, there is the possibility that some trees may need to be removed. Therefore, the terrestrial ecological resources affected predominantly would be communities previously impacted by clearing for the existing 500-kV ROW, construction of the aboveground transmission lines, and ongoing vegetation maintenance practices within the ROW that maintain a herbaceous community within the ROW. Terrestrial resources within the segment of the ROW in which the 69-kV underground line would be installed have been documented by the U.S. Department of Energy (DOE). Subsection 2.4.1 summarizes existing information from previous DOE surveys of this 5-mi segment of the 500-kV ROW where installation of the 69-kV underground line is planned. The data indicate that no recorded occurrences of federally or state-listed terrestrial species are known from within this ROW. However, if any clearing of trees is required, TVA would evaluate the potential for the trees to provide bat habitat. Depending on the amount and type of clearing to be done and the potential for the trees to provide bat habitat, bat surveys may be conducted.

Subsection 3.7.3.8 describes planned modifications to the existing transmission system outside the CRN Site, and Subsection 2.4.1.6 describes the ecological resources in the segments of the ROWs for those transmission lines that would potentially be affected. The uprating, reconductoring, and rebuilding activities would involve existing lines within existing ROWs, and additional ROWs would not be established, cleared, or developed. The resources within these ROWs (identified in Table 2.4.1-7) would not be noticeably affected by the temporary activities required for the planned upgrades. BMPs would be employed as described in Subsection 3.7.3.8 to prevent or minimize impacts to terrestrial habitats as a result of temporarily accessing and working on these line modifications.

As discussed above for the CRN Site, collisions of birds with transmission towers or other tall structures are possible; however, collisions of birds with structures are unlikely to be a major source of mortality for local bird populations. Based on NRC findings at other facilities, the lack of concentrated numbers of birds at the CRN Site, and the fact that new transmission towers would not be constructed off the CRN Site and some of those on the CRN Site would simply be relocated, increases in avian collisions with man-made structures is not expected. TVA would comply with federal and state regulations regarding the siting of transmission lines, use construction BMPs, and install the lines under state oversight. Therefore, avian collisions with man-made structures during preconstruction and construction activities in transmission corridors on or off the CRN Site are predicted to have a negligible effect on avian mortality and populations.

Terrestrial resources would be minimally affected by the relocation of lines on the CRN Site, installation of an underground line in an existing ROW off the CRN Site, or modifications to existing line segments of the transmission system. Therefore, impacts associated with preconstruction activities in transmission corridors are expected to be SMALL.

4.3.1.7 Summary of Impacts to Terrestrial Ecosystems during Preconstruction and Construction

The environmental effects from preconstruction and construction activities on the CRN Site and in adjacent offsite areas would not disrupt or alter important terrestrial ecosystems. Impacts on upland habitats would be minor based on the lack of high quality or unique habitats in the areas to be developed and the expanse of quality, undeveloped habitats in the vicinity and the region.

Impacts on wetlands would be minor and would be further reduced by mitigation. Important terrestrial habitats (e.g., ORR natural areas, managed areas, or other designated areas) would not be within the footprint of preconstruction and construction activities or otherwise adversely affected by these activities, and the impact of these activities on terrestrial wildlife and important terrestrial species would be minimal. Impacts on these components of the terrestrial ecosystem within transmission corridors similarly would be minimal. Accordingly, the overall impact of preconstruction and construction activities on terrestrial ecosystems on the CRN Site and affected offsite areas (Barge/Traffic Area and 500-kV transmission line ROW) would be SMALL for all resources.

4.3.2 Impacts to Aquatic Ecosystems

The aquatic ecosystems of the CRN Site are described in detail in Subsection 2.4.2. Subsection 2.4.2 also briefly describes aquatic resources in potentially affected areas off the CRN Site, including the Barge/Traffic Area and the Watts Bar NP – Bull Run FP 500-kV transmission line ROW from the CRN Site to the Bethel Valley substation. The principal aquatic ecosystem in the vicinity of the CRN Site is the Clinch River arm of the Watts Bar Reservoir. Preconstruction and construction activities that can affect aquatic ecosystems include: development of the intake structure and barge facility on the reservoir shoreline; installation of the discharge structure in the reservoir channel; and clearing and grading for temporary or permanent facilities, which can directly or indirectly affect streams and ponds on the CRN Site as well as in offsite areas where transmission lines or roads would be built. Adverse effects on aquatic ecosystems from the CR SMR Project would result predominantly from preconstruction activities. Such activities may directly cause physical alteration of aquatic habitats from activities such as underwater excavation, in-filling of streams and ponds, and placement of cofferdams, or they may indirectly cause degradation of habitat quality such as from sedimentation and accidental spills that reduce water quality.

Any alteration to a stream, river, lake, or wetland in Tennessee requires a water quality permit from the Tennessee Department of Environment and Conservation (TDEC) Division of Water Resources. Physical alterations to properties of waters of the state require an Aquatic Resource Alteration Permit (ARAP) or a Clean Water Act (CWA) Section 401 Water Quality Certification. A federal CWA Section 404 permit may also be required from the USACE for projects that include the discharge of dredged or fill material into waters of the United States. When a Section 404 permit is required, a Section 401 certification must first be obtained from TDEC to affirm that the discharge would not violate Tennessee water quality standards. TDEC has established General Permits that are developed and maintained by the Division of Water Resources to provide a streamlined, expedited means of authorizing projects that singularity or cumulatively propose minor impacts to water resources. Each of the General Permits contains conditions and mitigation measures required to be implemented as a part of the activity authorized by the permit. (Reference 4.3-14)

When the impacts of development on water resources (i.e., loss or degradation) cannot be avoided and/or minimized, the Division of Water Resources may require permittees to offset their activities through compensatory mitigation. Compensatory mitigation is used to replace lost or impacted habitat with habitat that has similar functions of equal or greater ecological value. Compensatory mitigation may be accomplished by taking a degraded water resource such as a stream or wetland and returning the resource to a reference condition and/or improving the value of the resource. This may be accomplished through activities such as the replacement restoration, and/or enhancement of degraded streams. Treatments that may be employed in stream mitigation include riparian buffer restoration, bank stabilization, and hydrologic buffering (e.g., stormwater detention basins). In addition to the regulatory preference for avoidance of impacts, there is a strong preference for mitigation of unavoidable impacts onsite where practicable. If necessary, offsite mitigation may be used in accordance with TDEC guidance. (Reference 4.3-14)

4.3.2.1 Streams on the CRN Site and the Barge/Traffic Area

In addition to the Clinch River arm of the Watts Bar Reservoir, there are four perennial streams, one intermittent stream, and 19 ephemeral streams/wet-weather conveyances (WWCs) on the CRN Site (Figure 2.4.1-2; (Reference 4.3-8)). The current footprint of the planned permanent facilities and temporary materials laydown and storage areas likely would directly impact one small perennial stream (S01) and 11 WWCs (Figure 2.4.1-2 and Figure 4.3-1). In planning and siting facilities, structures are located to avoid impacts to streams and other water bodies to the extent practicable. Nevertheless, stream S01 and six of these WWCs are within the footprint of the areas to be permanently developed. Portions of five WWCs are within the area in the northeast portion of the CRN Site to be temporarily developed then revegetated and restored following the completion of construction.

Of the perennial and intermittent streams on the CRN Site (described in Subsection 2.4.2.1.3), only perennial stream S01 would be substantially affected by construction activities. This small stream is within the area to be affected by construction of the cooling water intake and the pipeline from the intake to the CR SMR Project. Impacts from intake and pipeline installation potentially would result in the loss of the entire length of stream S01, approximately 925 ft of stream. Stream S01 is a small tributary to the Clinch River arm of the Watts Bar Reservoir. It is fed by a spring and small pond (P04) and flows through a small wetland (W008). A biological survey of S01 in 2015 sampled the stream's entire length and found no fish and only a few small crayfish. (Reference 4.3-9) The 19 WWCs located on the CRN Site and the 15 WWCs located in the Barge/Traffic Area are ephemeral streams that flow only in response to precipitation runoff and do not support communities of aquatic organisms. Stream S01 is expected to be subject to USACE jurisdiction. USACE jurisdiction concerning the WWCs has not been determined.

There are two perennial streams, four intermittent streams, and 15 WWCs (Figure 2.4.1-2) in the Barge/Traffic Area. Of these, two intermittent streams (S09 and S10) and six WWCs are likely to be impacted by preconstruction activities associated with the development of a new intersection and access ramps at TN 58 and improvements to Bear Creek Road to the CRN Site entrance (Figure 4.3-1). Intermittent stream S09 is crossed by Bear Creek Road. Impacts to that short stream segment would be possible in conjunction with widening and other improvements to the road at the existing stream crossing, but any such effects on the stream are expected to be temporary and minor. Impacts to the small, intermittent stream S10 and the six WWCs are expected to result from grading and filling for road development, and these impacts are likely to be permanent. Streams S09 and S10 are expected to be subject to USACE jurisdiction. USACE jurisdiction concerning the WWCs has not been determined.

Although sedimentation from erosion and stormwater runoff has the potential to impact nearby streams during and immediately following preconstruction activities, BMPs (described in Section 4.2) would be used to prevent or minimize erosion and sediment transport to streams and wet-weather conveyances on and off the CRN Site. A stormwater pollution prevention plan (SWPPP) would prescribe methods for collection and control of runoff from preconstruction and construction areas in accordance with state and federal regulations and permit requirements.

In summary, one small perennial stream and six short WWCs on the CRN Site and one small intermittent stream and six short WWCs in the Barge/Traffic Area are likely to be permanently impacted by the proposed development in these areas. Given the small size of these features, the minimal aquatic communities in the streams, and the lack of aquatic communities in the WWCs, preconstruction and construction activities on the CRN Site and in the Barge/Traffic Area would not result in substantial ecological impacts and would not notably affect aquatic species populations or communities in the vicinity; therefore the ecological impact to the streams would be SMALL. The SMALL impacts to streams would be further reduced by mitigation that would likely be required in accordance with TDEC and USACE guidelines.

4.3.2.2 Ponds on the CRN Site and the Barge/Traffic Area

Six small, constructed, freshwater ponds are present on the CRN Site (Figure 2.4.1-2 and Table 2.4.2-5). Five of these ponds were constructed as stormwater retention basins in conjunction with site preparation for the Clinch River Breeder Reactor Project (CRBRP), and one is a very small dug out pond. These ponds are generally shallow and have only intermittent connections to the Clinch River arm of the Watts Bar Reservoir during heavy rainfall events. Two of these small ponds (P04 and P06) are within the currently planned footprint of the switchyard and the parking lot, respectively, (Figure 4.3-1) and are expected to be filled and graded. The four onsite ponds not directly impacted would likely continue to be used as stormwater retention ponds during preconstruction and construction. Two ponds are present in the Barge/Traffic Area near the CRN Site entrance. Based on the proposed footprint of development in that area (Figure 4.3-1), neither pond is expected to be directly impacted by preconstruction or construction, and implementation of stormwater BMPs would prevent or minimize erosion and sediment transport to these ponds.

Construction activities for the CR SMR Project would result in the removal of two of the small, man-made ponds on the CRN Site and conversion of those areas to permanent facilities. Given the small size of these man-made ponds and the abundance of other pond and reservoir habitats both on the CRN Site and in the vicinity, the impact from the loss of the habitat provided by these ponds on aquatic resources on the CRN Site or in the vicinity would be SMALL.

4.3.2.3 The Clinch River Arm of the Watts Bar Reservoir

Preconstruction and construction activities that potentially would affect the aquatic community in the Clinch River arm of Watts Bar Reservoir include the installation of the intake and discharge structures, improvements to the barge facility, and installation of a new culvert under the access road at the Grassy Creek embayment of the reservoir. Section 3.9 describes in detail the construction activities. The proposed intake structure is located on the east side of the CRN Site at Clinch River Mile (CRM) 17.9, and the proposed discharge is located on the west side at approximately CRM 15.5. The culvert would be installed in conjunction with improvements to the access road where the road crosses the Grassy Creek embayment. The installation of these facilities may involve excavation near the shoreline in the immediate area of construction. These activities would affect only small areas of the reservoir and would be conducted in accordance with USACE permit and TDEC Aquatic Resource Alteration Permit and NPDES Construction Stormwater Permit requirements. Such requirements are expected to include the use of BMPs in on-shore areas (described in Section 4.2) to prevent or minimize erosion and sediment transport to the reservoir or its tributaries, as well as silt curtains and cofferdams where structures are to be built in the water or on the shoreline. A cofferdam is expected to be used for construction of the intake. The size and exact location that would be excavated will not be known until COLA. The cofferdam would serve as the principal BMP to prevent sedimentation from the excavation process.

The aquatic and benthic habitats within the footprints of the intake and discharge structures would be lost. However, these areas would be very small in comparison to the extensive area of such habitats present within the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site. As indicated by the results of the biological surveys and evaluations discussed in Subsection 2.4.2, the benthic community in these areas is relatively limited in abundance and diversity and does not include rare species, and the fish community is not dependent on these areas for spawning or other critical needs. In the immediate vicinity of the intake and discharge, increases in turbidity and sediment deposition may occur during development of these structures. These temporary and localized impacts would affect relatively small areas of the reservoir and would be minimized through the use of BMPs. Adverse effects on aquatic organisms from sedimentation are possible adjacent to and downstream of the activities if disturbed sediment escapes the immediate area. Potential impacts to aquatic organisms also may be possible as a result of spills of fuel, lubricants, solvents, or other liquids. Such impacts are unlikely due to the use of BMPs to prevent spills in accordance with an SWPPP.

The barge facility would be located just east of the TN 58 bridge. Re-development of the barge facility is not expected to involve dredging, and the area of reservoir bottom to be disturbed in conjunction with improvements to this facility would be negligible. If piles need to be driven into the reservoir bottom in conjunction with barge facility improvements, the aquatic and benthic habitats within the footprints of the pilings would be lost. The area potentially affected at the barge facility would be very small in comparison to the extensive area of such reservoir habitats in the vicinity. As discussed in Subsections 2.4.2.1.1 and 2.4.2.3, the benthic community in the vicinity of the barge terminal area is ecologically healthy, but the mussel component is in poor condition, and the community does not include rare species; the fish community is limited in abundance, does not include rare species, and is not dependent on the area for spawning or other critical needs. Increases in turbidity and sediment deposition may occur in the immediate vicinity during pile driving activity. However, these impacts would be temporary and localized, and they would be minimized through the use of BMPs. The underwater noise produced by pile driving would be expected to cause fish to avoid the area of the barge facility during the relatively brief duration of this activity, thereby preventing the possibility of injury from noise or physical contact.

A culvert currently is present at the location where a new culvert would be installed in conjunction with improvements to the access road across the Grassy Creek embayment of the Watts Bar Reservoir. Therefore, this installation would not result in more than a negligible loss of additional reservoir bottom habitat.

As discussed in Subsection 3.4.2.5, a bypass would be installed at Melton Hill Dam to provide a continuous flow of approximately 400 cubic feet per second (cfs) around the hydropower generating units in the dam. Because this conduit would be installed within the existing dam, the Melton Hill bypass would not substantially disturb sediment or affect aquatic life in the Clinch River arm of the Watts Bar Reservoir or the Melton Hill Reservoir.

Preconstruction and construction activities on the CRN Site likely would result in the permanent loss of small areas of aquatic habitat and the temporary alteration of additional habitat nearby. However, as indicated by the results of the biological surveys and evaluations discussed in Subsection 2.4.2, no aquatic habitats in the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site are known to be unique or essential to rare aquatic species or other important species. Fish and other mobile organisms would likely avoid these areas during construction activities, and impacts predominantly would be limited to temporary avoidance of the area. The more immobile benthic organisms would be displaced but likely would recolonize available habitats in the affected areas over time. For example, a study of the rate of colonization by macroinvertebrates of artificial substrate samplers in a Michigan stream found that multiple samplers placed on the substrate were colonized within 60 days by a diverse assemblage of taxa. The numbers of individuals colonizing the substrates reached a maximum after 39 days, and the number of taxa increased throughout the study period. (Reference 4.3-10) In addition, a study by the U.S. Environmental Protection Agency of the effects of suction dredging for commercial mining on freshwater benthic communities in several streams in Alaska found that the effects were local and short-lived even in such a relatively cold climate. In a river and a creek, impacts from small-scale dredging activity were contained primarily within the mined areas, and macroinvertebrates returned to pre-dredging densities within approximately 1 month. (Reference 4.3-11)

BMPs would contribute to minimizing impacts associated with the excavation that may be required to construct the intake and discharge structures, replace the Grassy Creek culvert, and other improvements on the Clinch River arm of the Watts Bar Reservoir. Accordingly, preconstruction and construction activities on the CRN Site and in the Barge/Traffic Area would not notably affect aquatic communities in the reservoir and the ecological impacts would be SMALL.

4.3.2.4 Important Aquatic Species and Habitats

Subsection 2.4.2.3.1 describes federally listed aquatic species that have recorded occurrences in Roane County, Subsection 2.4.2.3.2 describes species with state status and recorded occurrences in the county, and Table 2.4.2-6 summarizes these species and their status. The five aquatic species with a federal listing status that potentially occur in Roane County and are extant in the region (recorded occurrences within less than or equal to 25 yr) include three mussels, a fish, and a salamander. No live or relic specimens of these three mussel species were found during the 2011 mussel survey in the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site, and suitable habitats for the fish and salamander are not present on the CRN Site. Thus, federally listed species with the potential for occurrence in the vicinity are not present on the CRN Site or in the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site and would not be affected by preconstruction and construction activities for the CR SMR Project.

Subsection 2.4.2.3.2 discusses the aquatic species that have recorded occurrences in Roane County and a state listing or other protected status but no federal listing status. These species include one amphibian, four fish, and one plant. The amphibian, the hellbender, has been found in the tail waters below Melton Hill Dam, and the Clinch River arm of the Watts Bar Reservoir potentially provides habitat suitable for this large salamander. The four fish species with state status are unlikely to occur on or adjacent to the CRN Site due to unsuitable habitat conditions. The plant, a waterweed, potentially could occur in quiet waters of streams or ponds but has not been observed in botanical surveys of the CRN Site. The single small stream (S01) on the CRN Site that would be lost due to construction of the cooling water intake structure and pipeline does not provide suitable habitat for any of these species, and none were found in a survey of this stream. On the Barge/Traffic Area, surveys of streams S08, S09, and S12 also found no listed species. (Reference 4.3-9) Thus, aquatic species with state status and the potential for occurrence on the CRN Site, on the Barge/Traffic Area, or in the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site would not be affected by preconstruction and construction activities for the CR SMR Project.

Other important species in the project area that potentially could be affected by preconstruction and construction activities in or adjacent to the Clinch River arm of the Watts Bar Reservoir are commercially or recreationally important fish species that inhabit the reservoir. As discussed in Subsection 2.4.2.3.3, commercially or recreationally valuable fish species have been documented in the reservoir both upstream and downstream of the CRN Site. (These species are identified in Table 2.4.2-1). All of these fish are highly mobile and are able and expected to avoid the areas where excavation and other preconstruction and construction activities would be performed. These activities would create short-term disturbances and noise that would be likely to cause fish to avoid the immediate area. However, these activities would be temporary and very localized, and fish could readily avoid the source of disturbance. The number of individuals affected would likely be very limited, and populations would be essentially unaffected because individuals of these species could move away from the area of disturbance to suitable habitat elsewhere in the reservoir. Also, the limited water withdrawals associated with preconstruction and construction activities would not affect aquatic communities in the reservoir, including recreational fisheries. Thus, potential impacts to commercially or recreationally important aquatic species would be SMALL and temporary.

Invasive aquatic species, such as the zebra mussel and Asiatic clam, already are present the Clinch River arm of the Watts Bar Reservoir. With use of established TVA BMPs, preconstruction and construction activities associated with the CR SMR Project would not contribute to the spread of these or other exotic or invasive species or increase their impacts on native species. Thus, impacts from this project related to invasive species would be SMALL.

4.3.2.5 Transmission Corridors

Minor sedimentation or erosion due to runoff may occur during construction activities within the new segment of 161-kV ROW on the CRN Site and the installation of the underground 69-kV line within a 5-mi segment of the 500-kV ROW on the CRN Site and between the CRN Site and the Bethel Valley substation. If new access roads are needed for construction and maintenance of these lines, they would also have the potential to contribute to erosion and sedimentation at stream crossings. Three streams that cross the ROW are designated as aquatically sensitive areas (Figure 2.4.1-3). Ish Creek is an aquatic natural area (ANA1) that crosses the ROW approximately 0.5 mi from the CRN Site. Northwest Tributary is an aquatic reference area (ARA3) consisting of three small streams, two of which cross the ROW approximately 2 to 2.5 mi from the CRN Site. There are no recorded occurrences of federally or state-listed aquatic species within this ROW. The Tennessee dace, a fish designated by the state as in need of management, has been recorded in Ish Creek approximately 0.25 mi downstream of this ROW. Up to three additional streams also would be crossed: Streams S03 and/or S06 on the CRN Site near the northeastern boundary, and a small stream that crosses the ROW slightly southwest of the Bethel Valley substation.

Impacts on streams from installation of the underground line would be prevented or minimized through the use of BMPs such as hand clearing in sensitive areas, silt fencing, and other erosion control methods. BMPs for spill prevention would be employed to prevent chemical contamination of surface water within ROWs during preconstruction activities. The TVA procedural documents *Right-Of-Way Vegetation Management Guidelines* and *A Guide for Environmental Protection and Best Management Practices for Tennessee Valley Authority Transmission Construction and Maintenance Activities* provide guidance to TVA personnel conducting maintenance activities in transmission line ROWs (Reference 4.3-12; Reference 4.3-13). The guidelines address operations such as re-clearing of vegetation, maintenance of access roads, and erosion control. BMPs include methods for re-clearing, such as cutting of trees and herbicide application, and for protection of sensitive resources. Also, structural controls, standards, and specifications are identified for maintaining physical components such as riprap and culverts within ROWs.

Where streams are crossed during installation of the underground 69-kV line, it is expected that BMPs would be employed to minimize impacts from sedimentation and the short segment of stream directly affected by the installation would be restored immediately afterward. Preliminary plans are to tunnel under streams whenever practicable. Consequently, potential impacts on aquatic habitats due to the installation of transmission lines either on the CRN Site or within the offsite 500-kV ROW would be SMALL.

Subsection 3.7.3.8 describes planned modifications to the existing transmission system outside the CRN Site, and Subsection 2.4.2.1.4 describes the aquatic ecological resources in the segments of the ROWs for those transmission lines that potentially would be affected. The uprating, reconductoring, and rebuilding activities would involve existing lines within existing ROWs, and additional ROWs would not be established, cleared, or developed. BMPs would be employed to prevent impacts from temporarily accessing and working on these line modifications. The aquatic resources within these ROWs are identified in Table 2.4.1-7. These resources, including designated critical habitats for two endangered mussel species, would not be noticeably affected by the temporary activities required for the planned upgrades. BMPs would be employed as described in Subsection 3.7.3.8 to prevent or minimize impacts to aquatic habitats as a result of temporarily accessing and working on these line modifications in the vicinity of aquatic habitats. Therefore, potential impacts are expected to be SMALL.

4.3.2.6 Summary of Impacts to Aquatic Ecosystems during Preconstruction and Construction

The environmental effects from preconstruction and construction activities on the CRN Site and in adjacent offsite areas would not disrupt or alter important aquatic ecosystems. Impacts on aquatic habitats would be minor based on the lack of high quality or unique habitats in the areas to be developed or the adjacent reservoir and the presence of extensive reservoir, pond, and stream habitats in the vicinity and the region. Impacts on most streams or other aquatic ecosystems would be minor and would be further reduced by compliance with permitting requirements and compensatory mitigation.

Important aquatic habitats (e.g., natural areas, managed areas, or other designated areas) would not be within the footprint of preconstruction or construction activities or otherwise adversely affected by these activities, and the impact of these activities on important aquatic species would be minimal. Impacts on components of the aquatic ecosystem within transmission corridors similarly would be minimal. Accordingly, the overall impact of preconstruction and construction activities on aquatic ecosystems on or adjacent to the CRN Site and affected offsite areas (Barge/Traffic Area and 500-kV transmission line ROW) would be SMALL for all resources.

4.3.3 References

Reference 4.3-1. Dattilo, Adam J., "Clinch River Barge/Traffic Area - Terrestrial Plant Communities and Botanical Resources Survey Report," Tennessee Valley Authority, June 18, 2015.

Reference 4.3-2. Parr, Patricia D. and Hughes, Joan F., "Oak Ridge Reservation Physical Characteristics and Natural Resources," ORNL/TM-2006/110, Oak Ridge National Laboratory, U.S. Department of Energy, October, 2006.

Reference 4.3-3. Pilarski-Hall, Kim and Lees, Britta P., "Clinch River Small Modular Reactor Site - Wetland Survey Report - Revision 4," November 19, 2015.

Reference 4.3-4. Baranski, Michael J., "Natural Areas Analysis and Evaluation, Oak Ridge Reservation," ORNL/TM-2009/201, Oak Ridge National Laboratory, U.S. Department of Energy, November, 2009.

Reference 4.3-5. Nuclear Regulatory Commission, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," NUREG-1437, 2013.

Reference 4.3-6. U.S. Nuclear Regulatory Commission, "Final Environmental Impact Statement for Combined Licenses for Virgil C. Summer Nuclear Station Units 2 and 3," NUREG-1939, Vol. 1, Washington, DC, April, 2011.

Reference 4.3-7. Federal Highway Administration, "Synthesis of Noise Effects on Wildlife Populations," FHWA-HEP-06-016, September, 2004.

Reference 4.3-8. Howard, Charles S., Henderson, Andrew R., and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Evaluation of Aquatic Habitats and Protected Aquatic Animals Technical Report - Revision 5," Tennessee Valley Authority, December 22, 2015.

Reference 4.3-9. Henderson, Andrew R. and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Stream Survey Report - Revision 3," Tennessee Valley Authority, December 22, 2015.

Reference 4.3-10. Meier, Peter G., Penrose, David L., and Polak, Loren, "The rate of colonization of macro-invertebrates on artificial substrate samplers, Freshwater Biology 9: 381-392, 1979.

Reference 4.3-11. Prussian, Aaron M., Royer, Todd V., and Minshall, G. W., "Impact of suction dredging on water quality, benthic habitat, and biota in the Forty mile River, Resurrection Creek, and Chatanika River, Alaska," U.S. Environmental Protection Agency, Region 10, Seattle, Washington, June, 1999.

Reference 4.3-12. Muncy, J. A., "A Guide for Environmental Protection and Best Management Practices," 2012.

Reference 4.3-13. Tennessee Valley Authority, "Right-Of-Way Vegetation Management Guidelines; Energy Delivery Environmental Protection Procedures," Revision 3, September 23, 2013.

Reference 4.3-14. Tennessee Department of Environment and Conservation, “Stream Mitigation Guidelines for the State of Tennessee,” Division of Water Pollution Control, Natural Resources Section, July 1, 2014.

Table 4.3-1
Land Cover Types to be Disturbed by Development on the CRN Site

Land Cover Types	Approximate Acreage Affected	Approximate Percentage of Affected Areas	Percent of cover type affected on the CRN Site[1]
CRN Site			
Permanently Disturbed Areas			
Herbaceous/grassland	152	47	75
Mixed evergreen-deciduous forest	106	32	27
Deciduous forest	53	16	18
Roads/developed areas	13	4	93
Evergreen forest	3	1	9
Total	327	100	
Temporarily Disturbed Areas			
Mixed evergreen-deciduous forest	90	54	23
Deciduous forest	19	11	7
Evergreen forest	17	10	53
Herbaceous/grassland	41	25	20
Total	167	100	
Total of Permanently and Temporarily Affected Areas	494		
Barge/Traffic Area			
Permanently Disturbed Areas			
Herbaceous/grassland	1	3	N/A
Deciduous forest	9	30	N/A
Roads/developed areas	20	67	N/A
Total	30	100	
Temporarily Disturbed Areas			
Herbaceous/grassland	1	7	N/A
Deciduous forest	14	93	N/A
Total	15	100	
Total of Permanently and Temporarily Affected Areas	45		

[1] Approximate acreages used in the denominator of these percent calculations are from Table 2.4.1-1.
Source: Figure 4.3-1.

Note:
N/A – Not Applicable

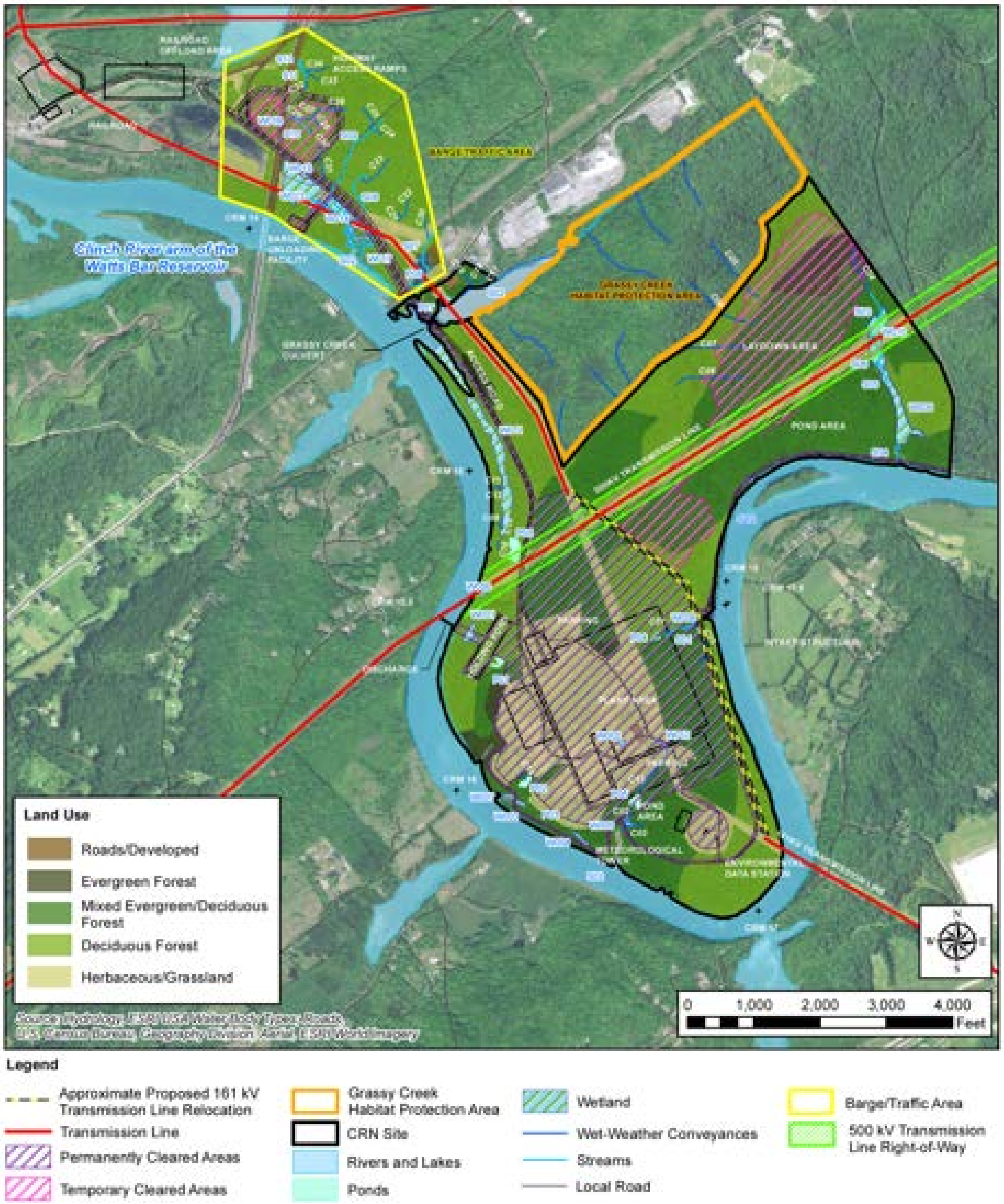

Figure 4.3-1. Areas to be Cleared and Land Cover Disturbed on the CRN Site and Barge/Traffic Area

4.4 SOCIOECONOMIC IMPACTS

This section describes the potential socioeconomic impacts associated with preconstruction and construction activities for the Clinch River (CR) Small Modular Reactor (SMR) Project, which includes the construction and operation of two or more SMRs at the Clinch River Nuclear (CRN) Site. The discussion is divided into three subsections. Subsection 4.4.1 describes physical impacts of preconstruction and construction activities on the community. Subsection 4.4.2 describes the social and economic impacts of the preconstruction and construction activities on the geographic area of interest and surrounding region. Subsection 4.4.3 describes environmental justice impacts within the region as a result of preconstruction and construction activities.

4.4.1 Physical Impacts

Preconstruction and construction activities can cause temporary and localized physical impacts such as noise, vibration, shock from blasting, odors, vehicle exhaust, and dust. This subsection addresses such potential construction impacts associated with the CRN Site that may affect noise, vibrations, and air quality.

4.4.1.1 Noise and Vibration

Preconstruction and construction related activities at the CRN Site and in the associated offsite areas (within the existing 500-kilovolt (kV) right-of-way (ROW) from the CRN Site to the Bethel Valley substation, the Barge/Traffic Area, potential rail modifications, and the borrow areas) have the potential to create elevated noise and vibrations beyond the baseline levels. The potential impacts of noise from the CRN Site preconstruction and construction have been analyzed by projecting construction-related noise levels at the CRN Site and within 5 miles (mi) of the CRN Site in comparison to ambient measurements described in Section 2.8, as well as to federal noise level guidelines. The results of these comparisons were then used to determine the magnitude of noise impacts at the various receptors identified in Section 2.8. Some activities which generate noise are also vibration-inducing activities; therefore, vibration impacts were analyzed in conjunction with the noise impacts.

The U.S. Department of Housing and Urban Development has established noise impact guidelines for residential areas based on day-night average sound levels (DNL) (Title 24 Code of Federal Regulations [24 CFR] 51.103). The CRN Site lies within the Oak Ridge city limits and the City of Oak Ridge has established noise ordinances based on the adjacent property uses. Adjacent property consists of the Clinch River Industrial Park on the north side of the CRN Site and the Oak Ridge Reservation (ORR) on the east side of the CRN Site. The Clinch River arm of the Watts Bar Reservoir is adjacent to the remainder of the CRN Site with residential areas on the opposite bank. The City of Oak Ridge sets a maximum limit of 80 A-weighted decibels (dBA) during the hours of 7:00 AM to 10:00 PM and a maximum of 75 dBA between 10:00 PM and 7:00 AM when the adjacent property use is residential. Additionally, the sound level should not exceed 65 dBA for more than half an hour during a one hour survey or 70 dBA for more than

10 minutes during a one hour survey. (Reference 4.4-1) Neither the State of Tennessee nor Roane County has developed noise regulations that specify acceptable community noise levels. When feasible, Tennessee Valley Authority (TVA) uses the U.S. Environmental Protection Agency (EPA) guideline of 55 dBA DNL as a design goal if the nearest receptor is residential. For industrial and commercial areas, TVA uses a 60 dBA equivalent noise level as a design goal at the property line. As described in Section 2.8, the DNL is the sound level average over a 24-hour (hr) period used to define the level of average noise exposure to a community during that 24-hr period. As part of the DNL sound level calculation, an additional 10 decibel (dB is added to nighttime (2200 to 0700) sound levels to account for the increased sensitivity of the community to nighttime noise. (Reference 4.4-2) When the background DNL is 60 dBA or less, TVA uses the Federal Interagency Committee on Noise recommendation that a 3 dB increase in DNL indicates a possible impact and necessitates further analysis (Reference 4.4-3).

Because the nearest adjacent property is the Clinch River Industrial Park, a commercial/industrial area, for the purpose of this Environmental Report, noise impacts are assessed using the DNL of 60 dBA at the property line as the level below which noise levels would be considered acceptable. As stated in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* Rev. 1, in general, noise levels below a DNL of 65 dBA outside a residence are considered to be acceptable. Therefore, DNLs up to 65 dBA are considered to be SMALL impacts.

The amount of impact preconstruction or construction noise and vibrations have on the surrounding environment depends on factors including sound intensity, frequency, duration, location on site, the number and type of noise and vibration sources, time of day, weather conditions, wind direction, time of year, etc. Typical preconstruction and construction noise and vibration are generated by the operation of machinery and vehicles, including internal combustion engines (e.g., front end loaders, tractors, scrapers/graders, heavy trucks, cranes, concrete pumps, and generators), impact equipment (e.g., pneumatic equipment, jack hammers, and pile drivers), other equipment (e.g., vibrators, saws, and hydro excavation equipment), and machine backup-alarms. Equipment noise and vibration associated with preconstruction and construction activities can be categorized as either continuous (ongoing) or impulse (periodic) in nature and can be either stationary or mobile in location. Equipment that operates in one location for one or more days at a time is considered stationary (e.g., pumps, generators, compressors, and screens). Pile drivers and pavement breakers may also be categorized as stationary equipment depending on the nature of their use. Mobile equipment includes machinery such as bulldozers, scrapers, loaders, and haul trucks that perform cyclic processes. The equipment type, age of equipment, specific model, equipment condition and the operation performed influence equipment noise and vibrations. Because of design improvements and technological advances, new machines are typically quieter than older models due primarily to better engine mufflers, refinements in fan design, and improved hydraulic systems.(Reference 4.4-4)

Noise levels as generated by typical equipment are shown in Table 4.4-1. This information is being utilized to illustrate a worst case scenario. Attenuated noise levels calculated in Table

4.4-1 are considered to be maximum noise levels. Construction equipment and vehicles generally do not operate at maximum levels continuously; therefore actual noise (and the associated vibration) levels are expected to be lower than those levels shown on Table 4.4-1 and may also be further reduced by the use of modern equipment, mufflers, and hydraulic systems.

The majority of the preconstruction and construction activities occurring at the CRN Site and in the offsite areas would generate noise levels below 65 dBA at each of the receptors. Those construction activities that could generate noise above 65 dBA at the CRN Site border or in the offsite areas would be temporary. Most preconstruction and construction activities would occur during normal daylight hours between 0700 and 1700. There are occasions when preconstruction and construction activities must be scheduled during night time hours. Typical instances requiring overnight activities include continuous concrete pours to ensure homogeneity and strength of the structures. At these times the noise level would remain as high as or higher than 60 to 90 dB at a distance of 100 feet (ft) from the equipment; however, the noise level should be attenuated to below 65 dBA at the CRN Site border.

The nearest residences are located across the Clinch River arm of the Watts Bar Reservoir on three sides of the peninsula. Because water is between the CRN Site and the residences, construction noise would not be attenuated with distance as it would by natural insulators (e.g., ground cover, earthen berms, grass, or trees with foliage). If construction activities occur within 500 ft of the CRN Site border or of the offsite areas (distance at which estimated dBA for equipment [other than pile driver] is less than 65 dBA), or noise levels become excessive, the nearby residences could be temporarily impacted by construction noise above the acceptable levels. Altering terrain during construction activities at the CRN Site could increase or decrease impact noise levels across the Clinch River arm of the Watts Bar Reservoir. Common practices to mitigate noise include, but are not limited to:

- Using noise reduction devices on heavy equipment (i.e., mufflers)
- Limiting driving speeds, use of “Jake brakes,” and tail-gate slamming
- Constructing earthen berms
- Placing foliage or ground cover between the noise sources and receptors

The industrial facilities located north of the CRN Site along West Bear Creek Road in the Clinch River Industrial Park could be adversely affected by construction noise. However, noise levels are expected to be lower than at the residences across the reservoir because of the elevated topography separating the industrial park from the CRN Site. Other receptors (i.e., recreation areas, hospitals, and schools) are located at distances at which noise levels during construction activities would be comparable to background levels.

Unusual noise and vibrations due to construction activities such as blasting, demolition and testing of the emergency warning siren may periodically be necessary. These activities could result in temporarily excessive noise levels. These noise and vibration generating activities are expected to fluctuate throughout the construction period. Blasting and demolition would occur early in the preconstruction and construction activities at intermittent frequencies and only occur during the daylight hours (between 0700 and 1700). If the construction activities occur in close proximity to the CRN Site border, then the residences closest to the CRN Site border (specifically those located across the Clinch River arm of the Watts Bar Reservoir) could temporarily experience noise and vibration impacts from the construction equipment. Mitigation measures as described previously would minimize noise and vibration.

Offsite preconstruction or construction activities include the installation of the 69-kV underground transmission line, roadway modifications, refurbishment of a rail siding, and improvements to the barge loading area, all located within property owned by the federal government and managed by the U.S. Department of Energy (DOE) or TVA and not in proximity to any residences. These offsite activities would, therefore, also be unlikely to cause direct impacts to the general public. However, workers at the Clinch River Industrial Park and ORR facilities could experience noise from construction activities, in particular the 5-mi long underground transmission line.

The identified potential offsite borrow areas for the CR SMR Project are located in areas in closer proximity to residences and communities than the CRN Site. Additionally, trucks transporting the borrow materials would travel near or through various communities in route to the CRN Site. These borrow areas are currently being used for the extraction of borrow material. Therefore preconstruction or construction activities at these borrow areas would be unlikely to create new impacts beyond those already occurring. Trucks hauling borrow materials would travel along roadways that are already used by a variety of vehicles, including similar trucks. Therefore, the transportation of borrow materials would also be unlikely to cause direct noise- or vibration-related impacts to the general public.

An increase in daily traffic (up to 3300 construction worker vehicles and 90 construction/transport vehicles per day) would be expected along Tennessee State Highway (TN) 58 and Bear Creek Road during peak construction. The composition of this traffic would include passenger cars and light-duty trucks of the construction workforce, as well as trucks for delivery of construction materials and heavy equipment used to support facility construction (e.g., excavators, bulldozers, heavy haul trucks, and cranes). This traffic would have the potential to increase noise along TN 58 and Bear Creek Road. Potential effects of this daily traffic are considered to be indirect impacts associated with onsite preconstruction and construction activities. Construction worker traffic would have a SMALL to MODERATE effect on noise levels along local roadways surrounding the CRN Site. Noise levels would vary over the course of construction based on the number of workers commuting to the CRN Site, with higher noise levels generated during the peak construction period. Because the construction workforce would be divided into three shifts (although approximately two-thirds of the construction workforce would work the day shift), the increased traffic would be concentrated at shift changes, including during the night and early morning. Therefore, the indirect noise and vibration impacts to the public from construction-related traffic on local roads associated with preconstruction and construction activities at the CRN Site would be SMALL to MODERATE.

Based upon the projected noise and vibration levels at various CRN Site and surrounding area receptors and the duration of preconstruction and construction activities, direct noise and vibration impacts from CRN Site construction are expected to be SMALL for the surrounding communities and the nearest residents.

4.4.1.2 Air Quality

Preconstruction and construction activities at the CRN Site and in the offsite areas would generate temporary air emissions of both gaseous and particulate pollutants. Potential air emission activities would likely include:

- Land clearing and material removal
- Material processing and handling
- Construction and preconstruction machinery operation and maintenance
- Material replacement (including subsurface preparation and concrete pouring and paving)
- Driving piles and erection of structures
- Truck deliveries of supplies and materials to the CRN Site and offsite areas
- Soil excavation and grading
- Soil transport and temporary stockpiling
- The workforce commute

In general, as stated in NUREG-1555, Subsection 4.4.1, "physical impacts to a community from construction of a nuclear plant are not markedly different from any other large heavy construction project."

Preconstruction and construction-related emissions, typically from fugitive dust and construction equipment engine exhaust, tend to be limited and localized to the immediate project area because they are generated from groundlevel or near groundlevel. Therefore, the project's preconstruction and construction phase geographic area of interest for air quality is estimated to extend no more than 5 mi from the CRN Site. Additionally, these emissions are intermittent, temporary and transient (e.g. the construction activities would not encompass the entire CRN Site at all times).

National ambient air quality standards (NAAQS) have been established by the EPA in 40 CFR 50 (Subsections 50.4 - 50.13 and 50.15 -50.18) for defined criteria compounds: sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter with a diameter less than 10 microns (PM_{10}), particulate matter with a diameter less than 2.5 microns ($PM_{2.5}$), lead (Pb), and ozone (O_3). In addition, the EPA has classified areas of the country where the NAAQS are met (attainment areas), locations that sufficient data are not available for setting a classification (unclassifiable or undesignated), and locations in the country that do not meet the NAAQS (nonattainment areas). These areas are designated on a pollutant-by-pollutant basis.

The portion of Roane County in which the CRN Site is located is in attainment for all air pollutants. Census Block Group 47-145-0307-2 in Roane County, located approximately 6 mi to the west of the CRN Site, is designated nonattainment for $PM_{2.5}$ (location shown in Section 2.7, Figure 2.7.2-1).

Preconstruction and construction activities associated with the operation of motor vehicles and engines would produce temporary emissions of both gaseous pollutants and particulate matter. These emissions are temporary in that equipment is only used for the preconstruction and construction phases of the project and this equipment is not used continuously during preconstruction and construction. An SMR technology has not yet been selected for the CR SMR Project; therefore, associated preconstruction and construction activities, including the numbers and types of equipment onsite and phasing, have not been determined. Preliminary estimates of emission factors for equipment typically used during preconstruction and construction phases are provided in Tables 4.4-2 and 4.4-3. Further evaluation of construction related emissions will be conducted at the combined license application stage once the SMR technology has been selected.

Because emissions from onsite preconstruction and construction activities are generally from near ground level, impacts are potentially greatest at sensitive receptors nearest to construction activities. Figure 2.7.6-1 shows the location of sensitive receptors in the area surrounding the CRN Site. The figure indicates the closest sensitive receptors are across the Clinch River arm of the Watts Bar Reservoir, at approximately 0.5 mi, to the northeast clockwise through the west-northwest. Emissions from preconstruction and construction activities would be temporary and are expected to be minor. Air permitting for the CR SMR under Tennessee and federal air laws are expected to address these emissions.

To minimize these temporary emissions, the CR SMR Project will utilize a preconstruction and construction-related mitigation plan. Mitigation measures may include:

- Scheduling preconstruction and construction activities to minimize running, inactive vehicles
- Phasing activities and equipment use
- Ensuring the use of heavy equipment that is in good condition, is properly maintained, and is compliant with applicable federal regulations for off-road diesel engines
- Ensuring all machinery is maintained and operated in accordance with the manufacturer’s specifications
- Minimizing idling time of vehicles delivering materials to the CRN Site
- Maintaining low vehicle speeds on dirt covered roads and exposed areas to minimize dust generation
- Watering down roadways and exposed areas
- Minimizing storage piles of soils

- Minimizing dust generating activities during high wind conditions
- Locating stationary equipment (e.g., generators and compressors) as far away from sensitive receptors as practical
- Implementing specific contractor's procedures to minimize the generation of dust via materials handling, vehicle movement, and wind erosion

On-road indirect source emissions would also be generated from motor vehicles used for truck deliveries to the CRN Site and from the preconstruction and construction workforce's commute. Measures to mitigate on-road emissions may include staggered shift times, requiring delivery vehicles to shut down engines during off-loading, and supporting/encouraging van/carpooling and other commuting alternatives. Motor vehicle emissions are not expected to create significant impacts but will also be addressed, along with mitigation measures, as required under federal and state regulations during the air permitting process.

Preconstruction and construction activities at the CRN Site and in the offsite areas would generate temporary air emissions of both gaseous and particulate pollutants. The effects on air quality from these temporary emissions are expected to be minor and would be minimized through use of a mitigation plan, which will be prepared when the design of the facility is complete and provided to the air reviewing agencies. Further, the transportation analysis in Subsection 5.8.2.3 indicates that measures to offset impacts from construction related activity on local roads would be sufficient to offset impacts to roadway levels-of-service (LOS). This would also mitigate the potential for addition emissions from vehicles due to roadway congestion. Accordingly, air quality impacts from CRN Site construction are expected to be SMALL for the surrounding communities and the nearest residents.

4.4.2 Social and Economic Impacts

This subsection evaluates the potential demographic, economic, infrastructure, and community impacts associated with preconstruction and construction activities for the CR SMR Project, which includes the construction and operation of two or more SMRs at the CRN Site. The geographic area of interest identified for social and economic impacts, which is defined by the areas where the construction workforce and their families would reside, spend their income, and use their benefits, is the four-county area including Anderson, Knox, Loudon, and Roane counties. The evaluation assesses potential impacts associated with construction-related activities and the size of the construction workforce. The analysis is based on the plant parameter envelope, which is discussed in Section 3.1 and provided in Tables 3.1-1 and 3.1-2, a peak construction and operations overlap workforce of 3666 workers, which is discussed in Section 3.10.

4.4.2.1 Population and Housing

This analysis of population and housing is based on the estimated peak overlap workforce expected to be onsite at any point during the construction and operations period. As described in Subsection 3.10.4, the CR SMR Project includes construction of multiple SMRs that would be brought into operation sequentially. Therefore, there would be a period of time when one or more SMR(s) is operating while other SMR(s) are being constructed, resulting in an overlap of construction and operations workers. The peak overlap workforce is defined in Subsection 3.10.4 as 3666, which is the peak construction workforce (3300) plus the peak operation workforce occurring during the same months as the peak construction workforce (366).

Based on the information presented in Section 3.10, it is anticipated that approximately 2185 construction workers already reside within the 50-mi region. The remaining 1115 workers would migrate into the region. It is conservatively assumed that 100 percent of this in-migrating workforce would relocate within the geographic area of interest. It is also estimated that 50 percent of the total operations workforce (250 workers) is recruited and trained from the Oak Ridge/Knoxville area, and 50 percent (250 workers) relocate to the Oak Ridge/Knoxville area from outside a 50-mi radius. This results in a total in-migrating workforce of 1365.

Population

In 2010, the permanent population within the 50-mi radius of the CRN Site was 1,158,026 and is projected to grow to 1,305,189 by 2021 (Tables 2.5.1-2 and 2.5.1-5). The four-county geographic area of interest, including Anderson, Knox, Loudon, and Roane Counties, had a population of 610,092 in 2010 and a projected population of 682,278 in 2020 and 807,594 in 2040 (Table 2.5.1-6).

It is assumed that each worker that relocates into the geographic area of interest would bring a family. The average household size in Tennessee is 2.48 (Reference 4.4-5). Therefore, an in-migrating workforce of 1365 would increase the population in the geographic area of interest by 3385 people, or 0.6 percent of the geographic area of interest population in 2010. Of the 11,433 employees at the DOE Oak Ridge facilities that reside within the geographic area of interest, 27 percent reside in Anderson County, 50 percent in Knox County, 6 percent in Loudon County, and 17 percent in Roane County (Reference 4.4-6). It is assumed that the residential distribution of the in-migrating workforce would resemble the residential distribution of the DOE workforce. Of the total population increase due to the in-migrating workforce, 914 people (27 percent of 3385) are expected to settle in Anderson County, 1693 people in Knox County, 203 people in Loudon County, and 575 people in Roane County. These numbers constitute 1.2 percent, 0.4 percent, 0.4 percent, and 1.1 percent of the 2010 populations of Anderson, Knox, Loudon, and Roane Counties, respectively.

The in-migrating workers and their families would represent a small increase to the populations of the four counties within the geographic area of interest and an even smaller increase to the total population in the geographic area of interest. Therefore, the potential impacts on population would be SMALL.

Housing

Subsection 2.5.2.6 and Table 2.5.2-12 review and show availability of housing in the year 2010 in the geographic area of interest and are used as a basis for estimating the number of housing units that may be available during the construction phase. Generally, the counties with larger populations (in particular Knox County) have more available vacant housing.

During the overlap between preconstruction/construction and operation, 3385 people would potentially seek permanent and temporary housing within the geographic area of interest.

There is currently enough housing to accommodate all the expected in-migrating families in Knox County alone. Knox County, with the greatest number of housing units in the geographic area of interest, had 17,700 vacant units in 2010, with 6777 for rent and 3747 for sale. In the geographic area of interest as a whole, there were a total of 26,403 vacant housing units, with 8984 for rent and 5120 for sale. It is likely adequate housing would be available within the geographic area of interest at the time the in-migrating peak overlap workforce would move into the area. It is also probable that workers on short-term assignments would utilize temporary housing in the form of hotels, seasonal homes (for long-term rentals), and recreational vehicle parks and campgrounds. As described in Subsection 2.5.2.6, there are over 8100 hotel rooms in the Knoxville area and another 1185 rooms in Anderson, Loudon, and Roane Counties. According to the 2010 Census, the geographic area of interest has 2329 seasonal housing units. Also, there are approximately 1302 temporary housing sites at recreational facilities in the geographic area of interest (Table 2.5.2-12).

The potential impacts on housing would be SMALL due to the large number of available vacant housing units in the geographic area of interest and the relatively small requirements for the in-migrating construction workforce.

4.4.2.2 Employment and Income

The in-migration of construction workers would be likely to create new indirect service jobs in the area and increase the amount of money used to purchase goods and services. The influx of new workers would spend a portion of their income on housing, food, entertainment, and other goods and services in the region, and additional jobs would be created through the multiplier effect. The number of times the final increase in consumption exceeds the initial dollar spent is called the multiplier. The U.S. Department of Commerce Bureau of Economic Analysis, Economics and Statistics Division, calculates multipliers for industry jobs and earnings within a specific region. The economic model they use is called the Regional Input-Output Modeling System (RIMS II).

RIMS II multipliers were obtained for the region consisting of Anderson, Knox, Loudon, and Roane counties. The RIMS II direct effect employment multiplier for construction jobs is 1.7415. Thus, for every newly created construction job, an estimated additional 0.742 jobs are created in the region. (Reference 4.4-7) Based on the Bureau of Economic Analysis multiplier and a maximum overlap workforce of 3666 during the peak overlap period, CRN Site construction would create approximately 2720 indirect jobs within the geographic area of interest, which would be expected to occur during the fourth year of a projected six-year construction schedule. The combined total of 6386 direct construction jobs plus indirect jobs represents approximately 1.6 percent of the geographic area of interest workforce.

Most indirect jobs are assumed to be service-related and not highly specialized. Therefore, it is expected that those jobs would be filled by the existing workforce within the geographic area of interest. Some of the indirect jobs could benefit unemployed or underemployed workers in the geographic area of interest. The total number of indirect jobs that would be generated by construction is approximately 11 percent of the 24,000 unemployed persons in the geographic area of interest.

For every dollar earned by a construction worker, an additional 0.6998 dollars is added to the regional economy based on the Bureau of Economic Analysis direct-effect earnings multiplier for the geographic area of interest (Reference 4.4-7).

The employment of the overlap workforce over a period of several years would have positive economic effects on the geographic area of interest and surrounding region. It would introduce millions of dollars into the regional economy, creating indirect jobs that could help reduce unemployment and business opportunities for housing and service-related industries. Much of this positive effect would be expected to occur within the geographic area of interest. Therefore the impact of construction on the economy of the geographic area of interest would be beneficial and MODERATE.

4.4.2.3 Transportation

Roadways

As shown on Figure 2.5.2-1, several federal highways and state roads provide access to the geographic area of interest. Construction traffic would typically access the CRN Site via Oak Ridge Turnpike (TN 58) and Bear Creek Road. Driveway access to and from the CRN Site is from one roadway, Bear Creek Road. TN 58 and TN 95 provide access to Bear Creek Road. For workers commuting from the north and south, there are interchanges on Interstate (I-) 40 for both TN 58 and TN 95. For workers commuting from the west, TN 61 and TN 62 provide access to Bear Creek Road via TN 327. From the east, US 321/TN95 intersects with Bear Creek Road. The roadway configuration results in a concentration, or funneling, of facility-related traffic from I-40 and various highways onto Bear Creek Road.

Capacity analyses were performed for the four existing intersections most likely to be affected by construction and operation of the two or more SMRs at the CRN Site, as described in Subsection 2.5.2.2.3. These intersections are TN 58 at Bear Creek Road ramp (Intersection 1), TN 58 at TN 327 (Intersection 2), TN 95 at Bear Creek Road (Intersection 3), and Bear Creek Road at Bear Creek Road ramp/US Government Property Road (Intersection 4). The capacity analyses evaluated existing (2013) conditions. The locations of Intersections 1 through 4 are shown on Figures 2.5.2-1 and 4.4-1. These figures illustrate the same roadways and intersections. Figure 2.5.2-1 shows the four existing intersections that were evaluated in the capacity analysis, and Figure 4.4-1 shows a schematic rendering of the proposed improvements to those intersections as well as the addition of two proposed new intersections.

A traffic assessment was completed for the four existing intersections (Intersections 1 through 4) as well as the two proposed new intersections (Intersections 5 and 6). This assessment included an analysis of traffic conditions on the roads adjacent to the CRN Site for the existing (2013) situation and for three future (2024) scenarios. The year 2024 is the expected peak traffic year, with an estimated construction workforce of 3300 (maximum number onsite during a 24-hr period) and an operation workforce of 366 for a peak overlap workforce of 3666. (Reference 4.4-8) The three future scenarios evaluated are:

- <u>Background = future conditions *without construction*</u>: Incorporates any historic background growth rates, any approved development traffic, and any planned roadway improvements independent of the project Site to estimate the future traffic volumes
- <u>Background + Site = future conditions *with construction*</u>: Estimates the future traffic volumes with the addition of proposed CRN Site traffic, based on existing roadway conditions
- <u>Future + Site = future conditions *with construction and traffic improvements*</u>: Estimates the future traffic volumes with the addition of proposed CRN Site traffic, assuming recommended roadway improvements are in place (Reference 4.4-8).

Traffic distribution and assignment were based on land uses and population densities in the area, as well as the surrounding roadway network. The majority of the workers (either construction or operation) were expected to commute from within a 50-mi radius, which includes the greater Oak Ridge and Knoxville, Tennessee metropolitan population areas. Approximately 40 percent of the proposed CRN Site traffic was expected to travel from the north (Oak Ridge and Oliver Springs, Tennessee) along TN 58, TN 95, and TN 327. The remaining 60 percent were expected to travel from the south (Kingston, Lenoir City, Farragut, and Knoxville, Tennessee) along TN 58 and TN 95 from I-40. (Reference 4.4-8)

The results of the traffic assessment, including level of service (LOS) and delay for each study intersection, are summarized in Table 4.4-4 for all periods analyzed. The LOS designations for *2024 Background + Site Scenario* represent traffic conditions at the intersections with the addition of proposed CRN Site construction based on existing roadways (without mitigation). The LOS for four of the intersections is F, the lowest level, which represents poor progression and extreme delay. This includes Intersection 3, TN 95 at Bear Creek Road, which would adversely affect access to the Clinch River Industrial Park on West Bear Creek Road. This represents a LARGE impact to traffic flow during construction.

As shown on Table 4.4-4, the LOS levels for *2024 Future + Site Scenario* represent project-related traffic conditions with the addition of roadway improvements (with mitigation).

Based on the future construction-related traffic analysis, the roadway improvements for the *2024 Future + Site Scenario* are expected to provide an acceptable operation for the peak year 2024. These improvements are summarized in Figure 4.4-1. The proposed additional northbound loop ramp between TN 58 and Bear Creek Road (Intersection 1) would provide the added capacity for the 2024 peak traffic year surrounding construction and operation. Rather than having all traffic entering/exiting the CRN Site from one ramp, the traffic would be distributed between two ramps. With this new distribution, Bear Creek Road at Bear Creek Road southbound ramp (Intersection 4) is expected to operate with an acceptable LOS. Another advantage of the ramp is that in the event of emergency, the ramp provides free flow movements to/from TN 58 for evacuation purposes. (Reference 4.4-8)

The addition of the proposed new Bear Creek Road northbound ramp is expected to provide added capacity to/from TN 58; however, the connection onto Bear Creek Road would also need to be improved (Intersection 6). Due to the large volume of traffic shifting to the proposed northbound ramp in morning peak hour, dual left-turn lanes would be needed (with a roundabout or a signal), requiring at least two receiving lanes onto Bear Creek Road. A roundabout instead of a signal (Intersection 6) is identified as a mitigation measure for efficiency and safety. (Reference 4.4-8)

During 2024 peak year of construction, the existing two-lane Bear Creek Road is projected to be over capacity during the morning (entering) and afternoon (exiting) peaks. An additional lane (reversible) is identified as a mitigation measure to accommodate the morning and afternoon peaks. The Bear Creek Road at Site Driveway (Intersection 5) should be realigned to a “T” intersection, eliminating the existing curve. A temporary traffic signal is recommended. It is encouraged that construction and operation workers enter the Site from TN 58 for traffic and safety reasons. TN 95, with the high speeds in conjunction with the horizontal (corners/bends) and vertical (hills/valleys) curvature, creates sight distance challenges along this route. (Reference 4.4-8)

Construction worker traffic would have a LARGE impact on local roadways surrounding the CRN Site. In order to avoid disruptions to local traffic during construction for the CR SMR Project, road modifications are proposed as mitigation for the potential adverse impacts. Although some intersections would still be operating at a LOS of D or worse, this would only be for less than 2 hr a day during shift changes. Deliveries would not be scheduled during these times in order to minimize potential adverse impacts. Additional measures such as traffic officers during peak hours could also be implemented in the event that traffic conditions are worse than anticipated. Once construction is complete, the smaller operations workforce would not create adverse impacts to local traffic conditions. With the recommended modifications, impacts to traffic flow during construction would be MODERATE and temporary.

<u>Traffic Accidents</u>

During development of representative commuter and construction traffic impacts, crash data on the primary roadways in the vicinity of the CRN Site for the years 2008 through 2012 were obtained from the Tennessee Department of Transportation. Peak overlap workforce traffic increases are anticipated to occur on TN 58, TN 95, and TN 327 when the first SMR unit is operational while the second SMR unit is under construction. Using the peak construction year of 2024 with 3666 total workers (3300 construction and 366 operational), an estimate of the new vehicles trips and additional traffic accidents including injuries and fatalities was conducted.

The estimated impacts of the peak overlap workforce associated with the CRN Site are shown in Table 4.4-8. Total annual traffic accidents on the three affected roadways in the vicinity of the CRN Site are anticipated to increase by 3.37 accidents, injuries from traffic accidents to increase by 1.17 injuries, and traffic fatalities to increase by 0.08 fatalities per year as a result of combined construction and operation activities at the CRN Site. The projected peak overlap workforce is expected to increase traffic on TN 58 by nearly 50 percent. While TN 58 has the lowest crash, injury, and fatality rates of the three primary roadways used to access the site, a substantial increase in vehicles is likely to result in additional crashes per year. The number of traffic accidents would noticeably increase, but this increase would not destabilize the traffic flow or safety along TN 58, thus having a moderate impact.

TN 95 carries half the traffic of TN 58, but has the highest crash and fatality rate. The increase in traffic would noticeably alter (increase) the number of accidents, injuries, and fatalities on this road; however, this increase in number of traffic accidents on TN 95 would not be sufficient to destabilize traffic flow or safety along TN 95, thus having a small impact.

TN 327 is expected to carry the fewest number of vehicles but is shown to have the highest injury rate. The increase in traffic from the peak overlap workforce would result in an increase of accidents, injuries, and fatalities on this road. The increase in accidents on TN 327 would be minor and would not noticeably destabilize traffic flow or safety along TN 327, thus having a small impact.

The addition of vehicles associated with concurrent construction and operation activities at the CRN Site is expected to result in a minor increase relative to the current traffic accident injury risk in the vicinity of the site. This minor increase would be minimized through implementation of roadway modifications as shown in Figure 4.4-1, and through the use of best management practices (BMPs), such as posting signs near construction entrances and exits to make the public aware of areas with high construction traffic; development of a traffic control mitigation plan; use of staggered shift start and end times; use of carpooling; and scheduling of deliveries to avoid peak traffic periods. Therefore, overall impacts to traffic accidents as a result of construction and operation at the CRN Site would be SMALL to MODERATE and temporary.

Railroads

As described in Section 3.9, some items such as heavy modules and large components would be delivered by rail. They could potentially enter the CRN Site via the Site Access Road from the rail spur (EnergySolutions Heritage Railroad), located approximately 2.5 mi north-northwest of the center point of the CRN Site. The use of this rail spur would not impact other transportation systems used by the local communities and the impact to railroads would be SMALL.

Waterways

As described in Section 3.9, very large components would be delivered by barge. The shipments would be offloaded at the refurbished DOE former K-1251 Barge Loading Area near Bear Creek Road between TN 58 and the CRN Site entrance, and brought to the CRN Site via Bear Creek Road and the Site Access Road. Because the majority of module and component deliveries would be over road and rail, and the barge shipments would be scheduled and arrangements made for the increased barge traffic as necessary, the impact to barge traffic on the Clinch River arm of the Watts Bar Reservoir would be SMALL.

Public Transportation

Public transportation services in the geographic area of interest are provided by the East Tennessee Human Resource Agency (including Oak Ridge Transit), Knoxville Area Transit, and Knox County Community Action Committee Transit (Reference 4.4-9). As discussed in Subsection 4.4.2.1, the estimated geographic area of interest population increase associated with construction of two or more SMRs at the CRN Site would be approximately 3385 people (2765 associated with construction and 620 associated with operation) for the overlap period between construction/preconstruction and operation or 0.6 percent of the geographic area of interest population in 2010). These numbers constitute approximately 1.2 percent, 0.4 percent, 0.4 percent, and 1.1 percent of the 2010 populations of Anderson, Knox, Loudon, and Roane counties, respectively. The construction workers and their families would represent a small increase to the populations of the four counties within the geographic area of interest and an even smaller increase to the total population in the geographic area of interest. This increase in the geographic area of interest population could increase public transportation usage, which would have a SMALL impact on public transportation facilities in the geographic area of interest.

4.4.2.4 Tax Revenues to Local Jurisdictions

Several types of taxes would be generated by construction activities and purchases and by workforce expenditures. These include sales and use taxes on corporate and employee purchases and personal property tax associated with employees. Anderson, Knox, Loudon, and Roane counties are the tax districts that are assumed to be most directly affected by the CR SMR Project.

As discussed in Subsection 2.5.2.3, TVA makes tax-equivalent payments to eight states under Section 13 of the TVA Act of 1933, including the State of Tennessee. TVA pays 5 percent of its gross proceeds from the sale of power (with certain exclusions) to states and counties where its power operations are carried out (the State of Tennessee and Roane County for the CR SMR Project). Payments to each state are determined based upon the proportion of TVA power property and power sales, in each state, compared to TVA's total power property and power sales, respectively.

Tennessee sets aside a percentage of the tax equivalent payments received from TVA each year to redistribute to counties designated by TVA as affected by construction of major facilities used by TVA to produce electric power. These Impact Payments are received by Tennessee counties directly from the State of Tennessee. The payments to impacted counties are made during the period of significant construction activity and for one full fiscal year after completion of such activity, with reduced Impact Payments made during the following three years. Impact Payment allotments are in addition to the TVA tax-equivalent funds distributed by the state to local governments. TVA's designation of counties eligible to receive Impact Payments related to a project is based on anticipated effects such as an increase in local traffic, larger numbers of school-age children entering the county school systems, and a greater demand for the county's health and social services. (Reference 4.4-10) A quantitative estimate of the Impact Payments associated with the CM SMR Project is not available at this time. The additional state allocation of TVA tax equivalent payments as Impact Payments to the eligible local governments during construction could be used to address some of the impacts on public services discussed in Subsections 4.4.2.7 and 4.4.2.8.

Sales and use taxes would be generated in the geographic area of interest and region through retail expenditures of the construction workforce. The purchase of construction materials and supplies for the CR SMR Project also would generate sales and use taxes. However, estimates of regional expenditures expected during the duration of construction are not available.

Property tax revenues would be generated by the increased economic activity involving the construction workforce. Revenues such as residential property taxes, real estate transfer fees, and motor vehicle taxes are collected by or on behalf of the state government. These funds are then distributed to the jurisdictions, including schools and public services.

Given the structure by which the TVA makes payments in lieu of taxes, the general distribution structure of funding by the State of Tennessee, as well as the increase in income, sales, and property taxes, the potential impact of taxes within the geographic area of interest and region would be small and beneficial. Although the amount of income, sales, and property taxes as well as TVA tax-equivalent payments would be large in absolute terms, it would be SMALL when compared to the total amount of taxes collected within the geographic area of interest.

4.4.2.5 Land Use

In NUREG-1437, Rev. 1, the U.S. Nuclear Regulatory Commission (NRC) defines levels of significance for identifying impacts to offsite land use related to refurbishment of an existing nuclear facility. The analysis is based on population changes caused by refurbishment activities. These significance levels are applicable to the analysis of the impacts associated with constructing a new nuclear power plant. NRC concluded that the impacts to offsite land use during refurbishment at nuclear plants are considered:

- SMALL: if population growth results in very little new residential or commercial development compared with existing conditions and if the limited development results only in minimal changes in an area's basic land use pattern
- MODERATE: if plant-related population growth results in considerable new residential or commercial development and the development results in some changes to an area's basic land-use pattern
- LARGE: if population growth results in large-scale new residential or commercial development and the development results in major changes in an area's basic land-use pattern

NRC identified key predictors of population-induced land use changes as:

- SMALL: if plant-related population growth is less than 5 percent of the study area's total population, especially if the study area has established patterns of residential and commercial development, a population density of at least 60 persons per square mile, and at least one urban area with a population of 100,000 or more within 50 mi
- MODERATE: if plant-related growth is between 5 and 20 percent of the study area's total population, especially if the study area has established patterns of residential and commercial development, a population density of 30 to 60 persons per square mile, and one urban area within 50 mi
- LARGE: if plant-related population growth is greater than 20 percent of the study area's total population and population density is less than 30 persons per square mile

During the overlap period between preconstruction/construction and operation, the population in the geographic area of interest would increase by 3385 people (2765 associated with construction and 620 associated with operation) as described in Subsection 4.4.2.1. In 2010, the four counties within the geographic area of interest had a population of 610,092 and covered a land area of 1435 square mi, for an overall population density of 425 persons per square mi. A temporary population growth of 3385 persons represents a 0.6 percent increase in the population of the geographic area of interest. According to NRC guidelines, population-induced land use changes would be SMALL because the construction-related population increase would be 0.6 percent of the geographic area of interest population, the area has an established pattern of residential and commercial development, a population density of greater than 60 people per square mi, and at least one urban area with a population of 100,000 or more within 50 mi (178,874 in Knoxville, Tennessee) (Reference 4.4-11). Additionally, land use changes would be SMALL because the population growth would result in very little new residential or commercial development compared with existing conditions and would be expected to result in minimal changes to the basic land use patterns in the vicinity of the CRN Site.

Population-induced land use changes would also be SMALL if the counties within the geographic area of interest are considered individually. As discussed in Subsection 4.4.2.1, population increases due to the peak overlap workforce constitute 1.2 percent, 0.4 percent, 0.4

percent, and 1.1 percent of the 2010 populations of Anderson, Knox, Loudon, and Roane counties, respectively. The population density is greater than 60 people per square mi for each county: 222.8 in Anderson County, 850.5 in Knox County, 211.8 in Loudon County, and 150.2 in Roane County.

4.4.2.6 Aesthetics and Recreation

Visual and aesthetic effects associated with a project occur as a result of the introduction of a structure or facility that is not consistent with the existing viewshed. Consequently, the character of an existing site is an important factor in evaluating potential effects of construction on the visual resource. Visual resources of the CRN Site and surrounding areas are described in Subsection 2.5.2.5.1. Because the areas immediately surrounding the CRN Site are bound by water features, forests, and ridge lines, direct visual access to facility construction is limited primarily to construction workers, residents living along the Clinch River arm of the Watts Bar Reservoir across from the CRN Site, and recreators using the reservoir.

Although most of the construction activities are not expected to be visible to the general public, construction of the facility would entail the use of large cranes. The largest is expected to be a heavy lift crane with a height of 638 ft, which would be visible from local public roads. The tallest power block structure would be 160 ft above plant grade (Table 3.1-2, Item 1.1.1) and its construction would be visible above the tree line. Additional activities such as use of large earth-moving equipment, relocation of a portion of the Kingston FP – Fort Loudon HP 161-kilovolt transmission line on the CRN Site, and the transportation of large materials onto the CRN Site could be visible to members of the public from the surrounding area. Night time lighting could be used during construction if work is to proceed at night and for security purposes, and would be visible from the surrounding area. Construction of the two or more SMRs would be visible to recreational users of the Clinch River arm of the Watts Bar Reservoir, the Melton Hill Reservoir and Melton Hill Dam Reservation, and the Gallaher Recreation Area. Construction activities would be most noticeable to these groups while the intake and discharge structures were being built. Because the impacts of construction activities on visual resources would be localized and the construction timeframe is limited, the aesthetic impacts to the general public would be small. For nearby residents and recreational users of the Clinch River arm of the Watts Bar Reservoir, the aesthetic impacts would be MODERATE.

A number of public and private recreational facilities and a range of outdoor activities are located in the vicinity of the CRN Site, as described in Subsection 2.5.2.5.2, and in the region, as discussed in Subsection 2.5.1.3. Recreational areas within the CRN Site vicinity and region could potentially be impacted by the increased population of construction workers and their families and the increased competition for transient housing. Workers who relocate to the geographic area of interest would be expected to utilize recreational areas and facilities to a similar degree as the permanent population of the geographic area of interest. Because many of the recreational opportunities of the region are outdoor activities without associated maximum capacities, it is difficult to accurately estimate utilization by the permanent population. Considering that an in-migrating workforce of 1365 would increase the population in the geographic area of interest by 3385 people, or 0.6 percent based on the 2010 population of 610,092 (as discussed on Subsection 4.4.2.1), sufficient recreational facilities are available to accommodate the associated increase in usage. Therefore, impacts to recreation resources during construction would be SMALL. Based on the regional supply of transient housing, including 2329 seasonal units and 1302 temporary housing sites at recreational facilities in the geographic area of interest (as discussed in Subsection 4.4.2.1), the impact on recreational facilities due to increased competition for transient housing also would be SMALL.

4.4.2.7 Community Infrastructure and Services

Construction demand from construction activities as well as associated population increases were considered when evaluating the effects of construction at the CRN Site on infrastructure and services. The peak overlap workforce is estimated to be 3666. During peak overlap period, an estimated 1365 workers would migrate into the geographic area of interest accompanied by 2020 family members, for a population increase of 3385 (as discussed in Subsection 4.4.2.1).

Water Supply Facilities

Potential impacts to potable water supplies would result from additional demands on water supply facilities associated with construction-related water needs and the increase in the local population (in-migrating construction workers). The total anticipated construction water use for the plant is 231,660 gpd, or 0.23 million gallons per day (mgd).The source of water for the potable and sanitary water systems, as well as concrete batch plant operation at the CRN Site, is municipal water from the City of Oak Ridge Public Works Department.. The U.S. Geological Survey (USGS) estimates that the average person uses 80 to 100 gpd of water at home, including bathing, laundry, and outdoor watering (Reference 4.4-12). Using the presumption that the construction workers would be present on site for 10 hr per day, it is assumed that a conservative estimate of 50 gpd of potable water per worker would be required. During construction, the peak overlap workforce of 3666 workers would require 183,300 gpd for potable and sanitary use. The balance would be used for concrete batch plant operation and other miscellaneous uses. Surface water from the Clinch River arm of the Watts Bar Reservoir (approximately 5000 gallons per day [gpd]) may be used during construction for purposes such as dust control. As described in Subsection 2.5.2.7.2, the Oak Ridge Department of Public Works obtains its raw water from the surface water in the Melton Hill Reservoir. As shown in Table 2.5.2-15, the utility has a maximum potable water capacity of 9.9 mgd and an average daily consumption of 7.7 mgd, for an excess capacity of 2.2 mgd. The onsite potable water usage of 0.23 mgd represents less than 11 percent of excess capacity and construction impacts to water supply facilities would be SMALL. Any future demands on the excess water capacity from the City of Oak Ridge would be evaluated for potential impacts on the municipality.

The impacts to the water supply systems within the geographic area of interest from construction-related population increase can be estimated by calculating the amount of potable water that is required by these individuals. Table 2.5.2-15 contains details regarding the more than 20 public water suppliers in the four counties of the geographic area of interest, including their maximum daily capacity and current demand. Most of these water supply systems are operating well below capacity. The USGS estimates that the average person uses 80 to 100 gallons of water per day at home (Reference 4.4-12). This represents an increased demand of approximately 338,500 gpd based on 3385 in-migrating construction workers and families and a consumption rate of 100 gpd. Because all of the local utilities are operating below capacity and the in-migrating workforce would be spread out among four counties, an increase of 3385 persons in the geographic area of interest would not adversely affect the local utilities' capacity to supply potable water to their customers. Therefore, impacts to public water supply systems in the geographic area of interest would be SMALL.

Wastewater Treatment Facilities

Similar to potable water supplies, potential impacts to wastewater treatment facilities would result from onsite construction-related needs and the increase in the local population associated with in-migrating construction workers. The wastewater generated during construction activities at the CRN Site would be discharged to the City of Oak Ridge Rarity Ridge sanitary treatment facility. As previously stated, the average person in the United States uses 80 to 100 gpd of water at home, including such activities as dishwashing, laundry, and outdoor watering (Reference 4.4-12). During construction, a peak of 3666 workers would be onsite. Assuming that half of their water consumption would occur onsite, it is expected that 40 to 50 gallons of wastewater per worker per day would be generated. At the peak of the construction process, a maximum of 183,300 gpd of wastewater would be produced onsite based on 3666 workers and a wastewater production rate of 50 gpd per worker. As shown on Table 2.5.2-16, the City of Oak Ridge Rarity Ridge facility has a maximum treatment capacity of 0.6 mgd and an average daily utilization of 0.1 mgd, for an excess capacity of 0.5 mgd. The onsite wastewater production of 0.17 mgd represents approximately 36 percent of excess capacity. Accordingly, the construction-related impact to wastewater treatment facilities would be MODERATE. However, this impact would be temporary, with the peak overlap workforce onsite during only six months of the six-year construction period (Table 3.10-2).

Table 2.5.2-16 lists the wastewater treatment facilities in the geographic area of interest, their maximum daily capacity, and wastewater flows processed daily. The increase to the geographic area of interest population of an estimated 2765 construction-related residents would increase demand for wastewater treatment. Because the in-migrating population would not be expected to settle in one area exclusively, this increased demand would be spread among several facilities in the four counties. All of the wastewater treatment facilities in the geographic area of interest are operating below capacity, and would be able to absorb the increased demand without adversely affecting the current customers. Therefore, based on the current excess capacities of the existing wastewater treatment facilities in the geographic area of interest, impacts to wastewater treatment facilities would be SMALL.

Police Services

The number of sworn law enforcement officers and the resident-to-officer ratio for the four counties and the larger cities in the geographic area of interest are given in Table 2.5.2-17. The recommended ratio of officers to residents is between 1 and 4 officers to 1000 residents, or a police-to-resident ratio between 1:250 and 1:1000 (Reference 4.4-13). Table 2.5.2-17 shows that the cities within the geographic area of interest are within this ratio range and the counties are at or slightly above 1:1000. As previously stated, during the peak overlap period an estimated 2765 workers and family members would migrate into the geographic area of interest. It is expected that most of these workers would reside in the larger cities in the area, including Knoxville, Oak Ridge, Clinton, Harriman, Kingston, and Lenoir City, Tennessee. These cities would be able to absorb the additional residents without the necessity of hiring more police officers because their police forces are already larger than the size required to achieve the recommended ratio of officers to residents ratio. Distribution of the construction workforce among the four counties within the geographic area of interest and the resulting increased total populations by county are shown in Table 4.4-5. These population increases would increase the police-to-resident ratios slightly. The percent increase in ratio attributed to construction would be 1.2, 0.4, 0.4, and 1.1 percent in Anderson, Knox, Loudon, and Roane counties, respectively. Based on the percentage increase in police-to-resident ratios, the impact of in-migrating construction-related population to police services would be SMALL.

Fire Protection Services

The existing levels of fire protection services in the geographic area of interest are close to the national average, as described in Subsection 2.5.2.7.3. Firefighter-to-resident ratios range from 1:205 in Roane County to 1:715 in Knox County. During construction, the City of Oak Ridge Fire Department would provide fire and emergency medical services to the CRN Site. The first responder would be the station located at the East Tennessee Technology Park, just north of the CRN Site. Distribution of the peak overlap workforce among the four counties within the geographic area of interest and the effect of the larger populations are shown in Table 4.4-6. These population increases would increase the firefighter-to-resident ratios slightly. The percent increase in ratio attributed to construction would be 0.6, 0.4, 1.2, and 1.0 percent in Anderson, Knox, Loudon, and Roane counties, respectively. Therefore, the potential impacts of the in-migrating residents to fire protection services during construction would be SMALL.

Medical Services

The available medical services in the geographic area of interest, including health care facilities and nursing homes, are described in Subsection 2.5.2.7.3 and Tables 2.5.2-18 and 2.5.2-19. During construction of the CRN facility, onsite medical personnel would be expected to treat minor injuries to workers. More extensive injuries would be treated at one of the medical centers in the vicinity of the CRN Site. The influx of temporary workers to the geographic area of interest would not disrupt the existing medical services available in the area. An addition of approximately 3385 construction-related residents would increase the geographic area of interest population by 0.6 percent and would not adversely affect existing medical services. Therefore, impacts to medical services would be SMALL.

Political and Social Structure

The political structure of the geographic area of interest is described in Subsection 2.5.2.7.1, including federal, state and local representation systems. Population centers range from large cities (Knoxville, Tennessee) to moderate-size municipalities (Oak Ridge and Farragut, Tennessee) to small unincorporated communities. Although many of the 3385 in-migrating construction-related population would likely settle in the larger cities in the geographic area of interest, they would not be likely to all relocate to the same population center. The influx of temporary workers and families to the geographic area of interest would not cause a change to the local political structure. Therefore, impacts to the political structure would be SMALL.

The social relations between members of a community, and the quality and quantity of their interactions, could potentially be affected by construction at the CRN Site. Regardless of the current state of the communities in the geographic area of interest, it is unlikely that an influx of 3385 new residents to the area would have a potentially significant effect on the current social structure and community cohesion. Small indirect changes could occur due to potential economic benefits to the geographic area of interest and individuals employed during construction. These changes would most likely be beneficial as they would involve a general increase in stability due to the availability of stable incomes and employment. Considering that the number of construction-related in-migrants to the area would be limited and that benefits to social structure and community cohesion are presumed to be small but beneficial, social impacts to communities in the geographic area of interest would be SMALL.

4.4.2.8 Education

NUREG-1437, Revision 1 presents criteria for the assessment of education impacts based on the baseline conditions of the potentially affected school system (e.g., whether it is below, at, or exceeding maximum allowed student/teacher ratio). These criteria are:

- SMALL: project-related enrollment increases of 3 percent or less; no change in the school systems’ abilities to provide educational services and no additional teaching staff or classroom space is needed
- MODERATE: project-related enrollment increases of 4 to 8 percent; school system must increase its teaching staff or classroom space
- LARGE: project-related enrollment increases above 8 percent; current institutions not adequate to accommodate the influx of students or project-related demand can be met only if additional resources are acquired.

Schools and student populations are discussed in Subsection 2.5.2.8. In the 2010 US Census Bureau estimates, 17.1 percent of the population of Tennessee was 5 to 17 years old (i.e., school age) and students account for 15.1 to 16.3 percent of total county populations in the four-counties within the geographic area of interest. There would be a population increase of 3385 at the peak overlap period (based on an average household size in Tennessee of 2.48 persons) (Reference 4.4-5). The increase of 3385 persons includes an estimated 552 school-aged children. This represents an increase of 0.6 percent in current public school enrollment. Project-related school enrollment increases would be less than 3 percent within the geographic area of interest.

It is assumed that 27 percent of the in-migrating construction workforce would reside in Anderson County, 50 percent in Knox County, 6 percent in Loudon County, and 17 percent in Roane County, as described in Subsection 4.4.2.1. Table 4.4-7 applies the population distribution percentage assumptions to the number of school-aged children in the construction workforce population to estimate the number of construction-related school-aged children in each of the four counties. It is estimated that Knox County would experience the largest increase in school-age population (276 students). This represents less than 0.5 percent of the current public school population of 58,000. Roane County, with an additional 94 students, would experience the largest relative increase at 1.26 percent. Current (2011-12) public school teacher-to-student ratios in the geographic area of interest are 1:14 in Anderson County and 1:16 in Knox, Loudon, and Roane counties (Reference 4.4-14). The increase in number of students would not change the teacher-to- student ratios (Table 4.4-7).

Increased revenues from property taxes and sales taxes on purchases as a result of construction activities and workforce expenditures would help offset any additional education-related costs. Therefore, impacts to education within the geographic area of interest would be SMALL.

4.4.3 Environmental Justice Impacts

Executive Order 12898 (59 FR 7629) directs federal executive agencies to consider environmental justice under the National Environmental Policy Act (NEPA). This Executive Order ensures that minority and/or low-income populations do not bear a disproportionate share of adverse health or environmental consequences of a proposed project, which in this instance is construction and operation of two or more SMRs at the CRN Site. TVA’s policy is to consider environmental justice in its environmental reviews.

Subsection 2.5.4 describes the evaluation process used to identify minority and low-income populations living within the region that meet the conditions associated with the NRC guidance. Census blocks, block groups, and relative distances of minorities and low-income populations around the CRN Site are identified in Table 2.5.4-1 and Figures 2.5.4-1 and 2.5.4-2.

As shown in Figure 2.5.4-1, the spatial distribution of block groups with minority populations in the region is clustered in the City of Knoxville, in Knox County, Tennessee and the City of Alcoa, in Blount County, Tennessee. No block groups in Roane County (in which the CRN Site is located) or in Anderson County contain minority populations as defined in Subsection 2.5.4.2. The identified aggregate minority population closest to the CRN Site is located approximately 20 mi to the east in Blount County, Tennessee. The closest Hispanic minority population is located in Loudon County, Tennessee, approximately 9 mi southeast of the CRN Site.

As shown in Figure 2.5.4-2, the majority of the low-income population in the geographic area of interest is in the City of Knoxville, in Knox County, Tennessee. There is one low-income population block group within Roane County, Tennessee and one within Anderson County, Tennessee. The closest low-income population block group is located in Loudon County, Tennessee, approximately 7 mi southeast of the CRN Site. As shown on Figures 2.5.4-1 and 2.5.4-2, there is some overlap between the locations of minority and low-income population groups.

As discussed below in Subsection 4.4.3.2, no other populations or groups (e.g., subsistence populations) were identified that represent environmental justice populations in the region. Two locations of potential significance to minority communities were identified, however. The Wheat Community Burial Ground is a mid-19th century African American cemetery located approximately 1 mi northwest of the northern boundary of the CRN Site on the east side of TN 58. The community of Scarboro, a small predominantly African American community established in 1950, is located in Anderson County approximately 0.5 mi from the Oak Ridge Reservation Y-12 plant.

4.4.3.1 Potential Physical Impacts

For the purposes of this environmental justice assessment, physical impacts under consideration due to facility construction include potential effects on land use, water, and ecology. Ecological resources are a concern in the event that any minority or low-income populations in the area are dependent on fishing or farming for subsistence. Potential impacts on land use are described in detail in Section 4.1. Impacts on water are described in Section 4.2. Ecological impacts are described in Section 4.3.

CRN Site construction would occur primarily within the CRN Site boundaries or the nearby and adjacent offsite construction areas. Offsite preconstruction or construction activities include the installation of the 69-kV underground transmission line, roadway modification, refurbishment of a rail siding, and improvements to the barge loading area, all located within property owned by the federal government and managed by the DOE or TVA and not in proximity to any residences. In addition, the potential offsite borrow areas currently identified as potential source areas for borrow material for the CR SMR Project are located in areas in closer proximity to residences and communities than the CRN Site. Most of the physical impacts would affect the properties adjacent to the CRN Site and the offsite construction areas.

As described in Section 4.1, the impacts on the surrounding public from any land use impacts as a result of CRN Site construction would be SMALL. Because the effects would be small and because of the spatial distribution of minorities and low-income population in the region, the potential for disproportionate land use impacts on minority and low-income populations would be SMALL.

As described in Section 4.2, the impacts on the surrounding public from any water related impacts as a result of CRN Site construction would be SMALL. Because the effects would be small and because of the spatial distribution of minorities and low-income population in the region, the potential for disproportionate water related impacts on minority and low-income populations would be SMALL.

As described in Section 4.3, the impacts on the surrounding public from any ecological impacts as a result of CRN Site construction would be SMALL. Because the effects would be small and because of the spatial distribution of minorities and low-income population in the region, the potential for disproportionate ecological impacts on minority and low-income populations would be SMALL.

Based on the evaluations of land use impacts, water-related impacts, and ecological impacts presented in Sections 4.1, 4.2, and 4.3, respectively, physical impacts are expected to be SMALL. Based on the small impacts overall, combined with the distribution patterns of minority and low-income populations, the potential for disproportionate impacts to minority and low-income populations would be SMALL.

4.4.3.2 Potential Socioeconomic Impacts

The socioeconomic resource categories with the greatest potential to affect minorities and low-income populations are transportation and housing. The impacts associated with the remaining socioeconomic resource categories (i.e., noise and air quality, land use, social and public services, economy, tax revenues, and recreation) would be SMALL, regardless of their spatial distribution relative to the CRN Site, and some would have beneficial effects.

Transportation during construction would be expected to have a moderate impact on local roads, including TN 58 and Bear Creek Road. However, as described in Subsection 4.4.2.3, road modifications are proposed as mitigation for the potential adverse impacts. Few houses are located along these access roads in the areas likely to be impacted by the construction traffic. None of the minority or low-income census blocks are located along either TN 58 or Bear Creek Road. Although the Wheat Community Burial Ground is located off of TN 58, construction traffic would not impede access to the cemetery. No relocations of traffic to local offsite roads as a result of the construction of the CRN Site are anticipated. Therefore, minority and low-income populations and locations of potential significance to minority populations would not be adversely impacted by construction traffic or disproportionately affected.

The impact of plant construction on the housing market in the CRN Site vicinity is expected to be small due to the large number of available vacant housing units and the relatively small requirements for the in-migrating construction workforce. Due to the increased demand for housing in the region, however, rental housing costs could increase and potentially displace low-income renters. Considering the available number of housing units and assuming construction workers would not be likely to need low-income housing, minority and low-income populations, including the Scarboro community, would not be adversely impacted or disproportionately affected by the construction-related demand for housing.

Positive socioeconomic impacts associated with construction are described in Subsection 2.5.2. These include increased employment opportunities, possible income increases, and generation of additional tax revenues, which are directly and indirectly related to facility construction. These beneficial impacts also would be realized by minority and low-income populations.

The possibility that uniquely vulnerable minority or low-income communities, such as subsistence populations, might be located near the CRN Site was also evaluated. As discussed in Subsection 2.5.4.4, inquiries were made to local agencies, such as planning departments and social services agencies, academic institutions, and local businesses. None of the persons contacted identified any unique economic, social, or human health circumstances and lifestyle practices through which the minority and low-income populations could be disproportionately adversely affected by the CR SMR Project.

Based on the evaluation of potential socioeconomic effects of construction, impacts are expected to be SMALL. Given the small impacts overall, combined with the distribution patterns of minority and low-income populations, the potential for adverse socioeconomic impacts that would disproportionately affect minority or low-income populations in the region would be SMALL.

4.4.4 References

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Reference 4.4-16. Federal Bureau of Investigation, Crime in the United States 2013, Table 78, Tennessee, Website: http://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2013/crime-in-the-u.s.-2013/tables/table-78/table-78-cuts/table_78_full_time_law_enforcement_employees_tennessee_by_city_2013.xls, 2013.

Table 4.4-1
A-Weighted Sound Levels (dBA) of Construction Equipment and Modeled Attenuation at Various Distances[1]

Noise Source	50 ft	100 ft	200 ft	300 ft	400 ft	500 ft	1000 ft
Backhoe	78	72	66	62	60	58	52
Crane	81	75	69	65	63	61	55
Dump Truck	76	70	64	60	58	56	50
Excavator	81	75	69	65	63	61	55
Front end loader	79	73	67	63	61	59	53
Concrete mixer truck	79	73	67	63	61	59	53
Auger drill rig	84	78	72	68	66	64	58
Dozer	82	76	70	66	64	62	56
Pile driver	101	95	89	85	83	81	75

[1] The dBA at 50 ft is a measured noise emission. The 100-ft to 1000-ft results are modeled estimates.

Table 4.4-2
Typical Emission Factors (grams/bhp-hr) for Construction-Related Equipment[1]

Equipment	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2	NO_X	CO_2
Concrete Pump	0.41	3.99	0.33	0.32	0.005	4.49	594.82
Portable Generator	0.19	1.00	0.24	0.23	0.005	2.52	530.41
Lifts	0.85	2.46	0.43	0.42	0.006	4.56	623.82
Off-Highway Trucks	0.19	1.42	0.15	0.14	0.005	4.15	536.23
Tractor	0.77	2.11	0.28	0.27	0.006	4.45	624.06
Dozer	0.35	1.26	0.15	0.14	0.005	3.82	535.71
Front End Loader	0.77	2.11	0.28	0.27	0.006	4.45	624.06
Excavator	0.19	1.42	0.15	0.14	0.005	4.15	536.23
Crane	0.19	0.92	0.11	0.10	0.005	4.38	530.44
Welding Machine	0.41	2.39	0.28	0.27	0.006	4.82	625.21
Motor Grader	0.35	1.26	0.15	0.14	0.005	3.82	535.71

1 grams/bhp-hr = grams per brake horsepower-hour

Table 4.4-3
Emission Factors (grams/veh-mi) for Vehicles on Construction Site[1]

Vehicle	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2	NO_X	CO_2
Car	0.136	2.767	0.071	0.014	0.002	0.180	357.4
Passenger Truck	0.205	4.355	0.108	0.021	0.003	0.390	471.4

1 grams/veh-mi = grams per vehicle-mile

Table 4.4-4
Summary of Overall LOS and Delay by Intersection

Intersection	AM Peak		PM Peak	
	LOS[1]	Delay (sec.)	LOS[1]	Delay (sec.)
1. TN 58 at Bear Creek Road Ramp				
2013 Existing	B	10.1	C	15.2
2024 Background	B	10.7	C	19.2
2024 Background + Site Scenario *(Unsignalized)*	F	900+	F	900+
2024 Future + Site Scenario *(Interchange)*[2]	C	20.5	C	23.2
2. TN 58 at TN 327				
2013 Existing	A	9.5	A	6.9
2024 Background	B	11.1	A	7.5
2024 Background + Site Scenario	B	14.2	A	8.9
2024 Future + Site Scenario	B	14.2	A	8.9
3. TN 95 at Bear Creek Road				
2013 Existing	B	10.5	C	24.9
2024 Background	B	10.8	F	54.3
2024 Background + Site Scenario	F	57.9	F	435
2024 Future + Site Scenario	F	57.9	F	435
4. Bear Creek Road at US Government Property Road				
2013 Existing	A	9.3	A	8.6
2024 Background	A	9.5	A	8.6
2024 Background + Site Scenario	F	563	B	14,9
2024 Future + Site Scenario	D	31.9	A	10.0
5. Bear Creek Road at Site Driveway				
2024 Background + Site Scenario (*Unsignalized*)	F	900+	F	900+
2024 Future + Site Scenario (*Signalized*)	D	42.0	B	10.5
6. Bear Creek Road at Bear Creek Road Northbound Ramp (Proposed)				
2024 Future + Site Scenario (*Signalized*)	B	19.6	B	15.0
2024 Future + Site Scenario (*Roundabout*)	B	15.7	A	7.0

1 Level of Service (LOS) Index:
A - Progression is extremely favorable and most vehicles do not stop at all
B - Good progression, some delay
C - Fair progression, higher delay
D - Unfavorable progression, congestion becomes apparent
E - Poor progression, significant delay
F - Poor progression, extreme delay

2 AM Peak (Northbound Diverge), PM Peak (Southbound Merge)

Notes:

The LOS designations for *2024 Background + Site Scenario* represent traffic conditions at the intersections with the addition of proposed CRN Site construction based on existing roadways (without mitigation).

The LOS levels for *2024 Future + Site Scenario* represent project-related traffic conditions with the addition of roadway improvements (with mitigation).

Source: (Reference 4.4-8)

Table 4.4-5
Police Protection in the Four Counties of Interest, Adjusted for the Construction Workforce and Associated Population Increase

Counties in the Geographic Area of Interest	Total Population in 2010	Additional Population Due to New Facility Construction	Total with Additional Population	Number of Sworn Law Enforcement Officers[1]	Current Officer-to-Resident Ratio	Officer-to-Resident Ratio with Additional Population	Percent Increase from Current Officer-to-Resident Ratio
Anderson	75,129	914	76,043	148	1 : 508	1 : 514	1.0
Knox	432,226	1693	433,919	851	1 : 508	1 : 510	0.4
Loudon	48,556	203	48,759	73	1 : 665	1 : 668	0.5
Roane	54,181	575	54,756	63	1 : 860	1 : 869	1.0

1 Including city police force(s) within each county.

Sources: (Reference 4.4-15; Reference 4.4-16)

Table 4.4-6
Fire Protection in the Four Counties of Interest, Adjusted for the Construction Workforce and Associated Population Increase

Counties in the Geographic Area of Interest	Total Population in 2010	Additional Population Due to New Facility Construction	Total with Additional Population	Number of Firefighters (Full time and Volunteer)	Current Firefighter-to-Resident Ratio	Firefighter-to-Resident Ratio with Additional Population	Percent Increase from Current Firefighter-to-Resident Ratio
Anderson	75,129	914	76,043	216	1 : 350	1 : 352	0.6
Knox	432,226	1693	433,919	604	1 : 715	1 : 718	0.4
Loudon	48,556	203	48,759	201	1 : 240	1 : 243	1.2
Roane	54,181	575	54,756	264	1 : 205	1 : 207	1.0

Table 4.4-7
School Enrollments and Teacher/Student Ratios

Counties in the Geographic Area of Interest	Students Enrolled in Public School System	Full-Time Equivalent Teachers	Teacher to Student Ratio	Construction-Related Population Increase - Percent by County	School-Age Population Increase	Percentage of Additional Public School Children per County	Teacher to Student Ratio with Additional Children
Anderson	12,598	925.1	1:13.62	27	149	1.18	1 : 13.8
Knox	58,815	3705.4	1:15.98	50	276	0.46	1 : 15.9
Loudon	7369	464.6	1:15.86	6	33	0.44	1 : 15.9
Roane	7413	475.2	1:15.6	17	94	1.26	1 : 15.8
Total	86,195	5570.3	NA	NA	552[1]	0.64	NA

[1] Based on addition of 552 school-aged children within geographic area of interest.

Note:
Na = Not Applicable

Source: (Reference 4.4-14)

Table 4.4-8
Construction and Operational Impacts in the Vicinity of the Clinch River Site

Roadway	Increase in Average Daily Traffic (ADT)	# of New Crashes per year	# of New Injuries per year	# of New Fatalities per year
TN 58 (L.M. 17.60 to L.M. 20.18)	4560	2.56	0.82	0.00
TN 95 (L.M. 0.00 to L.M. 3.00)	855	0.63	0.27	0.08
TN 327 (L.M. 0.00 to L.M. 2.20)	285	0.18	0.08	0.00
Total	5700	3.37	1.17	0.08

Notes:
ADT = Average Daily Traffic
L.M. = Log Mile

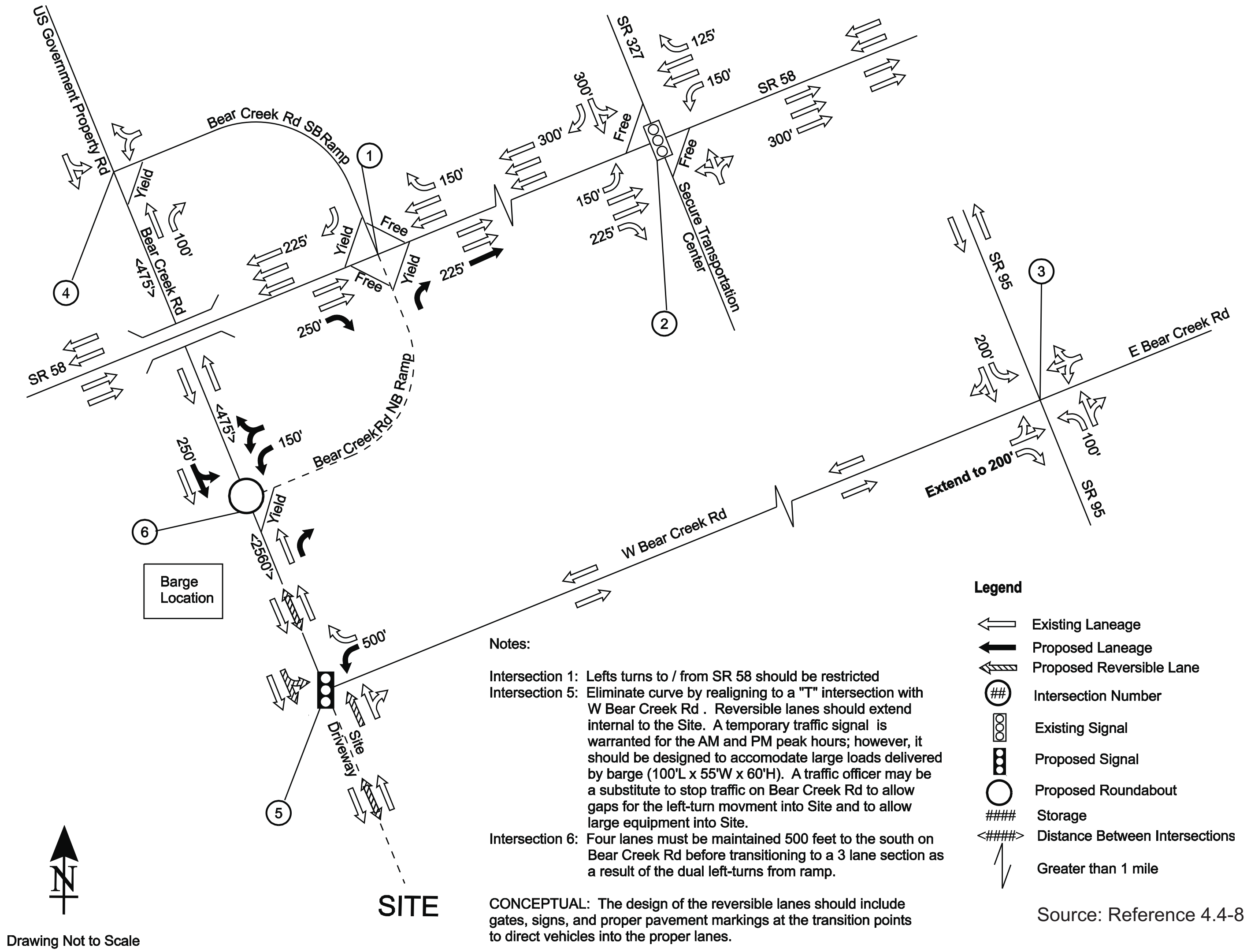

Figure 4.4-1. Proposed Geometry

4.5 RADIATION EXPOSURE TO CONSTRUCTION WORKERS

This section evaluates potential radiological impacts on construction workers during the period of construction of two or more small modular reactors (SMRs) at the Clinch River Nuclear (CRN) Site. At this site, it is assumed that multiple units are to be constructed sequentially, so that construction would occur adjacent to operating units. An exception to this is the NuScale SMR design where there is one structure containing multiple reactors, and for which construction work would be completed prior to installation and operation of the first reactor. As discussed in Section 3.9, the SMRs would be manufactured in factories, and large, fabricated components would be shipped to the CRN Site. Therefore, less onsite construction is required for installation of SMRs than for installation of a typical commercial reactor. The number of units would vary based upon the SMR design selected. In most SMR designs, the reactor containment vessel is underground. Because an SMR design has not yet been selected, a plant parameter envelope (PPE), described in Section 3.1, has been developed for use in evaluating potential environmental impacts.

As shown in Table 3.9-1, the projected construction schedule from the start of preconstruction and site preparation activities for the initial unit until the initiation of fuel load of the final unit is assumed to last 6 years (yr). For the purposes of this evaluation, it was assumed that there is a gap of at least 1 yr between the construction schedules of the new SMR units. This means that one or more units would be operating for 1 yr while construction continues on another unit. Because the number of units that ultimately would be constructed on the CRN Site is not yet known and all but one could be operational during construction of the last unit, the radiation dose to construction workers was conservatively calculated based on the assumption that all units are operating for the duration of the dose calculation.

4.5.1 Site Layout

The physical layout of the CRN Site is depicted in Figure 3.1-2. This layout was determined based upon representative layouts for each of the SMR designs under consideration and the PPE developed to bound these SMR parameters. Construction workers are expected to move around within the construction area during the course of their work in a given year. As the number of units on site is not known and all could be operational except the final unit under construction, the dose to the construction worker is conservatively modeled assuming all units are operating. For the purpose of calculating annual radiation doses to construction workers from one or more operating units, it was assumed that the average location of the workers is at the location representing the center of the reactor unit under construction.

4.5.2 Radiation Sources

This subsection describes the postulated location and characteristics of radiation sources and radioactive effluent emission sources to which construction workers could be exposed. Estimates conservatively assume that all units are operational when determining radiation dose rates to construction workers.

4.5.2.1 Direct Radiation

The SMRs are pressurized water reactors (PWR) designed for series construction, thus allowing multiple units to collectively function as a larger nuclear power plant. Contained sources of radiation in such light water reactors (LWRs) are shielded. Because when completed the SMR facility at the CRN Site is anticipated to produce 800 megawatts electric (MWe) or less, dose estimates for the larger 1000 MWe AP1000 LWR were used to determine that direct radiation from the SMR containment and other buildings would be SMALL (Reference 4.5-1).

Further, the U.S. Nuclear Regulatory Commission (NRC) conducted an evaluation of operating nuclear plants and stated the following in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* Rev 0:

> Direct radiation from sources within a light water reactor plant is due primarily to ^{16}N, a radionuclide produced in the reactor core by neutron activation of ^{16}O from the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of light water reactors are generally undetectable and are less than 1 mrem/year at the site boundary.

Three of the four proposed reactor designs (BWXT mPower, Holtec, and Westinghouse) include “heavily shielded areas” between reactor buildings containing an operating reactor(s) and adjacent reactor buildings under construction. After startup of the first reactor (for BWXT mPower, Holtec, and Westinghouse), the workers employed during construction of the subsequent units would be considered construction workers for the purpose of the construction worker dose analysis.

The NuScale design includes all reactors under a single structure. Building construction would be completed before the first reactor is installed and operated, so there would be no construction work on site after the first reactor is installed. Therefore, personnel installing additional NuScale reactor units after the initial facility startup will be radiation workers and are not considered construction workers for the purpose of the construction worker dose analysis.

4.5.2.2 Gaseous Effluents

As stated in Subsection 3.5.2, gaseous radioactive effluents may be released from stacks and vents of operating SMR units along with possible releases from steam exhauster systems and other radioactive waste management systems. Minor leakage of radioactive gases from plant systems may also provide radioactive gaseous effluents to the plant atmosphere.

Gaseous effluent release rates to the environment for the CRN Site were determined based on composite values from multiple vendors. As shown in Table 3.5-3, the total projected bounding site release activity in gaseous waste was estimated to be 7130 Curies (Ci)/yr.

4.5.2.3 Liquid Effluents

As discussed in Section 3.5 and Subsection 3.5.1, small amounts of liquid radioactive effluents may be released from normal operation of the SMR units, with monitored and controlled discharges into the Clinch River arm of the Watts Bar Reservoir.

Radioisotopes produced during normal plant operations may enter the reactor coolant by diffusing from the fuel and into the coolant. Another possible source of radioactive liquid effluents is corrosion and leachate products from plant components in the cooling water that may become activated by the reactor core neutrons during the cooling cycle.

Liquid effluent release rates to the environment for the CRN Site were determined based on composite values from multiple vendors. As shown in Table 3.5-1, the total projected bounding site annual release activity in liquid effluents was calculated to be 887 Ci/yr.

4.5.3 Construction Worker Dose Rates

Methodology for estimating the annual dose to the construction workforce for the Clinch River (CR) SMR Project included the use of conservative assumptions and the GASPAR II computer code.

4.5.3.1 Direct Radiation

An SMR design has not been selected for the CRN Site. In the absence of design-specific information, data available for larger operating PWRs provides an indication that the potential direct radiation doses to which construction workers next to operational SMRs would be small. TVA estimated an external dose to the SMR construction work based on doses measured using dosimeters placed on the protected area perimeter fence adjacent to two operating pressurized water reactors (Reference 4.5-1). These measurements were previously used to estimate the construction worker dose for the construction of Vogtle Electric Generating Plant Units 3 and 4. The average measure dose rate of 66.9 millirem per year (mrem/yr) is based upon continuous exposure for 24 hours (hr)/day or 8760 hr/yr (Reference 4.5-1). Because the exposure duration for the construction is 40 hr per week for 52 weeks per year, or 2080 hr/yr, the external dose for the construction worker is estimated to be 15.9 mrem/yr at a distance of about 410 feet (ft). Assuming up to two operating SMR units at the CRN Site during construction of a third and final unit and distances to the construction worker of 1162 and 387 ft from center of the first and second SMR nuclear islands, respectively, the total estimated dose to the construction worker would be 24 mrem/yr from direct radiation.

4.5.3.2 Gaseous Effluents

The GASPAR II computer program was used to calculate the anticipated dose to construction workers from onsite operational units. This program, prepared for NRC by Pacific Northwest Laboratory in 1987, implements the radiological exposure models described in NRC Regulatory Guide (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, to estimate the dose resulting from radioactive releases in gaseous effluent. As discussed in Subsection 2.7.6.2, routine diffusion and deposition estimates were determined using the XOQDOQ-82 modeling program, the NRC-recommended dispersion model for evaluating routine releases. Site-specific, validated meteorological data from June 1, 2011 through May 31, 2013 were used to quantitatively evaluate routine releases at the CRN Site.

GASPAR II evaluated both external and internal exposure to gaseous effluents from the SMR facility on the CRN Site, including:

- External exposure to gases
- External exposure to ground contaminated by gases
- Inhalation of gases

Input parameters for GASPAR are detailed in Section 5.4. All estimates assume the construction worker is located at the center of the power block under construction while all of the other proposed units are operational. The construction worker is assumed to spend 2080 hr out of the total 8760 hr in a year. As calculated using the GASPAR code, the construction worker is expected to receive a total body radiation dose of 28 mrem/yr and a maximum dose to another organ (skin) of 51 mrem/yr from normal radiological gaseous releases from the CR SMR Project.

4.5.3.3 Liquid Effluents

Potable water for construction workers would be supplied by the City of Oak Ridge Public Works Department and would not be affected by the liquid discharge from the operational SMRs at the CRN Site. Therefore, the construction worker would receive no dose from the liquid effluent pathway. This lack of exposure is consistent with NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*, guidance that discusses gaseous effluent exposure but does not mention liquid effluent exposure for the construction worker (NRC 1999).

4.5.4 Construction Worker Dose Estimates

The maximum construction worker dose was estimated for each exposure pathway for the period of construction of SMRs at the CRN Site. Associated dose estimates from direct radiation, gaseous effluents, and liquid effluents are discussed below. These annual dose estimates were conservatively based on the following assumptions:

- The average location of the construction worker is at the location representing the center of the reactor unit under construction.
- All SMR units are operating for the duration of the dose calculation.

- The construction worker is expected to spend 40 hr per week for 52 weeks per year, or 2080 hr/yr, at the CRN Site.
- The maximum number of workers during any period that a unit is under construction while another unit is operating, the peak workforce, is 3300.
- Dose calculation for the peak workforce is determined assuming the peak lasts one year.

4.5.4.1 Direct Radiation

As stated in Subsection 4.5.3.1, the total average annual direct radiation dose rate to the construction worker from two operating SMR units at the CRN Site is conservatively assumed to be 24 mrem/yr. The direct radiation dose to skin also is estimated to be 24 mrem/yr.

4.5.4.2 Gaseous Effluents

As stated in Subsection 4.5.3.2, the gaseous effluent dose to the construction worker calculated using the GASPAR II code is 28 mrem/yr, and the maximum dose to another organ (skin) is 51 mrem/yr. These dose estimates incorporate the construction worker onsite exposure duration of 2080 hr/yr. In accordance with NRC guidance, the total effective dose equivalent (TEDE) value for the construction worker was estimated by weighting the thyroid dose (48 mrem/yr) by 0.03 and summing with the total body dose of 28 mrem/yr, resulting in a TEDE of 29 mrem/yr from gaseous effluents (Table 4.5-1).

4.5.4.3 Liquid Effluents

As stated in Subsection 4.5.3.3, potable water for construction workers would be supplied by the City of Oak Ridge and would not be affected by the liquid discharge from the operational SMRs at the CRN Site. Therefore, the construction worker would receive no dose from the liquid effluent pathway. Doses from liquid effluent pathways to members of the public, including construction workers when not on the job, are evaluated in Section 5.4.

4.5.4.4 Workforce Dose

The collective workforce dose is determined for the maximum number of workers during any period that a unit is under construction while another unit is operating. This peak workforce for the CRN Site is 3300 workers. Although this peak workforce is expected to last less than 1 yr, it is conservatively assumed to last for 1 yr. The collective workforce dose is conservatively bounded by multiplying the total dose to an individual construction worker by the peak workforce of 3300 workers. Table 4.5-1 shows the calculated workforce dose from all units and all pathways for total body, thyroid, skin, and TEDE. The estimated total body workforce dose and the TEDE for the workforce is estimated as 170 person-rem per year (person-rem/yr).

4.5.5 Compliance with Dose Regulations

Annual doses to the construction worker at the CRN Site are summarized in Table 4.5-1. The annual total body dose for the construction worker is 52 mrem, which includes direct radiation, gaseous effluent, and liquid effluent doses. Similarly, the annual total doses for the thyroid and the skin pathways are 48 and 51 mrem, respectively. Using these annual total doses, the TEDE was estimated to be 53 mrem/yr.

The annual construction worker dose is compared to the dose limits for individual members of the public in 10 CFR 20.1301 to determine whether the CRN Site construction worker can be treated as a member of the public rather than being classified as a radiation worker. As shown in Table 4.5-2, the dose rates for CRN Site construction worker are lower than the 100 mrem/yr threshold for treatment as a radiation worker. Therefore, with the exception of certain specialty contractors loading fuel or using industrial radiation sources for radiography (who would receive specialized training and be treated as radiation workers when appropriate), construction workers will not be required to be qualified as radiation workers.

NRC regulations govern dose rates to members of the general public. Dose rate limits to the public are provided in 10 CFR Part 20.1301 and 10 CFR Part 50, Appendix I. The design objectives of 10 CFR Part 50, Appendix I apply to maintaining dose as low as reasonably achievable (ALARA) for construction workers. Compliance with these regulations is discussed below.

<u>10 CFR Part 20.1301</u>

The 10 CFR Part 20.1301 limits annual doses from licensed operations to individual members of the public to 100 mrem TEDE. In addition, the dose from external sources to unrestricted areas must be less than 2 mrem in any one hour. This applies to the public both outside and within access-controlled areas. Given that the relevant radiation sources operate at a relatively constant level over time, the hourly limit is met if the annual limit is met. Estimated construction worker doses are compared with 10 CFR Part 20.1301 criteria in Table 4.5-2. For an occupational year, i.e., 2080 hr on site, dose at the plant construction area would be 53 mrem TEDE. The use of 2080 hr assumes the worker works 40 hr per week for 52 weeks per year. The maximum unrestricted area dose rate would be 0.02 mrem/hr. Estimations of this maximum dose assume that the construction worker remains at the center of the unit under construction during all working hours of the year while all other SMR units (which are assumed to have been previously constructed) are operating. This value is less than the limits specified in 10 CFR Part 20.1301 for members of the public. Therefore, construction workers can be considered to be members of the general public and are not required to have radiation protection or monitoring.

<u>10 CFR Part 50, Appendix I</u>

The 10 CFR Part 50, Appendix I criteria apply only to effluents. These criteria ensure adequate design of effluent controls by establishing design objectives for releases from each reactor to

limit doses to individuals in unrestricted areas. For gaseous effluents, the relevant limits are 5 mrem to the total body and 15 mrem to organs, including skin. As shown in Table 4.5-3, there is no estimated dose rate to construction workers from gaseous effluents that exceeds the Appendix I dose limits and construction workers would not be exposed to liquid effluents. Therefore, these criteria have been met.

4.5.6 Summary of Radiation Exposure to Construction Workers

All operations conducted at the CRN Site would be governed by the radiation protection and ALARA programs in accordance with the guidance of NRC RG 8.8, *Information Relevant to Ensuring the Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable,* and 10 CFR Part 20.1302. These programs would be established as part of the combined license for the first operating SMR and would also cover construction activities of additional SMRs. Based on the analysis presented in this section, the project radiation dose to the construction worker from licensed operations would be less than 100 mrem/yr, and impacts to construction workers from radiation exposure would be SMALL.

4.5.7 References

Reference 4.5-1. Southern Nuclear Operating Company, Inc., Vogtle Electric Generating Plant, Units 3 & 4 COL Application, Part 2 Final Safety Analysis Report, Revision 5, Website: http://pbadupws.nrc.gov/docs/ML1118/ML11180A100.pdf, December 4, 2012.

Table 4.5-1
Total Doses to Construction Workers from All Units (mrem/yr)

Pathway	Total Body	Thyroid	Skin	TEDE[1]
Direct Radiation[2]	24	0	24	24
Gaseous Effluent	28	48	51	29
Liquid Effluent[3]	0	0	0	0
Total	52	48	75	53
Workforce Dose[4] from All Units (person-rem/yr)				
All pathways	170	160	250	175

1 TEDE value is estimated by weighting the thyroid dose by 0.03 and summing with the total body dose.
2 Direct radiation estimate is based on the occupational exposure measured adjacent to a commercial pressurized water reactor adjusted for differing distances from two operating small modular reactor (SMR) nuclear islands to the approximate construction area of a third SMR.
3 Liquid effluent dose to construction workers is zero. Water would be supplied to construction workers by the City of Oak Ridge, a source that is not affected by the liquids discharged from operational SMRs at the CRN Site.
4 Workforce dose is calculated by multiplying the total dose in rems to an individual construction worker by the peak workforce of 3300 workers. The peak work force of 3300 workers is conservatively assumed to remain onsite for a full year.

Notes:
mrem/yr = millirem per year
person-rem/yr = person-rem per year
TEDE = total effective dose equivalent

Table 4.5-2
Compliance of Construction Worker Doses from All Units with 10 CFR 20.1301 Criteria

	Construction Worker Dose	Limit
Annual Dose (mrem TEDE)	53[1]	100
Unrestricted Area Dose Rate[2] (mrem/hr)	0.006	2

1 From Table 4.5-1.
2 The unrestricted area dose rate is the sum of the total body gaseous effluent dose rate from all units (28 mrem/yr) and the direct radiation dose rate (24 mrem/yr) divided by 2080 hr/yr.

Notes:
mrem = millirem
TEDE = total effective dose equivalent

Table 4.5-3
Compliance of Construction Worker Doses from Each Unit with 10 CFR 50, Appendix I Criteria (mrem/yr)

Type of Dose from Gaseous Effluents	Construction Worker Dose	Limit[4]
Total Body Dose[1]	1.7	5
Skin[2]	4.5	15
Iodine and Particulates[3] (maximally exposed organ – thyroid)	0.31	15

1 Total body annual gaseous dose for construction worker is estimated as external gaseous effluent dose from each unit to adult MEI at site boundary weighted by the fraction of hours worker is onsite (2080 hr of 8760 hr) per year.
2 Skin annual gaseous dose for construction worker is estimated as external gaseous effluent dose from each unit to adult MEI at site boundary weighted by the fraction of hours worker is onsite (2080 hr of 8760 hr) per year.
3 Annual iodine and radioactive particulate dose for the construction worker is estimated as the sum of ground and inhalation dose to the organ receiving the highest dose from iodines and particulates, the thyroid, weighted by the fraction of hours a worker is onsite (2080 hr of 8760 hr) per year.
4 Dose limits in 10 CFR 50, Appendix I are based on each reactor unit.

Notes:
MEI= maximally exposed individual
mrem/yr = millirem per year

4.6 MEASURES AND CONTROLS TO LIMIT ADVERSE IMPACTS DURING CONSTRUCTION

This section summarizes the principal adverse environmental impacts of construction of the Clinch River (CR) Small Modular Reactor (SMR) Project and the associated measures and controls to limit these impacts. A modified Leopold Matrix has been developed to assess the cause-and-effect relationships between potential environmental disturbances and the corresponding affected environmental resources/receptors (Table 4.6-1).

The table compares environmental disturbances versus environmental resources (receptors). The top left horizontal axis on the measures and controls summary represents the principal environmental disturbances that could result from construction activities. The left vertical axis depicts the environmental resources or receptors that could potentially be affected by those disturbances. The table also summarizes the impact descriptions and measures and controls that have been identified for mitigating construction impacts.

The significance indicators provided in Table 4.6-1 are designated using the following descriptors: SMALL (S), MODERATE (M), or LARGE (L). The significance indicators are defined in Section 4.0. A blank cell in the environmental disturbance column denotes no impact of that type on the environmental resource.

The assignment of significance levels (S, M, L) in Table 4.6-1 is based on the assumption that for each impact description or activity corresponding mitigation measures and controls (or equivalents) are implemented. On Table 4.6-1, each impact description or activity has been assigned a number, and each corresponding mitigating measures and controls has been assigned the same number in parentheses.

The measures and controls in Table 4.6-1 are considered reasonable from a practical, engineering, and economic view. They are based on statutes and regulatory requirements, or they are accepted practices within the construction industry that do not present an unreasonable or undue hardship on the operator/owner.

Based on a review of the ecological surveys that have been completed and construction impacts described in this chapter, some general measures and controls for reducing these impacts at the Clinch River Nuclear (CRN) Site include:

- Cultural Resource surveys have been completed and are described in Subsection 2.5.3.1.
- Planning and engineering studies are to be conducted to determine how best to locate and construct infrastructure facilities (e.g., parking lots, storage facilities, office buildings, roads, etc.) so as to reduce construction impacts.
- Geologic borings, soil tests, and groundwater well data are to be used in combination with the planning and engineering studies to develop a stormwater pollution prevention plan (SWPPP).

- Fugitive dust emissions are to be suppressed by spraying water on excavated soil and unpaved roadways during dry weather.
- Standard Tennessee Valley Authority (TVA) safety plans are to be prepared and construction employees are to receive appropriate training in safety procedures, such as the use of hazardous materials and measures to be taken in the event of leaks, spills, or releases. All chemicals must be on the CRN Site-approved chemical list prior to being brought onsite and handled/stored in accordance with the site's chemical traffic control program.
- Safety data sheets are to be required for use of applicable hazardous materials at the CRN Site. Construction employees are to be trained in the appropriate use of hazardous materials. Hazardous materials are to be used in accordance with applicable federal, state, and local law and regulations.
- Hazardous wastes are to be treated, stored, and disposed of in accordance with the Resource Conservation and Recovery Act (RCRA), and any other applicable federal, state, and local law and regulations. Hazardous wastes are to be disposed using a TVA-approved vendor. Construction employees are to be trained in the appropriate handling and disposal of hazardous wastes, such as waste paints and oils.
- A safety/environmental officer is to oversee and inspect construction activities.
- Construction activities are to be performed in accordance with applicable local, state, and federal ordinances, laws, regulations, and permits intended to prevent or minimize adverse environmental effects of construction activities on air, water, and land, and on workers and the public.
- Construction activities are to comply with applicable permits and licenses.
- Construction activities are to be performed in compliance with applicable TVA safety and construction procedures.
- Pertinent construction permits and environmental requirements are to be included in construction contracts.

More specific mitigation measures are detailed in Table 4.6-1.

Principal adverse environmental impacts of construction of the CR SMR Project were considered for Land Use, Water, Ecological, and Socioeconomic Impacts and Radiation Exposure to Construction Workers. The impacts were separated on the basis of preconstruction and construction impacts and assigned a potential impact significance level of SMALL, MODERATE, or LARGE. Table 4.6-2 provides a summary of potential adverse environmental impacts for resource areas with an assigned potential impact significance level greater than SMALL. Estimates of the percentage of impacts attributable to preconstruction activities and to construction activities and the basis for the estimates are identified in the table. Preconstruction activities, which may include site exploration, preparing the CRN Site for construction of the SMRs, excavation, and other activities described in Title 10 of the Code of Federal Regulations

(10 CFR) 50.10(a)(2), are not related to nuclear safety and are generally more site-wide in scope. Conversely, construction activities are more likely to be unit-specific and include activities associated with safety-related structures, systems, and components (SSCs), certain fire- and security-related SSCs, and other activities as described in 10 CFR 50.10(a)(1). Activities constituting construction are the driving of piles, subsurface preparation, placement of backfill, concrete, or permanent retaining walls within an excavation, installation of foundations, or in-place assembly, erection, fabrication, or testing, which are for:

- SSCs of a facility, as defined in 10 CFR 50.2;
- SSCs relied upon to mitigate accidents or transients or used in plant emergency operating procedures;
- SSCs whose failure could prevent safety-related SSCs from fulfilling their safety-related function;
- SSCs whose failure could cause a reactor scram or actuation of a safety-related system;
- SSCs necessary to comply with 10 CFR part 73;
- SSCs necessary to comply with 10 CFR 50.48 and criterion 3 of 10 CFR part 50, appendix A; and
- Onsite emergency facilities, that is, technical support and operations support centers, necessary to comply with 10 CFR 50.47 and 10 CFR part 50, appendix E.

Only two resources areas, land use and socioeconomics, are assigned a potential impact significance level greater than SMALL in the Environmental Report. The evaluation of preconstruction-related versus construction-related impacts is based primarily on the consideration of two factors: the land area and the labor hours associated with construction of SSCs. Table 4.6-2 provides the percentage of those impacts attributable to preconstruction activities and to construction activities for those resources areas.

The construction-related impacts presented for Section 4.1 Land Use Impacts are based on an analysis of activity-specific considerations. The potential impacts to local roadways and waterborne transportation facilities in the vicinity of the CRN Site are related to roadway improvements and refurbishment of a barge terminal, which are preconstruction activities. The potential for impacts to historic properties also is related to preconstruction activities, including cleaning, grading, and excavation activities, which will precede any construction activities. Accordingly, 100 percent of the land use impacts for the CRN Site and vicinity and for historic properties are considered attributable to preconstruction.

The construction-related impacts for Section 4.4 Socioeconomic Impacts are based on labor hours associated with construction of SSCs. Per the construction schedule presented in Section

3.9, the total onsite construction workforce assumes an estimated 22 million construction hours associated with the preconstruction and construction activities. Construction activities are estimated to require approximately 65 percent of the total estimated labor hours. The remaining 35 percent of labor hours are considered to be associated with preconstruction activities. Construction labor versus preconstruction labor is considered a reasonable basis to separate the impacts given that factors such as noise and vibration levels and labor-related social and economic impacts are proportional to the labor percentage associated with construction and preconstruction activities.

Table 4.6-1 (Sheet 1 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.1 Land Use Impacts															
4.1.1 The Site and Vicinity				S-M			S				S		S	1. Construction of new buildings and impervious surfaces. 2. Ground-disturbing activities, including excavation, grading and re-contouring. 3. Removal of existing vegetation. 4. Removal of hazardous wastes/materials. 5. Stockpiling of soils onsite. 6. Use of borrow material. 7. Construction of offsite transportation improvements, relocation of existing transmission lines, and construction of underground transmission line.	(1 and 2) Limit ground disturbances to the smallest area practical to construct and maintain the units. (1 and 2) Conduct ground-disturbing activities in accordance with regulatory and permit requirements; use adequate erosion control measures to minimize impacts. (3) Limit vegetation removal to the area within the CRN Site designated for construction activities. (4) Removal of hazardous wastes/materials in rigorous compliance with applicable regulations using properly trained personnel with monitoring of handling procedures. (5) Restrict soil stockpiling and reuse to designated areas on the CRN Site. (6) Use best management practices (BMPs) and minimize footprint to the degree feasible. (7) Limit ground-disturbing activities and vegetation removal to smallest practical areas. Monitor construction activities for compliance with TVA procedures.

Table 4.6-1 (Sheet 2 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.1.2 Historic Properties		S					S						S - M	1. Erosion and ground disturbing activities.	(1) Conduct Phase II cultural resource surveys for any known archaeological or historic resources potentially eligible or of undetermined National Register of Historic Places (NRHP) eligibility within the Area of Potential Effect (APE). (1) Consult with the State Historic Preservation Officer (SHPO) with the results of the Phase II surveys to determine NRHP eligibility. (1) For all NRHP eligible archaeological and historic resources, implement avoidance mitigation measures from the Programmatic Agreement (PA) developed in consultation with the SHPO to mitigate impacts. Avoidance mitigation measures could include avoiding NRHP eligible resources, delineating sensitive areas and placing conditions on activities within these areas, and avoiding placing structures within the viewshed of NRHP-eligible resources.

Table 4.6-1 (Sheet 3 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.1.2 Historic Properties (continued)															(1) For all NRHP eligible resources that cannot be avoided, implement and comply with minimization and mitigation measures identified and agreed to in the PA in consultation with the SHPO. Mitigation would include additional consultation with the SHPO and development and implementation of data recovery plans for the impacted resources. (1) For all NRHP eligible historic architectural properties that cannot be avoided, develop mitigation in consultation with the SHPO. Mitigation could include vegetation screening, Historic American Building Survey or (Historic American Engineering Record -equivalent documentation, preparation of a Tennessee Historical and Architectural Resource form, preparation of an NRHP nomination, development of interpretative panels, and/or presentation of historic papers at public meetings or professional conferences.

Table 4.6-1 (Sheet 4 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other	Impact Description or Activity	Mitigating Measures and Controls
4.1.2 Historic Properties (continued)															(1) If a potential prehistoric, historic, cultural or paleontological resource is discovered during any construction activities, halt work within a 50-foot radius of the discovery, consult with the SHPO, protect and stabilize the site, and evaluate the NRHP eligibility of the site as described in the PA. (1) If previously unknown human remains are discovered during preconstruction or construction activities, all ground-disturbing activities would cease within a 10 foot radius of the discovery. The SHPO and Roane County Coroner would be notified within 24 hours (hr) and any PA signatories and potentially affiliated federally-recognized tribal governments would be notified within 72 hr and invited for comment on plans for treatment of the remains. The remains would be treated in accordance with all state and federal laws.

Table 4.6-1 (Sheet 5 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance: Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other	Impact Description or Activity	Mitigating Measures and Controls
4.2 Water Related Impacts															
4.2.1 Hydrological Alterations		S			S	S				S				1. Disturbance of soil and sediments during excavation and underwater excavation along the shoreline for construction at the intake and discharge locations. 2. Impacts of groundwater dewatering during excavation. 3. Changes in stormwater run-off resulting from construction of paved surfaces, buildings, and retention ponds.	(1) The activity would need to occur under the terms of the 1991 Interagency Agreement. (2) Installation of horizontal gravity drains in the excavated rock faces and pumping from sumps located around the perimeter of the excavation and at the base of the excavation. (3) Use of BMPs in addition to TVA, U.S. Army Corps of Engineers (USACE), and Tennessee Department of Environment and Conservation (TDEC) controls to protect affected water bodies. Establish and implement a SWPPP.
4.2.2 Water-Use Impacts		S				S		S			S			1. Surface water used in dust suppression and other construction-related activities. 2. Increased worker population would result in a small increase in potable water use.	(1 and 2) No measures or controls are necessary because impacts are expected to be too small to warrant consideration of any mitigation measures.

Table 4.6-1 (Sheet 6 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.2.3 Water Quality Impacts		S			S	S	S							1. Potential maintenance or refurbishment of the barge facility. 2. Potential erosion and sediment and stormwater runoff from construction activities into water bodies. 3. Potential minor spills of hazardous materials (i.e., fuels, oils, etc.).	(1) Use of BMPs in addition to TVA, USACE, and TDEC controls to protect affected water bodies. (2) Install stormwater drainage system at construction sites and stabilize disturbed soils. (2) Use BMPs to minimize erosion and sedimentation and establish and implement a SWPPP. (3) Use best construction practices to maintain equipment and prevent spills and leaks. (3) Establish and implement an Integrated Pollution Prevention Plan (IPPP) for construction practices.

Table 4.6-1 (Sheet 7 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.3 Ecological Impacts															
4.3.1 Terrestrial Ecosystems	S	S	S		S		S		S					1. Habitat loss due to clearing and grading; animals, such as birds and mammals, displaced from the construction site; less mobile animals killed. 2. Wildlife startled or frightened away by construction noises. 3. Potential impacts from bird collisions with manmade structures (cranes, buildings) during construction. 4. Release of hazardous materials or wastes into the ecosystem. 5. Disturbance or destruction of wetlands.	(1) Limit clearing to the smallest area practical. (1) Use established procedures for minimizing erosion and revegetating terrestrial habitats not permanently utilized for facilities. (1) Monitor site use by listed bat species if required by U.S. Fish and Wildlife Service. Monitor osprey nest on 161-kilovolt line if active during nearby construction activities. (2) Whenever practicable, schedule construction activities to avoid impacts to important susceptible species. (3) Impact is small and no reasonable mitigation measures have been identified. (4) Use best construction practices to maintain equipment and prevent spills and leaks. (5) Consult with USACE regarding any applicable wetlands permitting requirements. (5) Avoid wetlands to the extent possible.

Table 4.6-1 (Sheet 8 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.3.2 Aquatic Ecosystems		S			S	S				S				1. Potential impacts to surface water from stormwater pollution and spills associated with clearing and grading. 2. Disturbance of soil and sediments during excavation along the shoreline for construction at the intake and discharge locations and at the barge facility and construction of the Melton Hill by-pass. 3. Erosion and sediment transport into nearby water bodies. 4. Potential impacts to surface water from increased sediment deposition and disturbance during construction.	(1) Develop and implement a construction SWPPP. (1) Implement an IPPP for construction activities. (2) Conduct activities under the terms of the 1991 Interagency Agreement. (3 and 4) Implement erosion and sediment control plans that incorporate recognized BMPs. (3 and 4) Install appropriate barriers and use BMPs to protect reservoir prior to and during construction in water and on shoreline. (1, 2, 3, and 4) Monitoring of the effectiveness of BMPs in preventing erosion and sediment transport and deposition in aquatic habitats.
4.4 Socioeconomic Impacts															
4.4.1 Physical Impacts	S - M		S		S									1. Potential temporary and limited noise impacts to workers. 2. Potential temporary and limited noise impacts to the public. 3. Potential for worker accidents.	(1,2) Make public announcements or give prior notification of atypically loud construction activities. (1,2) Use of engineering controls such as noise mufflers, earthen berms and placing foliage between sources and receptors.

Table 4.6-1 (Sheet 9 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.4.1 Physical Impacts (continued)														4. Increased onsite air and dust emissions from construction equipment. 5. Increased offsite air and dust emissions from construction equipment. 6. Increased debris to existing landfills.	(1, 3, and 4) Train and appropriately protect employees and construction workers to reduce the risk of potential exposure to noise, dust, and exhaust emissions. (1, 3, and 4) Manage concerns from workers on a case-by-case basis through an employee-concerns resolution program. (2 and 5) Manage concerns from adjacent residents or visitors on a case-by-case basis through a public-concerns resolution program. (3) Provide onsite services for emergency first aid and conduct regular health and safety monitoring. (3) Provide appropriate job training to construction workers. (4 and 5) Use dust control measures such as watering, stabilizing disturbed areas, covering trucks. (4 and 5) Prepare a dust suppression plan and water unpaved roads and construction areas. (6) Establish procedures for, and perform audits to verify, waste disposal according to applicable regulations such as the RCRA. (6) Establish a waste minimization program.

Table 4.6-1 (Sheet 10 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.4.2 Social and Economic Impacts				M			S	S			S		S-M	1. Traffic congestion impacts in the vicinity of CRN Site due to increased traffic during peak construction period. 2. Potential short-term housing shortage. 3. Potential for increased housing construction impacts. 4. Potential short-term ability of infrastructure and schools to accommodate influx of students without additional facilities and teachers. 5. Potential for increased traffic accidents with increased construction traffic. 6. Beneficial impact on economy. 7. Beneficial impact on tax revenue. 8. Potential for aesthetic (visual) impacts to the general public, nearby residents, and recreational users of the Clinch River arm of the Watts Bar Reservoir.	(1 and 5) Construct improvements to roads adjacent to CRN Site and, if necessary, use traffic officers during peak hours. (2, 3 and 4) No measures or controls are necessary because impacts are expected to be too small to warrant consideration of any mitigation measures. (6, 7 and 8) No measures or controls required.

Table 4.6-1 (Sheet 11 of 11)
Summary of Measures and Controls to Limit Adverse Impacts During Construction

Environmental Resources (Section Reference)	Environmental Disturbance													Impact Description or Activity	Mitigating Measures and Controls
	Noise	Erosion	Air Quality	Traffic	Effluents and Wastes	Surface and Ground Water	Land Use	Water Use	Terrestrial Ecosystems	Aquatic Ecosystems	Socioeconomics	Rad Exposure	Other		
4.4.3 Environmental Justice														1. No disproportionately high adverse impacts to minority populations.	(1) No disproportionately high adverse impacts to minority populations.
4.5.4 Radiation Exposure to Construction Workers (Dose Estimates)															
4.5.4 Radiation Exposure												S		1. Construction worker exposure to radiation sources while the first unit is operating and additional units are being built.	(1) Controlling radiation exposure time, distance, and shielding; monitoring construction worker exposures; providing radiation worker training; and developing work plans and procedures that minimize construction worker radiation exposure and ensure it is within safe limits.

Table 4.6-2
Summary of Construction- and Preconstruction-Related Impacts for Safety-Related Structures, Systems, or Components

ER Section Reference	Combined Preconstruction and Construction Impact Significance[1, 2]	Preconstruction Impacts (%)	Construction Impacts (%)[3]	Basis of Estimate
4.1 Land Use Impacts				
4.1.1 The Site and Vicinity	SMALL to MODERATE	100	0	The potential for impacts to local roadways (modifications and construction of ramps) and to waterborne transportation facilities (refurbishment of barge terminal) is related to preconstruction activities, which will precede any construction activities.
4.1.3 Historic Properties	SMALL to MODERATE	100	0	The potential for impacts to historic properties is related to preconstruction activities, including clearing, grading, and excavation activities, which will precede any construction activities.
4.4 Socioeconomic Impacts				
4.4.1 Physical Impacts	SMALL to MODERATE	35	65	Construction worker traffic would have an effect on noise levels along local roadways surrounding the CRN Site. If the construction activities occur in close proximity to the CRN Site border, then the residences closest to the CRN Site border could temporarily experience noise and vibration impacts from the construction equipment. The percentage of labor hours associated with SSC construction is 65 percent. The remaining labor hours (35 percent) are associated with preconstruction activities. Estimated preconstruction and construction impact percentages are defined by the labor breakdown (35 percent and 65 percent, respectively).
4.4.2 Social and Economic	Employment and Income-MODERATE	35	65	
	Transportation - SMALL to MODERATE	35	65	Estimates of the impacts of preconstruction and construction are based on plant labor. The percentage of labor hours associated with SSC construction is 65 percent. The remaining labor hours (35 percent) are associated with preconstruction activities. Estimated preconstruction and construction impact percentages are defined by the labor breakdown (35 percent and 65 percent, respectively).

1 This table includes only impacts greater than SMALL.
2 The impact significance levels provided are based on the assumption that mitigation measures and controls would be implemented.
3 Construction refers to the construction of safety-related SSCs of a facility, as defined in 10 CFR 50.2. These SSCs are primarily located within the power block area and turbine area.

4.7 CUMULATIVE IMPACTS RELATED TO CONSTRUCTION ACTIVITIES

Section 4.7 contains a summary of potential cumulative environmental impacts associated with construction activities for the Clinch River (CR) Small Modular Reactor (SMR) Project. The term *cumulative impact* is defined in the regulations of the Council on Environmental Quality implementing the National Environmental Policy Act (NEPA) (Title 40 of the Code of Federal Regulations [40 CFR] 1508.7) as follows:

> "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

Past actions are projects prior to the Early Site Permit Application, while future actions commence upon U.S. Nuclear Regulatory Commission (NRC) issuance of an Early Site Permit. This section focuses on cumulative impacts of construction, so future activities in this context consist of reasonably foreseeable activities associated with subsequent NRC-authorized construction of the proposed SMR (including preconstruction activities) and continue through operation and decommissioning of the proposed SMR. For the purposes of this evaluation, reasonably foreseeable actions are projects that are clearly indicated in an available long-term master plan or comparable document and/or have received funding and/or have applied for a permit associated with construction or operation. Cumulative impacts can result from individually minor, but collectively significant, actions over time upon the same resources. The affected environment for the CR SMR Project is described in Chapter 2. Impacts due to construction of the CR SMR Project are described in Chapter 4.

This section presents a cumulative impact assessment for each geographic area of interest that may be affected by the proposed CR SMR Project. Potential impacts would include changes to any of the analyzed resources which would not occur if the CR SMR Project were not constructed.

4.7.1 Contributors to Cumulative Effects

4.7.1.1 Past, Present, and Reasonably Foreseeable Future Projects

A summary of past, present, and reasonably foreseeable projects that could have a cumulative effect within the geographic area of interest are listed in Table 4.7-1 and shown on Figure 4.7-1. The modifications to the existing transmission lines in conjunction with the CR SMR project, described in Subsection 3.7.1, would likely be limited to the current rights-of-way (ROWs) within the geographical area of interest. There would be no new corridors cleared and, other than the underground line, no new lines constructed off the site. Therefore, there would likely be essentially no contribution to cumulative impacts from these activities.

4.7.1.2 Global Climate Change

This subsection describes the general effect that greenhouse gas emissions have had, and are predicted to have, on climate in the vicinity of the Clinch River Nuclear (CRN) Site. The effects of these changes on each specific resource are addressed in each subsection associated with that resource.

Climate models forecast three trends that may affect resources: warmer mean annual temperatures, greater frequency of intense rainfall events, and drier summers with more severe droughts (Reference 4.7-1). These changes may affect overall water availability, as well as the timing and intensity of precipitation, which may in turn affect ecosystems and land uses. In the southeastern United States, climate change has already resulted in higher average temperatures, an increase in daily and five-day rainfall intensities, and an increase in the number of Category 4 and 5 hurricanes in the Atlantic basin (Reference 4.7-1).

In general, climate change is expected to result in drier conditions in the southwestern United States, and wetter conditions in the northeastern United States. Because East Tennessee is situated in a transition zone between these two regions, global climate change is expected to cause only small changes in precipitation relative to natural variation in the southeastern United States. The CRN Site, while located in the southeast region, is situated closer to the northeastern states and may experience wetter conditions (Reference 4.7-2).

Although the change in precipitation rates in the region is unknown, global climate change is still expected to reduce water availability through an increase in evaporation and transpiration rates as a result of increasing temperatures (Reference 4.7-2). In eastern Tennessee, one source predicts that the reduction in water availability in the CR SMR Project area as a result of global climate change would be small, on the order of less than 5 percent (Reference 4.7-2). Another source estimates that the combination of changes in rainfall and evapotranspiration would range from 6 percent drier to 8 percent wetter (Reference 4.7-3). Thus, the region overall may not experience major changes in water availability due to climate change, but there may be localized changes in precipitation patterns that could impact water availability and ecosystems in specific areas (Reference 4.7-3)).

4.7.2 Cumulative Land Use Impacts

This subsection addresses the land use impacts from the proposed CR SMR Project along with past, present and reasonably foreseeable future projects. Section 2.2 describes the land affected by the proposed CR SMR Project. Section 4.1 describes impacts to that land during preconstruction and construction activities at the CRN Site. As described in Section 4.1, overall the impacts of preconstruction and construction activities on land use would be SMALL and no mitigation beyond standard best management practices (BMPs) and compliance with federal regulations would be warranted.

The geographic area of interest for land-use impacts is a 50-mile (mi) radius around the CRN Site. There are 33 counties at least partially within 50-mi of the center point of the CRN Site. Three of these counties are in North Carolina, two are in Kentucky, and the rest are in Tennessee. The largest city in the 50-mi radius is Knoxville, Tennessee. Other population centers with populations of over 20,000 include Oak Ridge, Maryville, and Farragut, Tennessee. The geographic area of interest includes the primary counties, communities, and recreational areas (such as campgrounds) where the construction workforce and their families would reside and, therefore, are most likely to experience land use effects as a result of the proposed project.

Prior to World War II, land use within the immediate vicinity of the CRN Site was primarily forested and agricultural, with industrial pockets near the larger population centers. In 1942, the City of Oak Ridge was created to produce fissile material for the Manhattan Project (Reference 4.7-4). Shrouded in secrecy, this fenced military project evicted the sparse native population from the immediate area (60,000 acres [ac]) and built three industrial production plants along with a supporting city complete with temporary and permanent housing, roads, and schools for the workers and their families (Reference 4.7-4; Reference 4.7-5). In 1941, the 1200-ac CRN Property was acquired by the U.S. Army Corps of Engineers as part of the Manhattan Project. The Manhattan Project facilities shifted to civilian control in 1947 (Reference 4.7-6; Reference 4.7-5).

After the war, operations at the nuclear materials production plants continued to evolve. K-25 continued gaseous diffusion uranium enrichment until 1985, was demolished in 2013, and the reclaimed land became the East Tennessee Technology Park (ETTP) (Reference 4.7-7; Reference 4.7-8). The former electromagnetic uranium separation facility Y-12 has become a national security complex processing and storing highly enriched uranium for the U.S. Department of Energy (DOE). Similarly, the former graphite reactor X-10 has become the DOE's Oak Ridge National Laboratory (ORNL), a nuclear and high-tech research facility. (Reference 4.7-9) Operations at the Oak Ridge Reservation (ORR) continue to employ a large population and generate development in the surrounding area (Reference 4.7-10). Some of the buffer zones and undeveloped areas within the ORR are part of the Oak Ridge Wildlife Management Area (WMA). Tennessee Wildlife Resources Agency manages active hunting programs in these undeveloped areas (Reference 4.7-11).

The CRN Site was transferred to TVA in 1965. In 1982 and 1983, 240 acres of the CRN Site peninsula were under preparatory activities for the DOE's Clinch River Breeder Reactor Project (CRBRP). As discussed in Subsection 2.2.1.1, the CRBRP was terminated in late 1983 and the site was stabilized. Site redress included partial backfilling of the large excavated area in the central portion of the site and stabilization of stormwater runoff ditches, culverts, and ponds. In addition, grass was reseeded and vegetation was planted to further stabilize the site (Reference 4.7-12).

Because of continued growth in the region, much of the forest and farmland has been converted into urban developments around Knoxville, Oak Ridge, and Maryville/Alcoa with attendant growth in surrounding communities. Reasonably foreseeable urbanization could continue development within the geographic area of interest; thus contributing to cumulative impacts resulting from the proposed CR SMR Project.

As discussed in Subsection 4.7.1.2, the effects of global climate change are expected to include warmer mean annual temperatures, greater frequency of intense rainfall events, and drier summers with more severe droughts. Anticipated changes in the natural environment may lead to attendant modifications of zoning with an emphasis upon increased greenways and undeveloped areas (Reference 4.7-13).

As discussed in Subsection 4.1.1.1, Tennessee Valley Authority (TVA) expects to construct and operate an onsite landfill for construction, site clearing, and grading debris. Construction debris and associated waste not placed in the onsite disposal landfill would be shipped from the CRN Site via road, rail, and/or barge. Associated road, rail, and barge improvements within vicinity of the CRN Site are discussed in Subsection 4.1.1.2. Nonhazardous solid waste would be managed by a TVA-approved solid waste disposal vendor and disposed in a state-approved sanitary landfill such as the Sanitary Chestnut Ridge Landfill. Hazardous wastes, including oil wastes, paint wastes, solvent wastes, laboratory wastes, and universal wastes, as well as radioactive and mixed (hazardous and radioactive) waste, would be managed by TVA-approved vendors and disposed in accordance with TVA management procedures.

Because the majority of the preconstruction and construction waste would be disposed of in an onsite landfill, the volume of waste sent to an offsite sanitary landfill would be minimal and the duration of waste generation and disposal during preconstruction and construction would be brief. The Chestnut Ridge Landfill has a 50 year capacity to accept 1000 tons per day. Therefore, the impact of the minimal volume of nonhazardous waste disposed offsite during the brief duration of the preconstruction and construction activities to the cumulative impact of nonhazardous waste disposal would be SMALL. TVA’s use of hazardous waste management and minimization practices would also minimize the volume of hazardous waste generated and disposed of during the CRN Site preconstruction and construction activities. The volume of hazardous waste generated and disposed of in the immediate vicinity of the CRN Site in 2014 included contributions from the ORR and exceeded 81 metric tons; by comparison, the incremental increase of hazardous waste disposal associated with the CRN Site would be SMALL.

Cumulative impacts associated with the operational facilities listed in Table 4.7-1, including continued operation of ORNL’s Spallation Neutron Source and High Flux Isotope Reactor along with Y-12’s ongoing mercury cleanup activities, have already occurred in the form of land use and land cover changes. These cumulative impacts would be considered LARGE. These changes are reflected in the existing conditions described in Section 2.2 and in the impact analysis presented in Section 4.1. Cumulative impacts from preconstruction and construction activities at the CRN Site, the Barge/Traffic Area, and from other past, present, and future projects within the land use geographic area of interest could occur as a result of land use/land cover changes.

The future projects most likely to result in cumulative impacts in conjunction with the CR SMR Project are the land use and land cover changes in the geographic area of interest associated with new facilities including: the Sludge Build-Out Project at the Transuranic (TRU) Waste Processing Center, the proposed new Uranium Processing Facility (UPF) at the Y-12 Complex, the potential ETTP property transfer, and the Environmental Management Disposal Facility on the ORR. These projects involve potential land use and land cover changes from current conditions. Land use and land cover changes would occur such as conversion of non-developed land use types (forested areas, grasslands, etc.) to developed land use types (including facilities, parking lots, and roadways). These projects occur on land currently designated for the respective projects; therefore, these land use changes would not constitute significant impacts individually or cumulatively. The Sludge Buildout Project, new UPF, and ETTP property transfer would occur in already developed areas and are expected to involve limited, if any, land clearing activities. Substantial impacts to wetlands or changes to land cover from these projects are unlikely because the sites are developed. The Environmental Management Disposal Facility may involve clearing of forested land, adjacent to a developed area. However, the change in land cover would be negligible within the geographic area of interest. The combined change in land use and land cover resulting from these projects could contribute to cumulative impacts to land use in association with the CR SMR Project preconstruction and construction activities. However, overall, these incremental cumulative impacts would be SMALL and no mitigation is warranted.

4.7.3 Cumulative Water Impacts

This subsection addresses the cumulative water use and water quality impacts from the proposed CR SMR Project along with past, present and reasonably foreseeable future projects. Section 2.3 describes the surface water and groundwater affected by the proposed CR SMR Project. Section 4.2 describes impacts to water use and water quality during preconstruction and construction activities at the CRN Site.

4.7.3.1 Surface Water Hydrology Impacts

Subsection 2.3.1.1 describes the surface water bodies present on and near the CRN Site, and serves as the baseline for the analysis of cumulative impacts to surface water hydrology. As discussed in Subsection 2.3.1.1.1.5, the current surface water hydrology of the CRN Site is the result of the construction of a stormwater management system, so surface water hydrology has already been impacted by past projects. Subsection 4.2.1.1 describes further impacts to these onsite water bodies during preconstruction and construction activities. As discussed in Subsection 4.2.1.1, construction of the SMRs would directly impact one small perennial stream (S01) and 11 ephemeral streams/wet weather conveyances (WWCs). The perennial stream and six of the WWCs would be located within the footprint of the areas to be permanently developed, and would be removed. Portions of five WWCs are within an area to be temporarily disturbed, but would be revegetated and restored after construction. Additional impacts to onsite and adjacent surface water bodies would be minimized through the use of BMPs and compliance with the National Pollutant Discharge Elimination System (NPDES) permit. Therefore, impacts of pre-construction and construction activities would be SMALL.

For purposes of this cumulative impact analysis, the geographic area of interest for surface water hydrology impacts is the Clinch River arm of the Watts Bar Reservoir. Although projects within the drainage basin of the Tennessee River both upstream and downstream of the CRN Site can affect surface water hydrology throughout the entire basin, the potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site, and to decrease substantially with distance from the CRN Site. Generally, when impacts from a project within a local area are SMALL to none, it is expected that there would be no cumulative impacts greater than SMALL in the remainder of the geographic area of interest.

As discussed in Subsection 4.7.1.2, global climate change may affect the intensity and duration of precipitation events, but it is not expected to change the overall amount of precipitation in the vicinity of the CRN Site, and therefore is unlikely to have a substantial impact on the number or area of perennial streams or WWCs. However, past and present projects listed in Table 4.7-1 have cumulatively impacted perennial streams and WWCs throughout the region. These impacts have occurred through the disturbance of the land area associated with each project, and occupation of the original land area by a new facility or feature. The largest impacts to perennial streams and WWCs associated with the past and present projects likely resulted from the development of land area associated with agriculture, urban development, industrial development of the ORR, and development of the reservoirs operated by TVA. As a result, the total number and area of perennial streams and WWCs in the region has been reduced, and the impact of these cumulative projects has been MODERATE.

The number and area of perennial streams and WWCs would be further reduced by construction of the SMRs. However, given that the impacts of project construction would be SMALL, their cumulative contribution to the overall impact would also be SMALL.

4.7.3.2 Water Use Impacts

Cumulative water-use impacts are presented separately for surface water and groundwater.

4.7.3.2.1 Surface Water Use Impacts

Subsection 2.3.2.1 describes the use of surface water in the vicinity of the proposed CR SMR Project, and serves as the baseline for the analysis of cumulative impacts to surface water use. Subsection 4.2.2.1 describes impacts to surface water use during preconstruction and construction activities at the CRN Site. As discussed in Subsection 4.2.2.1, the use of surface water for dust suppression during preconstruction and construction activities would withdraw and consume less than 0.002 percent of the daily flow rate of the Clinch River arm of the Watts Bar Reservoir. The impacts of this withdrawal would be SMALL.

For purposes of this cumulative impact analysis, the geographic area of interest for surface water use impacts is the seven-county area (Anderson, Knox, Loudon, Meigs, Morgan, Rhea, and Roane counties) surrounding the CRN Site. This geographic area of interest incorporates all of the past, present, and reasonably foreseeable future projects listed in Table 4.7-1. Although water use within the drainage basin of the Tennessee River both upstream and downstream of the CRN Site can affect the availability of surface water throughout the entire basin, the potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site, and to decrease substantially with distance from the Site. Generally, when impacts from a project within a local area are SMALL to none, it is expected that there would be no cumulative impacts greater than SMALL in the remainder of the geographic area of interest.

As discussed in Subsection 2.3.1.1.1.2, the Tennessee River system is a network of dams and reservoirs that generates power, controls flooding, provides recreational opportunities, and boosts the regional and national economies. TVA owns or operates 49 dams and reservoirs in the mainstem Tennessee and Cumberland watersheds, including nine dams on the Tennessee River (Reference 4.7-14). The dams and reservoirs are operated year-round by TVA for the purposes of navigation, flood control, power generation, water supply, water quality, and recreation. (Reference 4.7-15)

The dams operated by TVA were installed starting in 1911, with the most recent, Tellico Dam, having been installed in 1979. The three dams in closest proximity to the CRN Site, having the highest potential to contribute to cumulative water use impacts, are Watts Bar Dam (constructed in 1942), Melton Hill Dam (constructed in 1963), and Fort Loudoun Dam (constructed in 1943). (Reference 4.7-15) TVA adopted its current reservoir operating policy in 2004 based upon the comprehensive Reservoir Operations Study (ROS), so the period from 2004 to the present was used as the baseline in the discussion of surface water flow conditions presented in Subsection 2.3.1.1.2 (Reference 4.7-16). Because the dams and their associated water users have been affecting surface water flow rates since before 1979, the baseline surface water flow conditions presented in Subsection 2.3.1.1.2.1 represent the ongoing cumulative effect of the construction and operation of all of the past and present dams in the system on surface water flow. In addition, because the ROS included long-range planning for the system to the year 2030, the analysis also represents all reasonably foreseeable conditions that may contribute to cumulative impacts on the river and reservoir system.

TVA's reservoir operations system has been designed, with the purpose of moderating flow rates throughout the year by releasing water flow in periods of low precipitation, and by storing flow in periods of high precipitation. As discussed in Subsection 4.2.2.1, withdrawal and consumption of surface water for dust suppression during construction of the SMRs would be less than 0.002 percent of the minimum daily flow rate in the Clinch River arm of the Watts Bar Reservoir. Therefore, construction of the SMRs would not modify the beneficial cumulative effect of the system of dams and reservoirs on surface water flow rates in the geographic area of interest.

In addition to moderating flow rates, TVA's system of dams and reservoirs serves to provide water supply for a variety of municipal, industrial, and agricultural users in the geographic area of interest. In 2014, TVA conducted a Regional Surface Water Use Study for the Clinch River Small Modular Reactor Project to evaluate all past and projected water uses within the seven-county area surrounding the CRN Site from 1995 to 2035 (Reference 4.7-16). The baseline data presented for surface water use in Subsection 2.3.2.1 represents the cumulative effect of past and present projects within the geographic area of interest on surface water use. In addition, because the analysis included projections of water use to the year 2035, it incorporates reasonably foreseeable water uses.

Many of the surface water uses in the geographic area of interest include substantial return flows; therefore, these uses do not have an adverse impact on surface water. However, some uses result in evaporation or transpiration of water by humans, livestock, or crops and are therefore consumptive. These consumptive uses reduce the availability of surface water in the geographic area of interest, and can result in adverse impacts to other users of surface water, including aquatic species.

TVA's reservoir operating policy was designed to meet the off-stream water needs of the Tennessee Valley until the year 2030 (Reference 4.7-16). The analysis was based on a geographic area of interest that includes the seven-county area surrounding the CRN Site, and therefore incorporates all of the past, present, and future projects listed in Table 4.7-1. The estimates used to develop the reservoir operating policy were a total withdrawal of 13,990 million gallons per day (mgd) with a return of 13,010 mgd resulting in a net water demand of 980 mgd. As discussed in Subsection 2.3.2.1.1, the net water demand in the geographic area of interest in 2010 was 471 mgd, or 3.9 percent of the total withdrawals. The current watershed projection of water demand to 2035 indicates a total withdrawal of 9449 mgd with a return of 8737 mgd resulting in a net water demand of 712 mgd. (Reference 4.7-16) Therefore, both the current and projected future water demands are within the limits established for the reservoir operating policy, and cumulative impacts to surface water uses would be SMALL.

Global climate change may affect surface water flows and water availability through changes in the timing and magnitude of precipitation. As discussed in Subsection 4.7.1.2, although the region as a whole may not experience major changes in water availability due to climate change, localized changes in precipitation patterns may impact water supply in specific areas. (Reference 4.7-3)

Overall, past, present, and reasonably foreseeable future projects, combined with the additional potential for a decrease in surface water availability due to global climate change, have resulted in cumulative impacts on surface water availability that are SMALL, and have included both adverse and beneficial effects. Surface water uses for municipal, agricultural, and industrial purposes, including many of the projects listed in Table 4.7-1, remove surface water from the geographic area of interest, resulting in adverse impacts to surface water availability. TVA's management of the dam and reservoir system stores excess surface water for use during periods of low precipitation. While this action does not increase the amount of surface water in the system, it does provide a beneficial impact on surface water availability by making water available during periods of low precipitation, except for periods of extreme drought. The incremental additional cumulative impact associated with surface water use for pre-construction and construction of the SMRs would be adverse, because it would remove surface water from the system. However, because the amount of surface water to be removed would be small in comparison to the total amount available in the reservoir and the total amount projected to be needed for future use, the additional cumulative impact would be SMALL.

4.7.3.2.2 Groundwater Use Impacts

Section 2.3 describes the groundwater affected by the proposed CR SMR Project. In general, groundwater at the CRN Site recharges through precipitation. Periodic recharge from the Clinch River arm of the Watts Bar Reservoir during high water stages may also be occurring.

Subsections 4.2.1.2 and 4.2.2.2 describe impacts to groundwater use during preconstruction and construction activities at the CRN Site. There are no planned uses for groundwater during preconstruction and construction activities. Potable water will be supplied to the CRN Site by the City of Oak Ridge. Planned construction activities include temporary dewatering activities localized to power block area excavations; previous groundwater conditions are expected to resume upon completion and no subsidence is anticipated. Therefore groundwater use impacts from dewatering would be SMALL.

This cumulative analysis considers impacts from preconstruction and construction activities along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to groundwater use within the geographic area of interest, the geographic area most likely to be affected by the proposed CR SMR Project. For the purposes of this cumulative impact analysis, the geographic area of interest for groundwater use impacts is the Lower Clinch River Watershed from Melton Hill Reservoir down to the confluence of the Clinch, Emory, and Tennessee Rivers.

Current and future operations at ORR include institutional controls and remedial activities to minimize impacts to groundwater. Impacts to groundwater from present and future activities could be affected by potential intense drought periods followed by intense precipitation events predicted by many of the climate change models for the region could result in less permeable soils and thus less infiltration and recharge of the groundwater system. These resultant changes to the groundwater system could result in different groundwater flow patterns; thus potentially changing contaminant transport through the groundwater system and thereby potentially reducing water availability. Although readily abundant surface water is expected to remain the chosen water source for the foreseeable future, potential changes in the groundwater quality could stress the water cycle system. In summary, because there are no planned uses for groundwater during CR SMR preconstruction and construction activities, the incremental additional cumulative impact associated with groundwater use would be SMALL.

4.7.3.3 Water-Quality Impacts

Cumulative water-quality impacts are presented separately for surface water and groundwater.

4.7.3.3.1 Surface Water Quality Impacts

Subsection 2.3.3.1 describes surface water quality in the vicinity of the proposed CR SMR Project, and serves as the baseline for the analysis of cumulative impacts to surface water quality. Subsection 4.2.3.1 describes impacts to surface water quality during preconstruction and construction activities at the CRN Site. As discussed in Subsection 4.2.3.1, compliance with the Site's NPDES permit, including the implementation of a site-specific Stormwater Pollution Prevention Plan (SWPPP) and the use of BMPs, would result in SMALL impacts from the proposed CR SMR Project to the quality of surface water during preconstruction and construction activities.

This cumulative analysis considers impacts from preconstruction and construction activities along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to surface water quality within the geographic area of interest, the geographic area most likely to be affected by the proposed CR SMR Project. For purposes of this cumulative impact analysis, the geographic area of interest for surface water use impacts is the Clinch River arm of the Watts Bar Reservoir. Although projects within the drainage basin of the Tennessee River both upstream and downstream of the CRN Site can affect surface water quality throughout the entire basin, the potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site, and to decrease substantially with distance from the CRN Site. Generally, when impacts from a project within a local area are SMALL to none, it is expected that there would be no cumulative impacts greater than SMALL in the remainder of the geographic area of interest.

Subsection 2.3.3.1 presents surface water quality results from a variety of sources, including studies of the U.S. Geological Survey in the Upper Tennessee River Basin, the Tennessee Department of Environment and Conservation (TDEC) 303(d) list, TVA's Reservoir Ecological Health Program, TVA's Site Preparation Monitoring Program, and TVA's Biological Monitoring Program. These studies provide a baseline for surface water and sediment quality based on analyses which occurred from 1994 to 2015, and have documented water quality impacts that resulted from the 1940s. Therefore, this baseline effectively represents the cumulative impact of all past and present projects.

Surface water quality in the Upper Tennessee River Basin usually meets existing guidelines for drinking water, recreation, and the protection of aquatic life (Reference 4.7-17). All sample results from the Site Preparation Monitoring Program for the Clinch River arm of the Watts Bar Reservoir upstream and downstream of the CRN Site indicate that TDEC's most stringent numeric criteria are being met and that site runoff (should it occur) would not have a significant impact to water quality (Reference 4.7-18). However, as discussed in Subsection 2.3.3.1, impacts to surface water and sediment quality as a result of industry, mining, agriculture, urbanization, and toxic spills and releases have been identified. Surface water quality impacts include elevated bacteria, nutrients, and herbicides as a result of agriculture; elevated concentrations of polychlorinated biphenyls (PCBs), dioxin, and mercury in water, and semivolatile organic compounds in sediment, due to industrial sources and coal mining; and the presence of mercury, PCBs, and cesium-137 in sediment, as a result of past operations at the ORR.

Several of the present and reasonably foreseeable future projects listed in Table 4.7-1 have the potential to cause adverse or beneficial impacts to surface water quality in the geographic area of interest in the future. All projects that involve site disturbance during construction, active work within surface water bodies, surface water withdrawal, and/or discharges to surface water bodies have the potential to affect water quality within the geographic area of interest. In general, each of these present projects are currently conducted, and future projects will be conducted, in accordance with applicable permits in order to protect surface water quality.

Global climate change may adversely affect surface water quality as increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts can result in increases in sediment, nitrogen, and other pollutant loads (Reference 4.7-2). Changes in agricultural practices, in response to climate change, can lead to increase in the release of pollutants to streams. Other factors, including operation of new projects under the regulation of the Clean Water Act, and the inclusion of water quality in the development of TVA’s ROS, have had the opposite effect, resulting in improvement of surface water quality.

TVA’s ROS has had a beneficial impact on water quality by managing water flows to increase aeration and dilute industrial discharges. As part of the CR SMR Project, TVA would manage construction-related discharges in accordance with the CRN Site’s SWPPP and NPDES permit and by following standard BMPs.

Overall, past and present projects, combined with the additional potential for a decrease in surface water quality due to climate change, result in MODERATE cumulative impacts on surface water quality. However, the incremental additional cumulative impact associated with preconstruction and construction of the SMRs on surface water quality would be SMALL.

4.7.3.3.2 Groundwater Quality Impacts

Section 2.3 describes the groundwater affected by the proposed CR SMR Project. In general, groundwater at the CRN Site recharges through precipitation and periodic recharge from the Clinch River arm of the Watts Bar Reservoir during high water stages.

Subsection 4.2.3.2 describes impacts to groundwater quality during preconstruction and construction activities at the CRN Site. There are no planned uses for groundwater during preconstruction and construction activities at the CRN Site and current plans include the use of BMPs to minimize potential releases to the environment of groundwater from dewatering activities in the power block area. Section 4.2.3.2 concludes that impacts to groundwater quality from minor releases of very small amounts of localized contaminants would be SMALL.

This cumulative analysis considers impacts from preconstruction and construction activities along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to the quality of groundwater within the geographic area of interest. The geographic area of interest for cumulative impacts to the quality of groundwater is the same as the groundwater use geographic area of interest which includes the Lower Clinch River Watershed from Melton Hill Reservoir down to the confluence of the Clinch, Emory, and Tennessee Rivers near Kingston.

Cumulative impacts to groundwater quality from past and present activities have occurred, and are MODERATE. Subsection 2.3.3.2.2.2 discusses the baseline groundwater sampling for the CRN Site. Legacy radionuclides strontium-90, tritium, and technetium-99 were detected along with legacy metals barium, cadmium, and chromium at the CRN Site. Arsenic, mercury, or uranium were not detected at the CRN Site. As discussed in Subsection 2.3.3.2.2.2, legacy contamination from historic ORR operations has resulted in contaminated groundwater plumes in various areas of the Reservation. Contaminant plumes on ORR include volatile organic compounds along with cesium-137, strontium-90, and tritium at ORNL along with uranium, nitrate, and mercury at Y-12. Plumes at ETTP also include chromium-6 and technetium-99. In addition, legacy groundwater contamination from the American Nuclear Corporation includes cobalt-60 and cesium-137.

In addition to these legacy groundwater contaminants, anticipated climate change may also contribute to groundwater quality cumulative impacts. As mentioned in Subsection 4.7.3.2.2, the increased incidence of both drought and flooding events predicted by some of the models would reduce the amount of infiltration recharging the groundwater system and thus possibly changing the favored flow patterns. These changes may include changes in contaminant transport through the groundwater system, thus changing water quality in the geographic area of interest.

Overall, past and present projects, combined with the additional potential for a decrease in groundwater quality due to climate change, result in MODERATE cumulative impacts on groundwater quality. However, the incremental additional cumulative impact associated with preconstruction and construction of the SMRs would be SMALL.

4.7.4 Cumulative Ecological Impacts

This subsection describes the cumulative impacts on terrestrial and aquatic ecological resources that may result from preconstruction and construction activities associated with the proposed CR SMR Project. The analysis considers these impacts in conjunction with other past, present, and reasonably foreseeable future activities within the geographic area of interest for each of these resources. Terrestrial and aquatic ecology impacts are discussed separately in the following subsections.

4.7.4.1 Terrestrial Ecology and Wetlands Impacts

Subsection 2.4.1 describes the terrestrial ecology resources, including wetlands, potentially affected by the proposed CR SMR Project and provides the baseline for analysis of cumulative impacts to terrestrial ecology. Subsection 4.3.1 describes impacts to terrestrial ecosystems during preconstruction and construction activities at the CRN Site and within the offsite Barge/Traffic Area and the offsite segment of the existing 500-kilovolt (kV) transmission line ROW in which an underground 69-kV transmission line is to be installed.

For the purposes of this cumulative analysis of the impacts of preconstruction and construction on terrestrial ecology, the geographic area of interest is defined as the area within approximately a 6-mi radius of the CRN Site. This area encompasses the CRN Site and associated offsite areas (Barge/Traffic Area and underground transmission line), and encompasses other projects potentially capable of interacting with the CR SMR Project during preconstruction and construction to affect terrestrial ecological resources.

Table 4.7-1 identifies the past, present, and reasonably foreseeable projects and facilities considered in the cumulative impacts analysis. Eleven of these are within the geographic area of interest for cumulative impacts on terrestrial ecology. Five of these projects may involve construction activities that potentially could affect terrestrial ecological resources relevant to those affected by the CR SMR Project. These include the following projects: transfer of property on the ETTP to private companies, which could subsequently construct facilities on the ETTP; the Roane Regional Business and Technology Park, where sites could be developed; and three roadway improvement projects by the Tennessee Department of Transportation (TDOT) on Tennessee State Highway (TN) 95 and TN 73. These five projects could involve land clearing and earth moving activities that may have the potential to produce erosion and sedimentation impacts in nearby water bodies. The other six projects in the geographic area of interest are not expected to have the potential to produce such effects. The Sludge Buildout Project and the CVMR Corporation relocation would occur in already developed areas; the ORNL and its associated Spallation Neutron Source and High Flux Isotope Reactor have been in operation for many years and would not involve construction; and the ongoing operation of the Melton Hill Hydroelectric Facility would not have cumulative effects in conjunction with effects from preconstruction and construction of the CR SMR Project.

Terrestrial Habitats

Past land uses on the CRN Site and in its vicinity, described in Subsection 2.2.1.1, have cumulative effects on the terrestrial ecology of the area. Historically, several small farmsteads were scattered across the Clinch River Property, and aerial photographs indicate that by 1936 substantial portions of the CRN Site peninsula had been cleared of forest for use as farmland. Natural succession led to reforestation of some areas before major portions (240 ac) of the peninsula were disturbed in 1982 and 1983 during site preparation for the CRBRP. The CRBRP was terminated in late 1983, and site redress plans were implemented to stabilize the site including reseeding of grass, and planting of trees, mulching cleared areas, installation of straw bales in shallow ditches, installation of small berms of riprap in larger ditches, installation of culverts to direct water from steep slopes, modification of the holding ponds for long-term stability, and partial backfilling of the large excavated area in the central portion of the site.

As described in Subsection 2.2.1.2, the vicinity of the CRN Site is primarily rural and covered by forest and pasture/hay cultivation. To the north, the CRN Site is adjoined by the ORR, which is largely undeveloped and includes forests, grasslands and old agricultural fields, bottomlands and wetlands, utility corridors, and ridges (Reference 4.7-19). Facilities within the ORR currently include the ORNL, the Y-12 National Security Complex, and the ETTP. To the east, south, and west across the Clinch River arm of the Watts Bar Reservoir, the land use in the geographic area of interest is rural and includes interspersed wooded areas, pastures, farm fields, and residences.

Subsection 4.3.1 describes the terrestrial ecological communities and acreages to be permanently and temporarily impacted by preconstruction and construction activities on the CRN Site, the Barge/Traffic Area, and the ROW for the proposed underground transmission line. Section 4.3.1 concludes that impacts to terrestrial ecological communities, including wetlands, would be SMALL.

This cumulative analysis considers impacts from preconstruction and construction activities along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to the terrestrial habitats within the geographic area of interest. The underground transmission line is planned within an existing aboveground transmission line ROW; therefore minimal temporary and no permanent development is anticipated within this area. The upland plant communities that would be permanently affected by the construction of facilities on the CRN Site comprise predominantly mixed evergreen-deciduous, deciduous, and evergreen forest (162 ac) and herbaceous (152 ac) habitats that are common in the vicinity. Of the approximately 45 ac in the Barge/Traffic Area that would be temporarily or permanently disturbed, approximately 20 ac are classified as developed and 25 ac are undeveloped (mainly forest) and potentially could be impacted permanently or temporarily by the planned improvements. These acreages are minor relative of the expanse of such communities within the geographic area of interest and the region. The ORR to the east, north, and west, encompasses more than 33,100 ac of federally-owned land that is mostly a relatively undisturbed ecosystem of nearly continuous forest within a surrounding region that is more fragmented by agriculture and development. The areas on the CRN Site that are cleared for temporary uses may be revegetated or otherwise restored after construction is completed. Over time, some of these areas likely would undergo succession and gradually transition from herbaceous to forest habitat. Therefore, it is expected that the additional incremental cumulative impacts on terrestrial habitats from preconstruction and construction activities on the CRN Site, the adjacent Barge/Traffic Area and the proposed underground transmission line ROW would be SMALL.

The total area of wetlands impacted by preconstruction activities on and off the CRN Site potentially would be approximately 2 ac, so impacts on wetlands would be SMALL and would likely be further reduced by mitigation. The five relevant projects planned for the geographic area of interest would require permitting and potential mitigation of any wetland impacts. Substantial impacts to wetlands from these projects are unlikely because the ETTP and the Roane Regional Business and Technology Park comprise areas of existing development and areas suitable for development, and the three TDOT projects involve improvements to existing roads that would be unlikely to affect more than small areas of wetlands, if present, adjacent to the roadways. Accordingly, cumulative impacts on wetlands in the geographic area of interest are expected to be SMALL.

Wildlife

Subsection 2.4.1.4 describes the terrestrial wildlife that could be affected by the proposed CR SMR Project, including listed and other important species on the CRN Site, Barge/Traffic area, and the underground 69 kV transmission line ROW. Table 2.4.1-7 summarizes the important terrestrial habitats, wetlands, and listed species that occur in ROWs of the segments of the transmission system outside the CRN Site that would require modifications (uprating, reconductoring, or rebuilding). Only small portions of two of these segments are within the geographic area of interest. Subsection 4.3.1.4 describes the impacts to wildlife from preconstruction and construction activities on the CRN Site and the Barge/Traffic Area. Because the underground transmission line location is within an existing ROW for an aboveground transmission line, the wildlife community has previously been altered by clearing of forest and ongoing vegetation maintenance. This is also the case for the offsite line segments to be modified. Temporary disturbance for installation of the underground line and modification of existing lines is anticipated to have a SMALL impact on wildlife within these ROWs.

The disturbance of approximately 494 ac of habitat (approximately 167 ac temporarily disturbed and 327 ac permanently disturbed) at the CRN Site and 45 ac (approximately 15 ac temporarily disturbed and 30 ac permanently disturbed) in the Barge/Traffic Area would result in mortality or temporary displacement of wildlife in those areas. However, this acreage would be a small component of the accessible, undeveloped habitat in the geographic area of interest to which animals can disperse with minimal effects on populations in the area. Similarly, wildlife seeking to avoid noise by moving away from areas where preconstruction and construction activities are occurring would be temporarily displaced, but their populations would be minimally affected. The low likelihood of collisions with structures also indicates that such collisions would have a negligible impact on bird or bat populations in the area. Subsection 4.3.1.4 concludes that, overall, impacts on terrestrial wildlife from preconstruction and construction are expected to be SMALL. Impacts to wildlife from five relevant projects planned for the geographic area of interest are expected to be SMALL because the ETTP and the Roane Regional Business and Technology Park comprise areas of existing development and areas suitable for development with minimal wildlife habitat, and the three TDOT projects involve improvements to existing roads that would be unlikely to affect more than small areas of marginal wildlife habitat adjacent to the roadways.

In addition to the specific, reasonably foreseeable projects and activities within the geographic area of interest identified above, cumulative effects on terrestrial ecological resources may result from ongoing activities and processes in the region (e.g., agriculture, silviculture, and commercial, industrial, and residential development) and on a national or global scale (e.g., climate change). These development and land use activities are likely to continue to contribute to the processes of forest reduction and fragmentation and associated decreases in habitat that have occurred historically. The cumulative effects of development in the geographic area of interest could alter attributes of the terrestrial environment by reducing wildlife habitat in localized areas. However, this would not substantially affect the overall availability of wildlife habitat near the CRN Site or the general extent of forests or other habitat types in the geographic area of interest. Extensive areas of relatively unfragmented and undisturbed forest habitat have been maintained in the geographic area of interest and the region, minimizing the cumulative impacts of the relatively small areas affected by current and reasonably foreseeable activities. Accordingly, cumulative impacts on wildlife in the geographic area of interest are expected to be SMALL, and cumulative impacts on listed species similarly are expected to be SMALL.

A report by the Electric Power Research Institute summarizes existing research on the effects of climate change on natural resources in the region of the southeastern United States served by TVA. The authors found that literature describing how climate change specifically would impact ecological resources of the TVA region is very limited. This region currently is one of the richest in the country in terms of biological diversity, and the TVA region provides habitat to an unusually high concentration of threatened and endangered species. (Reference 4.7-3) Some analyses indicate a slightly warmer dryer climate, other climate models indicate the opposite effects (lower temperatures and higher precipitation). Higher temperatures without additional precipitation could adversely affect forests, but higher carbon dioxide concentrations potentially could compensate by increasing water use efficiency by trees. By 2050, however, larger temperature increases and potential decreases in precipitation could make forest disturbances (e.g., fire, drought, and insect outbreaks) more prevalent, and shifts in forest species composition could become more important. Forests in the TVA region currently are dominated by hardwoods, but several studies suggest that climate change could make conditions in the region more suitable for southern pine species. (1373 Electric Power Research Institute 2009)

Some of the more modest changes in forest ecosystems that might result from climate change in the TVA region may have more substantial effects on terrestrial habitats and species that currently are rare, threatened, or endangered. Specific predictions about which areas and species might be most affected are difficult due to the limited studies of these effects. (1373 Electric Power Research Institute 2009) Available studies indicate that resident non-game birds, a category that includes the state-status species observed at the CRN Site (the bald eagle and sharp-shinned hawk), may not be greatly affected by climate change. The federally-listed Indiana bat could be adversely affected if winter temperatures are not sufficiently low and stable in the caves where they hibernate. (Reference 4.7-1) The other two federally-listed bat species occurring at the CRN Site, the gray bat and northern long-eared bat, may be similarly adversely affected if temperatures increase in the caves in which they hibernate. Thus, although individuals of these listed bat species would be minimally affected by construction of the proposed CR SMR Project, their populations may be vulnerable to cumulative impacts from climate change over the long-term.

Summary of Cumulative Terrestrial Ecology Impacts

Cumulative impacts on terrestrial ecological resources were assessed for the past, present, and reasonably foreseeable future activities and processes occurring in the geographic area of interest. The assessment considered impacts on terrestrial communities from factors such as the effects of preconstruction and construction for the CR SMR Project, the loss of vegetation and wildlife habitat, increased habitat fragmentation from continued development, and global climate change. These large-scale processes are ongoing and likely to continue. Based on this analysis, the cumulative impacts on terrestrial ecological resources in the geographic area of interest from past, present, and reasonably foreseeable future actions, including preconstruction and construction of the proposed CR SMR Project on the CRN Site, would range from SMALL to MODERATE. The incremental contribution from preconstruction and construction activities for the CR SMR Project to these cumulative impacts on terrestrial ecology within the geographic area of interest would be SMALL.

4.7.4.2 Aquatic Ecology Impacts

Subsection 2.4.2 describes the aquatic ecology resources potentially affected by the proposed CR SMR Project at the CRN Site and provides the baseline for analysis of cumulative impacts to aquatic ecology. Subsection 4.3.2 describes impacts to aquatic ecosystems during preconstruction and construction activities at the CRN Site, on the offsite Barge/Traffic Area, and within the offsite, 500-kV transmission line ROW in which an underground 69-kV transmission line is to be installed.

The geographic area of interest for this analysis of cumulative impacts on aquatic ecological resources is defined as the CRN Site, Barge/Traffic Area, and 69-kV underground transmission line ROW, and the Clinch River arm of the Watts Bar Reservoir in the vicinity (within approximately a 6-mi radius) of the CRN Site. This geographic area of interest encompasses drainages associated with the CRN Site and associated offsite areas where project-related preconstruction and construction would occur. It also includes the limited area within the Clinch River arm of the Watts Bar Reservoir that may be affected by activities on the CRN Site as well as other activities capable of having aquatic effects that could interact with the CR SMR Project during preconstruction and construction to cumulatively affect aquatic ecological resources. This portion of the Clinch River arm of the Watts Bar Reservoir generally includes the area of the reservoir downstream to the confluence with the Emory River arm of the Watts Bar Reservoir and upstream to Melton Hill Dam (approximately Clinch River Mile [CRM] 5 to 23). The potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site and to decrease substantially with distance from the CRN Site.

Aquatic Habitats and Organisms

Past uses of the CRN Site and the Clinch River arm of the Watts Bar Reservoir in its vicinity have had cumulative effects on the aquatic ecology of the geographic area of interest. As discussed in Subsection 4.7.3.2.1, past projects to regulate the Tennessee River system have substantially altered the natural flow regime of the Tennessee River and its tributaries, including the Clinch River. The Tennessee River system is described in Subsection 2.3.1.1.1.2.

As stated in Section 4.7.3.1.1, the three dams in closest proximity to the CRN Site are Watts Bar Dam (constructed in 1942), Melton Hill Dam (constructed in 1963), and Fort Loudoun Dam (constructed in 1943). (Reference 4.7-15) The TVA system has been designed and is operated with the purpose of moderating flow rates throughout the year by releasing water flow in periods of low precipitation and by storing flow in periods of high precipitation. TVA adopted its current reservoir operating policy in 2004 based on the comprehensive ROS (Reference 4.7-16). Because the dams and their associated water users have been affecting surface water flow rates since before 1979, the baseline surface water flow conditions described in Subsection 2.3.1.1.2.1 and the ecological community described in Subsection 2.4.2.1.1 represent the cumulative effects on surface water flow from the ongoing operation of all of the dams in the system. In addition, because the ROS included long-range planning for operation of the system to the year 2030, the analysis also represents all reasonably foreseeable flow conditions that may contribute to cumulative impacts on aquatic ecology.

The cumulative effects of the system of dams and reservoirs on surface water flow in the Tennessee River system has had a LARGE impact on the aquatic community that historically existed in formerly free-flowing riverine ecosystems. Construction of Norris Dam in 1936 at CRM 80 and Melton Hill Dam in 1963 at CRM 23, both on the main channel of the Clinch River, dramatically altered the aquatic fauna and likely had a great impact on native aquatic species in this area. Additionally, Watts Bar Reservoir, completed on the Tennessee River mainstem in 1942, impounded the lowermost portion of the Clinch River. In the Clinch River arm of the Watts Bar Reservoir, the relatively low abundance and species richness of the mollusk community and poor habitat relative to historical conditions are presumed to be the result of the impoundment of the Clinch River by Melton Hill Dam and Norris Dam and of the mainstem Tennessee River by Watts Bar Dam. (Reference 4.7-20)

The effects of these impoundments on aquatic fauna in the Clinch River have included fragmentation and loss of riverine habitats, disruption of the natural flow regime, altered temperature regimes, extreme water level fluctuations, changes in water quality parameters such as turbidity and oxygen concentrations, increases in concentrations of heavy metals, and impeding migrations of fish that are hosts to mussel larvae. A 1968 study of changes in freshwater fish populations after construction of Melton Hill Dam documented a reduction in nongame fish species. Rare and uncommon riverine fish species, such as the federally-threatened sender chub and the state-protected blue sucker, have not been documented in the Clinch River since 2002. Studies also have found mussel diversity and abundance are low in comparison to preimpoundment surveys, likely due to the construction of impoundments, channelization, and dredging of the waterway for navigation. (Reference 4.7-20)

Additionally, the lower Clinch River arm of the Watts Bar Reservoir also has been subject to contamination from the Manhattan Project and ORNL many decades ago, which has contributed to legacy sediment toxicity issues between White Oak Creek (near CRM 21) upstream of the CRN Site and the Watts Bar Dam downstream of the CRN Site. These releases also likely contributed to mussel declines in this area. In 1991 TVA began a Reservoir Release Improvement program at Melton Hill Dam (CRM 23) and other dams to increase dissolved oxygen levels and water flow in the lower Clinch River arm of the Watts Bar Reservoir, which may have improved habitat conditions for mussels since its implementation. (Reference 4.7-20) Due to the passage of time and remedial actions to improve water quality in the Reservoir, cumulative impacts from past projects have had been MODERATE. Because the CR SMR Project would comply with all BMPs, permits and regulations, preconstruction and construction activities would not contribute to the cumulative effects of sediment contaminants on aquatic organisms in the geographic area of interest.

As discussed in Subsection 4.2.2.1, the withdrawal and consumption of surface water for dust suppression during construction of the SMRs would be less than 0.002 percent of the minimum daily flow rate in the Clinch River arm of the Watts Bar Reservoir. Therefore, preconstruction and construction activities for the CR SMR Project would not modify the cumulative effects of the system of dams and reservoirs on surface water flow rates in the geographic area of interest and would not contribute to the cumulative effects of the system on aquatic ecological resources in the geographic area of interest.

As discussed in Subsection 4.3.2, the effects of preconstruction and construction activities on the CRN Site and in adjacent offsite areas (Barge/Traffic Area and 69-kV underground transmission line ROW) would not disrupt or alter important aquatic ecosystems. Impacts on aquatic habitats would be SMALL based on the lack of high quality or unique habitats in the areas to be developed or the adjacent reservoir and also the presence of extensive reservoir, pond, and stream habitats in the vicinity and the region. Impacts on most streams would be SMALL and would be further reduced by mitigation. Important aquatic habitats (e.g., natural areas, managed areas, or other designated areas) on the CRN Site or the Barge/Traffic Area would not be within the footprint of preconstruction or construction activities or otherwise adversely affected by these activities, and the impact of these activities on important aquatic species would be SMALL. Impacts on components of the aquatic ecosystem within transmission ROWs similarly would be SMALL.

Historical impacts affecting aquatic habitats on the CRN Site principally occurred during preparatory activities for the CRBRP. These activities resulted in the alteration of site topography, changes in drainage patterns, and the development of multiple stormwater retention ponds, described in Subsection 2.4.2.1.3. The CR SMR Project would retain the preexisting ponds, and incremental impacts on these small aquatic habitats on the CRN Site would be SMALL.

Other activities in the geographic area of interest potentially contributing to cumulative aquatic impacts include activities not directly related to the CR SMR Project, such as the development or operation of other facilities (e.g., those identified in Table 4.7-1), residential and agricultural water use, and water-based recreational activities such as fishing and boating. Natural environmental stressors contributing to cumulative aquatic impacts include short-term and long-term changes in precipitation or temperature and the spread of invasive aquatic organisms.

Factors not directly associated with preconstruction or construction activities for the CR SMR Project also may contribute to cumulative impacts on the aquatic biota of the Clinch River arm of the Watts Bar Reservoir and other aquatic habitats in the geographic area of interest. These impacts include habitat loss due to development that directly impacts streams or ponds; non-point-source pollution related to increased development within the watershed of the Clinch River arm of the Watts Bar Reservoir; and hydrological and water quality alterations resulting from changes in stormwater runoff and infiltration as a result of development in the watershed. Such impacts could result from increased development in the geographic area of interest. Excessive sedimentation is the principal non-point-source pollutant in Tennessee, smothering substrates that are critical habitats for many species of fish and mussels (Reference 4.7-1). As discussed in Subsection 4.3.2, BMPs would be used to prevent or minimize erosion and sediment transport to the Clinch River arm of the Watts Bar Reservoir and to streams on and off the CRN Site, and a SWPPP would prescribe methods for collection and control of runoff from preconstruction and construction areas in accordance with state and federal regulations and NPDES permit requirements. As a result, the incremental contribution to sedimentation impacts from the CR SMR Project during the period of preconstruction and construction activities in conjunction with other development activities in the watershed would be SMALL.

The geographic area of interest for aquatic resources around the CRN Site is likely to continue to be predominantly rural in character and covered mainly by forest. However, reductions in natural vegetation and open space due to increased development or agricultural land uses likely would result in increased stormwater runoff and associated increases in nonpoint source pollutants such as nutrients, pesticides, and petroleum compounds. The cumulative effects on aquatic biota of development of other facilities in the geographic area of interest in combination with preconstruction and construction activities for the CR SMR Project are expected to be SMALL.

As discussed in Subsection 4.7.1.2, climate models forecast three trends that may affect aquatic habitats: warmer mean annual temperatures, greater frequency of intense rainfall events, and drier summers with more severe droughts. Such changes may affect water levels and flows in Tennessee reservoirs through increased evaporation. Increases in temperatures and the intensity of storms may affect reservoir water levels and flows. This higher climate variability may result in less predictable management of reservoir hydrology, with resulting effects on fish habitat, abundance, community composition, and population dynamics. (Reference 4.7-1)

Climate change could result in additional erosion and sedimentation during intense rain events. Increased precipitation may increase runoff and sedimentation in areas where riparian buffers are poor or inadequate. (Reference 4.7-1) The ongoing maintenance of riparian buffers around streams and reservoirs on and in the vicinity of the CRN Site is expected to minimize sedimentation effects from climate change in the geographic area of interest. As discussed in Subsection 4.3.2, the use of BMPs, a SWPPP, and compliance with regulations would prevent or minimize erosion and sediment transport to the Clinch River arm of the Watts Bar Reservoir and to streams on and off the CRN Site. As a result, the incremental cumulative contribution to sedimentation impacts from the CR SMR Project during the period of preconstruction and construction activities in conjunction with global climate change would be negligible or SMALL.

Summary of Cumulative Aquatic Ecology Impacts

Cumulative impacts on aquatic ecological resources were assessed for the past, present, and reasonably foreseeable future activities and processes occurring in the geographic area of interest. The assessment considered impacts on aquatic communities from factors such as the effects of preconstruction and construction for the CR SMR Project, consumptive water loss, regulation of water levels and flows by dams, construction and operation of other commercial and industrial facilities in the watershed, and other natural and anthropogenic stressors, including climate change. This assessment indicates that cumulative impacts from past, present, and reasonably foreseeable future actions on aquatic resources in the geographic area of interest would range from SMALL to LARGE. The incremental contribution from preconstruction and construction activities for the CR SMR Project to impacts on aquatic resources of the water bodies in the geographic area of interest would be SMALL.

4.7.5 Cumulative Socioeconomics and Environmental Justice Impacts

The following subsections describe the evaluation of cumulative impacts on socioeconomics and environmental justice that may result from preconstruction and construction activities at the CRN Site.

4.7.5.1 Socioeconomic Impacts

Socioeconomic resources addressed in this subsection include physical impacts (air quality and noise) and social and economic impacts.

4.7.5.1.1 Physical Impacts

Sections 2.7 and 2.8 address air quality and noise, respectively, in the vicinity of the CRN Site and serve as the baseline for analysis of cumulative impacts to these resource areas. Subsection 4.4.1 describes the potential impacts of preconstruction and construction activities at the CRN Site on air quality and noise levels.

Air Quality

Subsection 2.7.2 describes current air quality conditions for Roane County in which the CR SMR Project would be located. Air quality-related activities during the preconstruction and construction phases for the CR SMR Project are addressed in Subsection 4.4.1.2.

As discussed in Subsection 2.7.2.1, the CRN Site location is in attainment for all criteria pollutants, indicating pollutant levels are below air quality standards. Because preconstruction and construction emissions (fugitive dust and engine exhaust from construction equipment) are generated from ground level or near ground level sources and because they are temporary (not operating continuously and only for the preconstruction and construction phases) and transient (activity does not encompass the entire site at all times), a relatively small geographic area of interest is indicated. Therefore, the geographic area of interest for the preconstruction and construction phases has been defined as a 6-mi radius from the CRN Site. As discussed in Subsection 4.4.1.2, the CR SMR Project plans to utilize a preconstruction and construction-related mitigation plan to minimize these temporary emissions.

Emissions from motor vehicles, used for both the workforce commute and deliveries to the CRN Site, and construction equipment would generate additional air emissions. As noted in Subsection 4.4.1.2, these emissions would be temporary as with other preconstruction and construction activities, and would be mitigated through measures provided in the construction mitigation plan and roadway improvements. Further, emissions from the workforce traffic would be limited to the hours of shift changes.

Table 4.7-1 provides a list of proposed projects, ongoing construction projects, and operational facilities in the region around Oak Ridge, with 13 of these facilities proposed or currently located within 6 mi of the CRN Site. All new significant projects, including the CR SMR Project, are required to secure air related “permits to construct” prior to initiating preconstruction and construction activities. For major air quality sources, projects are also required to obtain a Title V Operating Permit (40 CFR 70). In general, all newly proposed projects for which either state and/or federal air permits are required must have a construction mitigation plan to mitigate construction-related emissions. Through the state and federal air permitting process, proposed projects must demonstrate that air quality would not violate state and Federal ambient air quality standards. Under the reviews that occur through these regulatory processes, along with the State of Tennessee’s ambient air quality monitoring program, air quality in Roane County is expected to remain in attainment for all criteria pollutants during the preconstruction and construction phases of the CR SMR project. Further, state and federal air permitting would ensure cumulative impacts from existing and proposed new sources would comply with the Clean Air Act. A cumulative modeling impact analysis, if required, would include the CRN project plus any existing sources that emit significant air emissions or have significant downwind impacts (based on air regulatory significance definitions). Larger sources in Table 4.7-1, beyond 6 mi from the plant, such as the Bull Run Fossil Plant and Kingston Fossil Plant would also be considered as potential sources for a cumulative air quality modeling study.

As a result of these air permitting requirements, the temporary and limited nature of preconstruction and construction emissions, and mitigation measures to limit onsite construction activity emissions and mobile source emissions, project impacts would be expected to be SMALL for criteria pollutants.

Because climate change is global in nature and currently focuses on the policies established by national governing agencies, the project's region of influence needs to be considered in the context of United States policy and national greenhouse gas (GHG) emissions. Further, individual states are developing GHG regulations, thus consideration of GHG emissions under state regulations would in all likelihood also be necessary. Thus for GHG emissions, the project's geographic area of interest is national in scale.

In 1992, the United States signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC). Under the requirements of the UNFCCC agreement, the U.S. Environmental Protection Agency (EPA) tracks and periodically publishes GHG emissions. In EPA's recent April 15, 2015 report entitled *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2013* (EPA-430-R-15-004), the EPA estimates the United States annual GHG emissions for 2013 were 6673 million metric tons (MMT). (Reference 4.7-21) For the State of Tennessee, the EPA provides a 2012 estimate of 99.91 MMT of carbon dioxide (CO_2) for fossil fuel combustion (Reference 4.7-22). The State of Tennessee GHG emissions are estimated to be 122 MMT of GHGs using a GHG to CO_2 scaling factor of 1.22. (This scaling factor is based on EPA's April 15, 2015 report and national data provided for the year 2012 for the various GHG.)

Estimated annual GHG emissions from the CR SMR Project are only a small fraction of national and State of Tennessee GHG emissions. Because GHG emissions and associated impacts require a global perspective, small incremental changes from individual projects must be evaluated collectively. This is beyond the scope of an individual project and is therefore addressed by the US under the authority of the EPA at the national scale. Mitigation measures, however, provide individual projects with the ability to minimize GHG emissions. Generally, measures to alleviate emissions of criteria pollutants from fossil fuel-fired equipment would likewise reduce GHG emissions. In summary, cumulative GHG impacts are expected to be MODERATE due to the global nature of the GHG issue. However, the incremental cumulative contribution GHG emissions from the CR SMR Project would be SMALL.

Noise

Ambient noise levels at sensitive receptors site within 5 mi of the CRN Site are described in Section 2.8. This discussion provides a baseline for analysis of cumulative impacts on sensitive receptors. As discussed in Subsection 4.4.1.1, based upon the projected noise and vibration levels at various CRN Site and surrounding area receptors and the duration of preconstruction and construction activities, noise and vibration impacts from CRN Site construction are expected to be SMALL for the surrounding communities and the nearest residents. The noise and vibration impacts to the public from construction-related traffic on local roads associated with preconstruction and construction activities at the CRN Site would be SMALL to MODERATE.

The geographic area of interest for noise includes the CRN Site and the areas within 5 mi of the CRN Site. As shown in Table 4.7-1, 12 of the proposed projects, ongoing construction projects, and operational facilities in the region around Oak Ridge, Tennessee are located within 5 mi of the CRN Site. The closest noise-generating projects or facilities are approximately 3 mi from the CRN Site. Due to the distance, the potential for cumulative impact on noise levels associated with these projects and facilities in conjunction with noise levels generated by CRN Site construction would be SMALL. Construction workers and delivery vehicles for proposed and ongoing construction projects could potentially use the same roadways as traffic associated with construction at the CRN Site. Therefore, there would be the potential for SMALL to MODERATE cumulative impacts on noise levels associated with construction-related traffic on local roads.

4.7.5.1.2 Social and Economic Impacts

Subsections 2.5.1 and 2.5.2 describe the social and economic characteristics potentially affected by the proposed CR SMR Project, including population, economy, transportation, taxes, land use, aesthetics and recreation, housing, community infrastructure and public services, and education. These discussions provide the baseline for analysis of cumulative impacts to these resource areas. Subsection 4.4.2 evaluates the social and economic impacts of preconstruction and construction activities at the CRN Site. Impacts associated with activities at the CRN Site would be SMALL with the exception of transportation. Construction-related traffic would have a LARGE impact on local roadways. However, with the recommended modifications, impacts to traffic flow during construction would be MODERATE and temporary. Taxes as well as TVA tax-equivalent payments would have a SMALL and beneficial economic impact.

This cumulative analysis considers impacts from preconstruction and construction activities along with impacts from past, present, and reasonably foreseeable future actions that may contribute to cumulative impacts to communities within the geographic area of interest, the geographic area most likely to be affected by the proposed CR SMR Project. The geographic area of interest for socioeconomic impacts includes Roane, Anderson, Knox, and Loudon counties. As described in Subsection 2.5.2.1, the services, government, and manufacturing sectors employ the greatest number of workers in the geographic area of interest. The services sector employs the greatest number of workers and experienced the largest growth from 2001 to 2011 in all four counties within the geographic area of interest. Farming experienced the largest decline in Anderson and Loudon counties during this period, while manufacturing had the largest decline in Knox and Roane counties.

The socioeconomic impacts associated with the operational facilities (past and present projects) listed in Table 4.7-1 have already been addressed in the baseline conditions presented in Subsections 2.5.1 and 2.5.2 and in the impact analysis presented in Subsection 4.4.2. This cumulative impacts evaluation focuses on reasonably foreseeable projects and ongoing (present) construction projects.

Cumulative impacts from preconstruction and construction activities at the CRN Site and from other past, present, and reasonably foreseeable future projects within the socioeconomic geographic area of interest could temporarily contribute to adverse cumulative effects on some socioeconomic resources, primarily transportation. Road improvements, including TDOT pending projects and CRN SMR-related improvements proposed for roadways near the CRN Site, would have temporary MODERATE cumulative impacts. The potential improvements associated related to the rail siding would have temporary and SMALL cumulative impacts. The influx of temporary construction workers for the proposed projects and ongoing construction projects would have a MODERATE and temporary cumulative impact on traffic within the geographic area of interest.

Construction employment, including in-migration of construction workers, as well as new indirect service jobs created by the spending of the construction workers' income would produce a positive cumulative effect on employment and income in the geographic area of interest. Therefore, the cumulative economic impact on the geographic area of interest of construction of the CR SMR Project and other ongoing construction projects and reasonable foreseeable projects on employment, income, and taxes would be beneficial and MODERATE. Although the amount of income, sales, and property taxes (as well as TVA tax-equivalent payments) generated by the projects would be large in absolute terms, it would be SMALL when compared to the total amount of taxes collected within the geographic area of interest.

4.7.5.2 Environmental Justice Impacts

Executive Order 12898 (59 FR 7629) directs federal executive agencies to consider environmental justice under the NEPA. This Executive Order ensures that minority and/or low-income populations do not bear a disproportionate share of adverse health or environmental consequences of a proposed project.

Subsection 2.5.4 provides baseline information on minority and low-income populations within the region (i.e., within a 50-mi radius of the CRN Site) for the cumulative impacts assessment of environmental justice. As shown in Figure 2.5.4-1, the spatial distribution of block groups with minority populations in the region is clustered in the City of Knoxville, in Knox County, Tennessee and the City of Alcoa, in Blount County, Tennessee. No block groups in Roane County (in which the CRN Site is located) or in Anderson County contain minority populations as defined in Subsection 2.5.4.2. The identified aggregate minority population closest to the CRN Site is located approximately 20 mi to the east in Blount County, Tennessee. The closest Hispanic minority population is located in Loudon County, Tennessee, approximately 9 mi southeast of the CRN Site. As shown in Figure 2.5.4-2, the majority of the low-income population in the geographic area of interest is in the City of Knoxville, in Knox County, Tennessee. There is one low-income population block group within Roane County, Tennessee and one within Anderson County, Tennessee. The closest low-income population block group is located in Loudon County, Tennessee, approximately 7 mi southeast of the CRN Site. No other populations or groups (e.g., subsistence populations) were identified that represent environmental justice populations in the region.

Subsection 4.4.3 evaluates the potential environmental justice impacts from preconstruction and construction activities at the CRN Site. Subsection 4.4.3.2 discusses the potential for impacts to the Wheat Community Burial Ground, located off TN 58 about 1 mi from the CRN Site and concludes that the CR SMR Project would not adversely impact the burial ground, which is of cultural significance to the African American community. Based on the location and expected impacts of the projects listed in Table 4.7-1, no adverse cumulative effects to the Wheat Community Burial Ground are expected. Because of the spatial distribution of the minority and low income populations across the region, the potential for disproportional impacts to low-income and minority populations from preconstruction and construction activities is SMALL. No uniquely vulnerable low-income or minority community, such as a subsistence population, was identified in the region. In summary, the overall SMALL impact of the CR SMR Project, combined with the spatial distribution of the low-income and minority population, results in a SMALL potential for adverse socioeconomic impacts that would disproportionately affect low-income and minority communities.

The cumulative analysis considers impacts from preconstruction and construction activities at the CRN Site along with past, present, and reasonably foreseeable actions that could cause disproportionately high and adverse impacts on minority and low-income populations. The environmental justice analysis presented in Subsection 4.4.3 provides a baseline comparison for consideration of cumulative environmental justice impacts associated with the projects and activities listed in Table 4.7-1. Given that the reasonably foreseeable projects are located within the region assessed for the CRN Project, and no uniquely vulnerable low-income or minority populations were identified within the region, there would be no cumulative impacts on environmental justice populations. The incremental additional impacts from future projects, in combination with preconstruction and construction activities at the CRN Site, would be SMALL.

In summary, there would be no disproportionately high or adverse cumulative impacts to minority or low-income populations within the 50-mi geographic area of interest. Therefore, there would be no (SMALL) cumulative environmental justice impacts.

4.7.5.3 Historic Properties Impacts

Subsection 2.5.3 describes the historical and cultural resources affected by the proposed CR SMR Project.

The geographic area of interest for the analysis of cumulative impacts to historic properties includes:

- The archaeological resources and historic properties within the CR SMR Project Area of Potential Effect (APE) defined in Subsection 2.5.3 as the approximately 1200-ac Clinch River Property, an additional approximately 105 ac northwest of the property near the CRN Site entrance and along Bear Creek Road and Tennessee State Highway (TN) 58, the Melton Hill Dam, and a 0.5 mi radius around the Melton Hill Dam.
- The Historic Architecture APE is 0.50-mi radius surrounding the proposed cleared areas.

- The historic properties (those eligible for listing on the National Register of Historic Places [NRHP]) within a 10-mi radius of the center of the CRN Site (Figure 2.5.3-2).

Subsection 4.1.3 describes impacts to historic and cultural resources during preconstruction and construction activities at the CRN Site. Fifty-nine recorded archaeological sites, four isolated finds, one non-site locality, one NRHP-eligible historic district, and one cemetery have been identified within or immediately adjacent to the CR SMR Project APE. Of the archaeological sites, one is considered eligible for listing on the NRHP; 16 are considered potentially eligible for the NRHP; and 42 are considered not eligible for the NRHP. Ten of the eligible and potentially eligible sites are avoidable. Within the CRN Site, sites 40RE0107, 40RE0595, 40RE0549, 40RE0104, and 40RE0105 would potentially be impacted by CR SMR Project preconstruction and construction activities. In the Barge/Traffic Area, sites 40RE138 and 40RE233, may be affected by CR SMR Project preconstruction and construction activities. The NRHP-eligible Melton Hill Hydroelectric Project/Melton Hill Dam and historic district would potentially be impacted by preconstruction and construction activities and potentially by operational activities. As described in Subsection 4.1.3, impacts to historic properties would be SMALL to MODERATE.

This cumulative analysis considers impacts from preconstruction and construction, along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to historic and cultural resources within the geographic area of interest, the geographic area most likely to be affected by the proposed CR SMR Project. The geographic area of interest for archaeological resources is the CR SMR Project APE. For historic architectural resources the geographic area of interest is the 0.5-mi radius around the CRN Site.

As discussed in Subsection 4.1.3, TVA has developed a Programmatic Agreement (PA) pursuant to 36 CFR 800.14(b)(3). Signatories are TVA, the Tennessee State Historic Preservation Officer (SHPO) and invited concurring party, the Eastern Band of the Cherokee Indians. The PA records the terms and conditions agreed upon to resolve potential adverse effects of the undertaking. It provides for modifications to the CR SMR Project APE, evaluating the NRHP eligibility of unevaluated resources (archaeological sites and historic architectural resources), evaluating project effects to resources, and resolution of adverse effects. A discovery plan will be developed in consultation with the SHPO and any federally-recognized Native American tribe that attaches religions significance and cultural significance to the historic property affected by the undertaking, to deal with the subsequent discovery or identification of additional historic properties affected by the undertaking. This plan would be implemented in the unlikely event that an unanticipated discovery occurs during preconstruction and construction activities. (Reference 4.7-24)

Cumulative impacts to historic and cultural resources from past and present activities have occurred, and are MODERATE. The impacts from past activities have resulted in the destruction, removal, and/or disturbance, of historic and cultural resources within the geographic area of interest. Cultural resources are nonrenewable and therefore impacts are cumulative in nature. The preconstruction and construction activities associated with the CR SMR Project would contribute additional cumulative impacts to some cultural resources within the geographic area of interest in association with other reasonably foreseeable future projects listed in Table 4.7-1, including development within Roane Regional Business and Technology Park and the ETTP, the new general aviation airport, various projects within ORR, and relocation of CVMR Corporation. Most of these projects are located within areas previously developed and therefore have a limited potential to impact historic properties within the geographic area of interest. Several of these projects are also located on federal land and would therefore be subject to Section 106 reviews to examine the potential for impacts to historic properties. A final assessment of impacts and any required mitigation associated with the CR SMR Project are dependent on the outcome of the Phase II testing, in consultation with the SHPO and any federally-recognized Native American tribes that attach religious and cultural significance to the historic property that is potentially impacted. Because the extent of impacts from the CR SMR project are not yet known, cumulative impacts to cultural resources from preconstruction and construction of the CR SMR Project could range from SMALL to MODERATE.

4.7.6 Radiological Health Impacts

As described in Section 4.5, the radiological impacts on the construction worker from construction of the CR SMR Project would be SMALL. During the construction period, operating reactors may also have an impact on the public. Details of the evaluation of the potential dose to the public from all operating reactors are provided in Section 5.4. Specifically, as described in Subsection 5.4.3, the total body dose to a hypothetical maximally exposed individual (MEI) member of the public from the operation of all SMRs at the CRN Site is estimated to be 11 mrem/yr.

For this analysis of cumulative radiological impacts, the geographic area of interest was considered to be the area within a 50-mi radius of the CRN Site. The NRC historically has used 50 mi as the radius bounding the geographic area for evaluating doses to the public from routine releases from nuclear power plants. Table 4.7-1 summarizes past, present, and reasonably foreseeable future projects and actions that could contribute to cumulative effects. Among these are several radiological projects or facilities. Within the geographic area of interest, planned federal projects on the ORR, including the Transuranic (TRU) Waste Processing Center, Uranium Processing Facility (UPF) at Y-12 complex, and Environmental Management Waste Management Facility (EMWMF), have the potential to contribute to cumulative radiation exposures in conjunction with the CR SMR Project. In addition, currently operating facilities on the ORR include the High Flux Isotope Reactor (HFIR), a nuclear research located at Oak Ridge National Laboratory (ORNL), and the ORNL Spallation Neutron Source. Off the ORR, TVA’s Watts Bar Nuclear (WBN) Units 1 and 2 and American Nuclear Corporation will continue to operate. These four facilities identified in Table 4.7-1 have the potential to contribute to cumulative radiation exposures in conjunction with the CR SMR Project. Each of these facilities would be constructed and operated or continue to operate in accordance with environmental regulations that limit the radiation exposures received by members of the public, as discussed in Subsection 4.5.5.

Ongoing activities within the ORR likely will continue to release small quantities of radionuclides to the environment in the future. The ORR *Annual Site Environmental Report* provides results from a detailed analysis of radiation doses to a hypothetical MEI from all pathways of exposure to radionuclides released from all DOE facilities on the ORR. The maximum radiation dose that a hypothetical MEI could have received from DOE activities on the ORR in 2014 was estimated to include approximately 0.6 millirem (mrem) from air pathways, 1 mrem from water pathways (i.e., drinking, consuming fish, swimming, and other recreational uses of the water and shoreline), and 1 mrem from consumption of wildlife (e.g., deer, geese, and turkey) harvested on ORR. The annual dose to an MEI from the combination of all these potential exposure pathways was estimated to be approximately 3 mrem. (Reference 4.7-23)

There are several non-DOE facilities on or near the ORR that could also contribute to radiation doses to the public. DOE requested information from these facilities regarding their potential radiation doses to members of the public, and nine facilities responded with information about their dose contributions. DOE estimated that maximum annual doses to members of the public from air and water emissions and external radiation from both non-DOE and DOE sources on and near the ORR were less than 100 mrem. Of the less than 100 mrem total dose, 45 mrem is from direct radiation reported from onsite dose monitors at one of the nine responding facilities. (Reference 4.7-23) The CRN Site MEI would be outside the physical range of this direct radiation. Therefore, the dose to an MEI from the non-DOE facilities on or near ORR is estimated at maximum of 55 mrem/yr.

The WBN Units 1 and 2 are located within the 50-mi geographic area of interest. According to NUREG-0498, Supplement 2 – *Final Environmental Statement: Related to the Operation of Watts Bar Nuclear Plant*, the combination of potential doses from the ongoing operation of WBN Unit 1 with estimated doses from the operation of the new WBN Unit 2 result in a total body dose of 2.6 mrem/yr for an MEI at the WBN site.

Other facilities in the geographic area of interest, such as industrial facilities and hospitals, may use radiological materials, but their potential contributions to the cumulative dose received by the CRN Site MEI during the construction period would be negligible. Because radiation dose is highly location dependent and an individual in one location cannot receive the maximum possible dose from all of the multiple sources, the sum of the doses estimated above is conservative. Summing the doses of 11 mrem/yr from the CRN Site, 3 mrem/yr from DOE facilities, 55 mrem/yr from non-DOE facilities, and 2.6 mrem/yr from WBN Units 1 and 2, provides an estimate of the cumulative dose impact from radiation sources in the geographic area of interest during construction. The CRN Site contribution to this total is well below the annual dose limit of 100 mrem/yr from 10 CFR Part 20.1301, and the total cumulative impact is significantly less than the approximately 300 mrem average annual dose to individuals from natural or background radiation in the United States (Reference 4.7-23). Therefore, the cumulative dose impact will be SMALL.

4.7.7 Nonradiological Health Impacts

Sections 2.2, 2.3, and 2.7 describe the land, water, and air affected by the proposed SMR project at the CRN Site. Sections 4.1, 4.2, and 4.4 describe impacts to health and the physical environment during preconstruction and construction activities at the CRN Site. Compliance with the site permits coupled with BMPs, would result in SMALL impacts from the proposed SMR project to nonradiological health from preconstruction and construction activities.

Nonradioactive health impacts from preconstruction and construction at the CRN Site include localized impacts from noise, vibrations, and dust along with occupational injuries to the construction workers. Cumulative noise and vibration impacts from preconstruction and construction activities would include current ongoing and planned developments at ETTP and at Bull Run Fossil Plant. Future cumulative noise and vibration impacts would include possible roadway improvements and urbanization within 10 mi of the CRN Site. Cumulative dust impacts would behave similarly.

Cumulative health impacts to construction workers also include occupational injuries coupled with noise, vibration, and emission impacts from current and future activities within the worker's commute region. Current and future activities within a 50-mi radius of the CRN Site including road, airport, and building construction along with decommissioning and demolition activities at ORR would contribute to cumulative health impacts to construction workers.

Further nonradioactive health impacts include effects from GHG emissions and particulates from transport of construction crew and supplies and from preconstruction and construction activities at the CRN Site. Cumulative health impacts to workers and the public from these GHG and particulate emissions would include state and national contributors. State and federal air permitting coupled with the use of BMPs would help mitigate contributions from the proposed SMR project along with current and future projects; thus helping minimize the health impacts from these emissions.

In addition, projected climate change for the region contributes to the potential nonradiological health of the populace in the geographic area of interest. Climate change has already resulted in warmer, wetter weather patterns with greater incidence of severe storm events. These severe storms tend to increase water pollution from runoff including increased fertilizers, herbicides, and pesticides along with increased sedimentation impairing the water quality and contributing to adverse health effects (Reference 4.7-2). Additionally, less regular precipitation events coupled with increased evaporation and transpiration from increased air and water temperatures, may also lead to reduced availability of timely water resources and a need for crop irrigation; thus reducing the local availability of fresh water and food. Further, global changes in climate are expected to result in decreasing availability of food and water and thus negatively impact human health through increased competition for more limited resources (Reference 4.7-2).

Although the nonradiological health impact of the proposed project at the CRN Site is SMALL, the cumulative impact of the observed and projected increase in temperature and storm severity along with impacts from preconstruction and construction activities at the CRN Site would be SMALL to MODERATE.

4.7.8 References

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Reference 4.7-17. U. S. Geological Survey, "Water Quality in the Upper Tennessee River Basin, 1994-1998," Circular 1205, 2000.

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Reference 4.7-21. U.S. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013," EPA 430-R-15-004, April 15, 2015.

Reference 4.7-22. U.S. Environmental Protection Agency, State Energy CO2 Emissions, Website: http://www3.epa.gov/statelocalclimate/resources/state_energyco2inv.html, July 8, 2015.

Reference 4.7-23. Oak Ridge National Laboratory, "Oak Ridge Reservation Annual Site Environmental Report," DOE/ORO-2502, September, 2015.

Reference 4.7-24. Tennessee Valley Authority and Tennessee State Historic Preservation Officer, "Programmatic Agreement between the Tennessee Valley Authority and the Tennessee State Historic Preservation Office regarding the management of historic properties affected by the Clinch River SMR Project," July 20, 2016.

Table 4.7-1 (Sheet 1 of 3)
Past, Present and Reasonably Foreseeable Future Projects and Other Actions Considered in the Cumulative Analysis of Oak Ridge Reservation

Project Name	Summary of Project	Relative Location (from center of CRN Site)	Status
CRBRP	Site preparation for the construction of a liquid metal fast breeder reactor	On the CRN Site	Site preparation from 1972-1983. Site redress through the mid-1980s.
Sludge Build-Out Project at the TRU Waste Processing Center	Changes to the method of sludge processing and changes to waste shipping routes	Approximately 3 mi east	Projected to begin in 2016
UPF at Y-12	New building in Y-12 complex	Approximately 10 mi northeast	Planning documents, no explicit schedule
Mercury Cleanup Activities at Y-12	Mercury environmental remediation	Approximately 10 mi northeast	Ongoing
Old Y-12 Steam Plant	Burned 51,000 tons coal producing 5000 tons ash (used as cover material at Y-12 landfill.)	Approximately 10 mi northeast	Operational 1950s through 2010. Coal yard capped.
New Y-12 Steam Plant	Natural gas power generation for Y-12 operations.	Approximately 10 mi northeast	Operational since 2010
Potential ETTP Property Transfer	Transfer of property to private companies	Approximately 2 mi north	Ongoing
Roane Regional Business and Technology Park	Business and Industrial Park with sites for development	Approximately 0.5 mi east	Operational since 2001
ORNL	DOE Nuclear and High Tech Research Facility	Approximately 5 mi northeast	Operational since 1942
ORNL - Spallation Neutron Source	Accelerator-based neutron pulse for research and development (R&D).	Approximately 5 mi northeast	Operational since 2006
ORNL - High Flux Isotope Reactor	Critical reaction providing a stable beam of neutrons for R&D.	Approximately 5 mi northeast	Operational since 1965. Decommission anticipated after 2060.
Environmental Management Disposal Facility on ORR	New onsite landfill east of existing EMWMF	Approximately 10 mi northeast	Preliminary schedule; Construction could start in 2018
TDOT Projects	Roadway improvements	TN 95 (Bear Creek)-Approximately 4 mi northeast	By 2019, pending Federal funding
TDOT Projects	Roadway improvements	TN 95 and Bethel Road – Approximately 3 mi northeast	By 2019, pending Federal funding
TDOT Projects	Roadway improvements	TN 29 – Approximately 10 mi west	By 2019, pending Federal funding

Table 4.7-1 (Sheet 2 of 3)
Past, Present and Reasonably Foreseeable Future Projects and Other Actions Considered in the Cumulative Analysis of Oak Ridge Reservation

Project Name	Summary of Project	Relative Location (from center of CRN Site)	Status
TDOT Projects	Roadway improvements	TN 73 – Approximately 3 mi southeast	By 2019, pending Federal funding
McGee Tyson Airport	Public and military airport	Alcoa; approximately 22 mi southeast	Operational
Island Home Downtown Airport	Public aviation facility	Knoxville; approximately 28 mi to the east	Operational
Construction of a General Aviation Airport	Development of a general aviation airport	Approximately 3 mi north	Potential Construction Starting in 2017. Not considered in cumulative evaluation because it does not meet the criteria established in 4.7
CVMR Corporation	Relocation of Global Headquarters and operation of a refining facility on the old Steam Plant property of the former K-25	Approximately 4 mi northeast	Ongoing
City of Oak Ridge Sanitary Sewer System Upgrades	Sanitary Sewer Improvements	Approximately 11 mi northeast	Ongoing
Sequoyah Unit 1 Nuclear Reactor	Power Generation	Approximately 61 mi southwest	Operational since 1981
Sequoyah Unit 2 Nuclear Reactor	Power Generation	Approximately 61 mi southwest	Operational since 1982
Watts Bar Unit 1 Nuclear Reactor	Power Generation	Approximately 30 mi southwest	Operational since 1996
Watts Bar Unit 2 Nuclear Reactor	Operation of Watts Bar Unit 2	Approximately 30 mi southwest	Scheduled for commercial operation June 2016
Melton Hill Hydroelectric Facility	Hydroelectric power and Melton Hill Reservoir	5 mi east	Operational since 1963
Bull Run Fossil Plant	Net capability 870 MWe	Bull Run Creek; approximately 15 mi northeast	Operational since 1967
Kingston Fossil Plant	Net capability 1379 MWe	Watts Bar Reservoir; approximately 8 mi west	Operational since 1955
Fort Loudoun Dam	Hydroelectric power and Fort Loudoun Reservoir	Tennessee River; approximately 11 mi southeast	Operational since 1943
Norris Dam	Hydroelectric power and Norris Reservoir	Clinch River; approximately 28 mi northeast	Operational since 1936

Table 4.7-1 (Sheet 3 of 3)
Past, Present and Reasonably Foreseeable Future Projects and Other Actions Considered in the Cumulative Analysis of Oak Ridge Reservation

Project Name	Summary of Project	Relative Location (from center of CRN Site)	Status
Douglas Dam	Hydroelectric power and Douglas Dam Reservoir	French Broad; approximately 47 mi east	Operational since 1943
Cherokee Dam	Hydroelectric power and Cherokee Reservoir	Holston River; approximately 53 mi northeast	Operational since 1941
Great Falls Dam	Hydroelectric power and Great Falls Reservoir	Caney Fork River (not on the Tennessee River watershed); approximately 70 mi west	Operational since 1916
Tellico Dam	Flood Control and Tellico Reservoir	Little Tennessee River; approximately 11 mi southeast	Operational since 1979
Watts Bar Dam	Hydroelectric power and Watts Bar Reservoir	Tennessee River; approximately 30 mi southwest	Operational since 1942
American Nuclear Corporation	Production of radioactive sources and detectors	Braden Branch Creek (CRM 50.5); approximately 15 mi northeast	Operational1962-1970. Cleaned and fenced. Decay in place.
Former Anderson County Landfill	28 ac waste disposal	CRM 51 to CRM 52 (Blockhouse Valley Road); approximately 15 mi northeast	Operational 1973-1981. Non-NPL. Deer hunting permitted.
Whiteoak Dam	Manhattan Project impoundment on White Oak Creek with 25 ac settling pond. Formed to reduce radioactive waste runoff into Clinch River arm of the Watts Bar Reservoir	Approximately 3 mi east-northeast	Operational since 1943

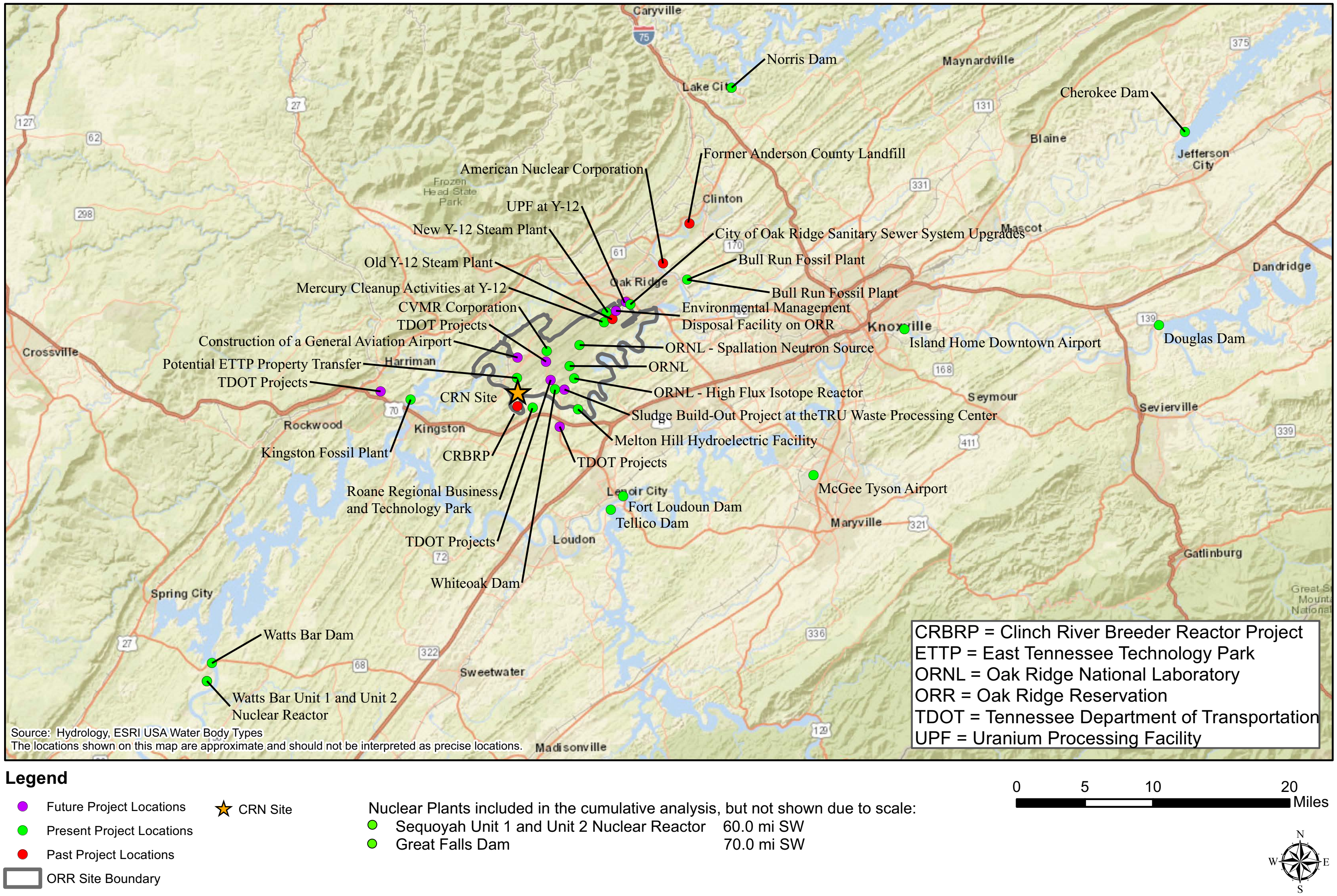

Figure 4.7-1. Oak Ridge Reservation Past, Present and Reasonably Foreseeable Future Projects

CHAPTER 5 ENVIRONMENTAL IMPACTS OF STATION OPERATION

Chapter 5 presents the potential environmental impacts of operation of the Clinch River (CR) Small Modular Reactor (SMR) Project, which includes operation of two or more SMRs at the Clinch River Nuclear (CRN) Site.

In accordance with Title 10 of the Code of Federal Regulations (10 CFR) Part 51, impacts are analyzed, and a significance level of potential impact to each resource (i.e. SMALL, MODERATE, or LARGE) is assigned consistent with the criteria that U.S. Nuclear Regulatory Commission (NRC) established in 10 CFR Part 51, Appendix B, Table B-1, Footnote 3. Unless the impact is identified as beneficial, the impact is adverse. In the case of “SMALL,” the impact may be negligible. The definitions of significance are as follows:

SMALL — Environmental effects are not detectable or are so minor that they neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the NRC has concluded that those impacts that do not exceed permissible levels in the NRC’s regulations are considered SMALL.

MODERATE — Environmental effects are sufficient to alter noticeably, but not to destabilize important attributes of the resource.

LARGE — Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

This chapter is divided into 11 sections:

- Land Use Impacts (Section 5.1)
- Water-Related Impacts (Section 5.2)
- Cooling System Impacts (Section 5.3)
- Radiological Impacts of Normal Operation (Section 5.4)
- Environmental Impacts of Waste (Section 5.5)
- Transmission System Impacts (Section 5.6)
- Uranium Fuel Cycle and Transportation Impacts (Section 5.7)
- Socioeconomics Impacts (Section 5.8)
- Decommissioning Impacts (Section 5.9)
- Measures and Controls to Limit Adverse Impacts During Operation (Section 5.10)
- Cumulative Impacts Related to Station Operation (Section 5.11)

These sections present the potential environmental impacts of operation of the CR SMR Project. Impacts are analyzed and a significance level of potential impact to each resource is assigned. In addition, this section presents ways to avoid, minimize, or mitigate adverse impacts of CR SMR Project operations.

5.1 LAND USE IMPACTS

This section describes the potential impacts on land use of operating two or more small modular reactors (SMRs) at the Clinch River Nuclear (CRN) Site. For the purposes of this Environmental Report, the CRN Site, vicinity, and region are defined in Chapter 2. Subsection 5.1.1 describes the effects on land use at the CRN Site and vicinity. Subsection 5.1.2 describes effects that could occur along transmission lines and in offsite areas resulting from operation and maintenance activities. Subsection 5.1.3 describes potential effects on historic properties at the CRN Site and in the vicinity, along transmission corridors, and at offsite areas.

5.1.1 The Site and Vicinity

Adverse impacts to land use at the CRN Site and vicinity occur primarily during construction, as documented in Section 4.1.

5.1.1.1 The Site

Land use within and adjacent to the CRN Site is discussed in Subsection 2.2.1 and Table 2.2-1. Figure 2.2-2 illustrates land use. No new areas are expected to be disturbed after the construction phase ends, and no agricultural crop production is expected to occur on the CRN Site. Therefore, operations at the CRN Site are expected to have SMALL impacts on the pasture and developed land within the CRN Site.

Prime farmland at the CRN Site is discussed in Subsection 2.2.1.1. Figure 2.2-3 shows and Table 2.2-2 lists the soil types on the CRN Site and in the site vicinity. As described in Subsection 2.2.1.1, the modern prime farmland classification of soils should be similar to the first-class (good to excellent cropland) 1942 classification. There are no first-class soils within the CRN Site or in the immediate vicinity of the Oak Ridge Reservation (ORR). Therefore, the impact of the Clinch River (CR) SMR Project on the relative value of farmland would be SMALL.

The cooling systems that are used for the operation of two or more SMRs at the CRN Site are described in Subsection 3.4.1. Heat dissipation to the atmosphere from operation of the CR SMR Project cooling towers and the effects of the cooling tower plumes and drift are discussed in Subsection 5.3.3. The impacts of the cooling tower plume salts on the CRN Site area are also discussed in Subsection 5.3.3.

Transmission lines on the CRN Site are discussed in Subsection 2.2.3 and Section 3.7. During operations, actions associated with the onsite transmission lines would consist of routine maintenance and clearing activities. Impacts associated with routine maintenance and clearing activities are addressed in Section 5.6. Overall, the impact to land use associated with operation of the transmission lines on the CRN Site would be SMALL.

5.1.1.2 The Vicinity

Land use within the vicinity of the CRN Site is discussed in Subsection 2.2.1.2. Figure 2.2-4 illustrates land use within the vicinity. The majority of land located north and east in the vicinity of the CRN Site is federal land and is part of the ORR. No offsite land is expected to be disturbed after the construction phase, and operational land-use impacts of the CR SMR Project are confined to the CRN Site. Therefore, operations at the CRN Site would have a SMALL impact on the developed land and rural farmland in the vicinity of the CRN Site.

Land use impacts associated with CR SMR Project operation that may have social and economic effects in the region are discussed in Section 5.8. Housing is discussed in Subsection 2.5.2.6 and housing impacts related to the in-migrating plant operations workforce are discussed in Subsection 5.8.2.1. The effects of the cooling tower plumes and drift associated with the CR SMR Project are discussed in Subsection 5.3.3.

The CR SMR Project is expected to generate waste that requires disposal in permitted facilities and landfills. Discussions of impacts of non-radioactive waste as well as hazardous and mixed waste on land are provided in Section 5.5.

5.1.2 Transmission Corridors and Offsite Areas

Transmission lines at the CRN Site are discussed in Subsection 2.2.3 and Section 3.7. No additional transmission lines associated with the SMR Project in offsite areas are expected to be installed during the operations phase of the CR SMR Project. The impact to land use associated with offsite transmission lines during CR SMR Project operations would be SMALL.

The road and highway system in Roane, Loudon, Anderson, and Knox counties is shown in Figure 2.5.2-1 and discussed in Subsection 2.5.2.2. Information pertaining to the effects of operations workers on the local road and highway system is presented in Subsection 5.8.2.3. The land use impact on local roadways would be SMALL.

5.1.3 Historic Properties

This subsection focuses on the potential for the CR SMR Project to affect historic properties within the CRN Site, within a 0.5-mile (mi) radius surrounding the area in which vegetation clearing would take place, at the Melton Hill Dam, and within 0.5 mi of the Melton Hill Dam. Archaeological sites and aboveground historic properties are among the properties that can be considered for listing on the National Register of Historic Places (NRHP). They are the principal historic properties of concern with regard to effects from CR SMR Project operations at the CRN Site along with traditional cultural properties. Additionally, Subsection 2.5.3, Tables 2.5.3-1 and 2.5.3-2, and Figures 2.5.3-1 and 2.5.3-2 present the site numbers, locations, and NRHP status of relevant historic properties within the 10-mi radius of the CRN Site center point, which includes the Melton Hill Dam. Direct effects from CR SMR Project operations to historic properties are possible within the CR SMR Project area of potential effect (CR SMR Project APE). The CR SMR Project APE is described in Subsection 2.5.3.

As described in Subsection 2.5.3, no NRHP-listed properties are listed on or immediately adjacent to the CRN Site. One NRHP eligible district is located within the CR SMR Project APE. Fifty-nine recorded archaeological sites, four isolated finds, one non-site locality, and one cemetery have been identified within or immediately adjacent to the CR SMR Project APE. Of these sites, one site is considered to be eligible for the NRHP, 16 sites are considered potentially eligible (or of undetermined eligibility) for the NRHP; and 42 are considered not eligible for the NRHP. Ten of the eligible and potentially eligible sites are avoidable.

As discussed in Subsection 4.1.3, Tennessee Valley Authority (TVA) has executed a Programmatic Agreement (PA) pursuant to Title 36 of the Code of Federal Regulations 800.14(b)(3).The PA provides for modifications to the CR SMR Project APE, evaluating the NRHP eligibility of unevaluated resources (archaeological sites and historic architectural resources), evaluating project effects to resources, and resolution of adverse effects. TVA would implement the provisions of the PA in the event of any changes to the CR SMR Project. The PA provides measures to mitigate impacts to historic properties associated with operations of the CR SMR Project.

5.1.3.1 Prehistoric and Historic Archaeological Sites

The highest potential for effects to archaeological sites would occur during the construction period as described in Subsection 4.1.3. Operations at the CR MR Project would occur in areas previously disturbed by CR SMR Project construction and preconstruction activities. A final assessment of effects to archaeological sites within the CR SMR Project APE and any required mitigation are dependent on the outcome of the Phase II testing/reporting as stipulated by the PA and conducted in consultation with the State Historic Preservation Officer (SHPO) and any federally recognized Native American Tribe that attaches religious and cultural significance to the historic property. Operational effects to archaeological sites determined in consultation to be eligible for listing in the NRHP would be treated pursuant to mitigation measures developed in consultation with the consulting parties as described in Subsection 4.1.3. Because most effects to archaeological properties would be anticipated during the construction period, impacts to archaeological sites on the CRN Site in association with CR SMR Project operations would be SMALL.

With preconstruction and construction activities, there is the possibility for the inadvertent discovery of previously unknown archaeological resources or human remains. The PA describes the measures that will be implemented in the event of such discoveries. Should previously unknown archaeological resources be discovered, sites will be protected and stabilized to prevent any further disturbance. Ground-disturbing work will stop within a 50-foot radius of the discovery. TVA, in consultation with the SHPO and federally recognized Native American tribes that attach religious and cultural significance to the property affected by the undertaking, would develop and implement a discovery plan to make an informed NRHP eligibility determination. TVA would continue to fulfill all stipulations of the PA and its obligations under Section 106. Ground-disturbing work would not resume at the previously unknown site until completion of the NRHP determination and PA signatory consultation. (Reference 5.1-1) Subsection 4.1.3.1 describes the stipulations of the PA TVA would implement in the event of a discovery of previously unknown archaeological resources.

5.1.3.2 Historic Structures

As discussed in Subsection 2.5.3.7, one eligible district, the Melton Hill Hydroelectric Project/Melton Hill Dam was identified within the CR SMR Project APE. As described in Subsection 3.4.2.5, the Plant Parameter Envelope (PPE) includes minor modification to the flow of the Clinch River in the CR SMR Project vicinity to maintain up to 400 cfs flow. As described in Subsection 4.1.3.2 such a flow modification could require changes at Melton Hill Dam. Project designs would not be proposed until a reactor design is selected and most modifications are anticipated to occur during the preconstruction and construction phase. The Melton Hill Dam (including spillway) is a contributing structure to the Melton Hill Hydroelectric Project nominated NRHD. TVA will adhere to and comply with the stipulations of the PA with respect to modifications of the Melton Hill Dam. Therefore, impacts to historic structures as a result of operation activities associated with the CR SMR Project would be SMALL to MODERATE. Implementation of the mitigation measures as stipulated in the PA would minimize the potential for LARGE impacts to historic structures.

5.1.3.3 Cemeteries

One cemetery, the Hensley Cemetery, exists on the CRN Site. As discussed in Subsection 2.5.3.9, this cemetery is not eligible for the NRHP. TVA has determined that this cemetery would remain in place onsite, TVA would maintain the cemetery grounds and access road, and families would be able to access the cemetery (Reference 5.1-2). Therefore, impacts to the Hensley Cemetery associated with CR SMR Project operations would be SMALL and beneficial resulting in greater preservation, upkeep, and access.

5.1.3.4 Traditional Cultural Properties

As discussed in Subsection 2.5.3.10, no traditional cultural properties have been identified in consultation with any federally recognized Native American tribe that attaches religious and cultural significance to an archaeological historic property, or any other interested parties on the CRN Site or within a 0.5-mi surrounding the area in which vegetation clearing would take place.

5.1.4 References

Reference 5.1-1. Tennessee Valley Authority and Tennessee State Historic Preservation Officer, "Programmatic Agreement between the Tennessee Valley Authority and the Tennessee State Historic Preservation Office regarding the management of historic properties affected by the Clinch River SMR Project," July 20, 2016.

Reference 5.1-2. AECOM, "Final Clinch River Site Land Use and Recreation Technical Report - Revision 2," Greenville, SC, Tennessee Valley Authority, October, 2014.

5.2 WATER-RELATED IMPACTS

This section provides information that describes the hydrological alterations, plant water supply, and water-related impacts of facility operations at the Clinch River Nuclear (CRN) Site. Water-related impacts from facility operations are addressed in the following subsections:

- Hydrologic Alterations and Plant Water Supply (5.2.1)
- Water-Use Impacts (5.2.2)

5.2.1 Hydrology Alterations and Plant Water Supply

This subsection presents an analysis of the impact of small modular reactor (SMR) operation on surface water and groundwater hydrology, as well as the sufficiency of the proposed water source to support facility operations.

5.2.1.1 Hydrologic Setting

5.2.1.1.1 Surface Water

A description of the hydrologic setting of surface water in the vicinity of the CRN Site is presented in Subsection 2.3.1.1. The CRN Site is located on the Clinch River arm of the Watts Bar Reservoir, which is the proposed water source and receiving water body for facility operations. The CRN Site is located on the reservoir between approximately Clinch River Mile (CRM) 14.5 and approximately CRM 19.0 (Reference 5.2-1). Within the CRN Site, the proposed surface water intake is located at approximately CRM 17.9, and the proposed discharge is located at approximately CRM 15.5.

Watts Bar Dam impounds the Watts Bar Reservoir. Watts Bar Dam is located on the Tennessee River at Tennessee River Mile (TRM) 529.9, approximately 52.4 river miles downstream of the CRN Site. The reservoir has approximately 722 miles (mi) of shoreline and over 39,090 acres (ac) of water surface (Reference 5.2-2). Water enters Watts Bar Reservoir from two primary sources: releases of water from the Melton Hill Dam on the Clinch River arm of the reservoir, and releases of water from Fort Loudoun Dam on the main body of the reservoir along the Tennessee River. Melton Hill Reservoir is located upstream of Melton Hill Dam, and releases water into Watts Bar Reservoir 4.1 mi upstream of the CRN Site. The Fort Loudoun Dam also releases water into Watts Bar Reservoir. Therefore, operations of both Melton Hill Dam and Fort Loudoun Dam can affect water levels and other characteristics on Watts Bar Reservoir. River flow direction at the CRN Site can be upstream, downstream, or quiescent, depending on the modes of operation of Melton Hill Dam, Watts Bar Dam, and Fort Loudoun Dam. For example, a flow reversal (upstream river flow) may occur from an abrupt shutdown of Melton Hill and Watts Bar Dams and by releasing water from Fort Loudoun Dam. (Reference 5.2-3)

The current operating policy of the Tennessee Valley Authority (TVA) river system, implemented in 2004, is defined by the TVA Reservoir Operations Study (ROS) (Reference 5.2-4). The daily average releases from Melton Hill Dam for 2004 through 2013 are shown in Figure 2.3.1-5. For this period, the overall average release from Melton Hill Dam, and consequently the expected approximate average river flow past the CRN Site during operations, is about 4670 cubic feet per second (cfs), equivalent to 2,095,896 gallons per minute (gpm). The maximum Melton Hill Dam daily average release observed for this period is about 21,700 cfs. The minimum single-day average release may be 0 cfs. The ROS guideline for the minimum daily average release over a 48-hour period from Melton Hill Dam is 400 cfs. The ROS guideline minimum daily average has been maintained since 2008, and, as discussed in Subsection 3.4.2.5, is ensured during SMR operations by installation of a continuous flow outlet (bypass) at Melton Hill Dam.

5.2.1.1.2 Groundwater

A description of the hydrogeological setting of groundwater in the vicinity of the CRN Site is presented in Subsection 2.3.1.2. The CRN Site is surrounded on three sides by the Clinch River arm of the Watts Bar Reservoir, which is likely to be the discharge area for CRN Site groundwater. The most likely pathway for groundwater flow is recharge in the upland areas with discharge to the Clinch River arm of the Watts Bar Reservoir. An alternate groundwater pathway is recharge in the upland areas with seepage to onsite drainages and surface water discharge into the Clinch River arm of the Watts Bar Reservoir. Natural discharge of the Valley and Ridge Province aquifers is primarily through streams, rivers, and springs. In the area of the CRN Site, the Clinch River arm of the Watts Bar Reservoir acts as a sink to which all groundwater migrates. Groundwater recharge is derived primarily from precipitation. Although periodic recharge from the Clinch River arm of the Watts Bar Reservoir during high stages of the reservoir may also be occurring, this is not considered to represent a significant part of the recharge to the aquifer.

5.2.1.2 Impacts of Facility Operations on Hydrology

5.2.1.2.1 Surface Water

Facility operations that could cause hydrological alterations to surface water include consumptive use of water from the reservoir, modification of shoreline stability, modification of wetlands or marshes by artificial fill, discharge of stormwater, and modification of flow or sedimentation characteristics as a result of Circulating Water System (CWS) intake and discharge flows.

The proposed water supply for makeup water to the CWS is surface water from the Clinch River arm of Watts Bar Reservoir. The water use from the reservoir is discussed in Section 3.3 and shown in Figure 3.3-1. The proposed intake withdraws an average of approximately 18,423 gallons per minute (gpm), and a maximum of approximately 30,708 gpm. Of this total, approximately 17,078 gpm average (approximately 25,608 gpm maximum) serves as makeup water for the CWS for the surrogate plant cooling towers. The proposed mechanical draft cooling towers consume some of this water through evaporation and drift. The average and maximum drift rate is 8 gpm, and the both the average and maximum evaporation rate is 12,800 gpm. For further explanation, see Subsection 3.4.1.4 for a discussion of average and maximum drift and evaporation rates. Of the water intake, 1345 gpm average (5100 gpm maximum) is directed to the plant and facilities, from which it is distributed to various auxiliary systems. The consumptive uses of water within these systems is negligible. The total blowdown rate for water which is proposed to be discharged to the holding pond from the CWS and auxiliary systems is an average of 4270 gpm, and a maximum of 12,800 gpm. Water from miscellaneous raw water uses, miscellaneous demineralized water users, and fire protection system is also discharged to the holding pond at an average rate of 445 gpm (maximum of 4200 gpm). Water from the holding pond along with water from the liquid radwaste treatment system is returned to the Clinch River arm of the Watts Bar Reservoir at an average rate of 5615 gpm and a maximum rate of 17,900 gpm.

Based on the average water withdrawal rate of 18,423 gpm discussed in the previous paragraph, and the average flow rate of 2,095,896 gpm in the portion of the reservoir adjacent to the CRN Site, the facility withdraws approximately 0.9 percent of the flow within the reservoir. Of this, the consumptive use of water is an average and a maximum of 12,808 gpm, which represents approximately 0.6 percent of the average flow rate. In the most conservative scenario, with a maximum water withdrawal rate of 30,708 gpm and a minimum daily average release of 400 cfs (179,520 gpm) from Melton Hill Dam, the facility withdraws approximately 17 percent of the daily average flow in the portion of the reservoir adjacent to the CRN Site, and approximately 7 percent of the daily average flow is consumed.

Considering Watts Bar Reservoir as a whole, these estimates are conservative, because the water released from Melton Hill Dam is not the only source of water for the reservoir. The Tennessee River below Fort Loudoun Dam comprises the main body of Watts Bar Reservoir and supports a much larger conveyance than that of the Clinch River arm of the reservoir. For example, for 2004 through 2013, the overall average release from Fort Loudoun Dam is about 18,310 cfs (compared to 4670 cfs for Melton Hill Dam). By comparison, the expected maximum consumptive use of water at the CRN Site, about 12,808 gpm (28.5 cfs), is essentially inconsequential compared to the combined average conveyances from Melton Hill Dam and Fort Loudoun Dam (0.1 percent). As such, hydrologic impacts of water consumption at the CRN Site on the overall flow and pool levels in Watts Bar Reservoir would be SMALL

As shown on Figure 3.4-3, the proposed intake system is constructed on the shoreline of the reservoir, along a length of approximately 50 feet (ft). Removal of sediment to maintain the intake during operations would be of a smaller scale than the shoreline excavation required for construction. In addition, removal of sediment to maintain the intake would be conducted following the same monitoring and consultation requirements as shoreline excavation during construction.

As discussed in Subsection 2.4.2.1.3, there are four perennial streams other than the Clinch River arm of the Watts Bar Reservoir, one intermittent stream, and 19 ephemeral steams/wet-weather conveyances (WWCs) on the CRN Site (Figure 2.4.1-2; (Reference 5.2-5)).

As discussed in Subsection 4.3.2.1, the current footprint of the planned permanent facilities would directly impact one small perennial stream (S01) and six WWCs (Figure 2.4.1-2 and Figure 4.3-1). Stream S01 is within the area to be occupied by the cooling water intake and the pipeline from the intake to the CR SMR Project. Impacts from intake and pipeline installation potentially would result in the permanent loss of the entire length of stream S01, approximately 925 ft of stream. Stream S01 is a small tributary to the Clinch River arm of the Watts Bar Reservoir. It is fed by a spring and small pond (P04) and flows through a small wetland (W008). Stream S01 is expected to be subject to the U.S. Army Corps of Engineers (USACE) jurisdiction. A biological survey of S01 in 2015 sampled the stream's entire length and found no fish and only a few small crayfish. (Reference 5.2-6) The WWCs located on the CRN Site are ephemeral drainages that flow only in response to precipitation runoff and do not support communities of aquatic organisms. The USACE has not made a final jurisdictional determination concerning the WWCs.

Given the small size of these features, permanent removal would not result in substantial hydrological impacts. The impacts to the stream would be further reduced by mitigation that likely would be required in accordance with USACE guidelines. In addition, the hydrologic function of these features in conveying stormwater from the CRN Site would be incorporated into the stormwater management system for the CRN Site.

There are currently stormwater runoff/collection ponds and associated piping on the CRN Site remaining from the Clinch River Breeder Reactor Project. Modifications to these ponds and piping would be made, as needed, to support the CR SMR Project. Stormwater would be managed in accordance with a site-specific Integrated Pollution Prevention Plan (IPPP). Stormwater best management practices are employed in the IPPP to prevent or minimize the discharge of pollutants with stormwater in accordance with all relevant permits and licenses such as the National Pollutant Discharge Elimination System (NPDES) industrial stormwater permit.

The proposed technology for the discharge is a submerged, bottom-mounted multiport diffuser. The basic diffuser design includes circular conduits aligned approximately perpendicular to the daily average flow in the river. The diffusers contain circular outlet ports situated in the upper, downstream quadrant of the diffuser conduits. The velocity of the flow discharging from the ports typically varies between approximately 8 and 10 ft per second. This diffuser technology is used at TVA nuclear power plants. The diffuser design meets objectives of maximizing thermal and chemical mixing while limiting local scour and the possible formation of problematic water velocities and flow patterns in the reservoir.

5.2.1.2.2 Groundwater

There are no facility operations that could cause hydrogeological alterations to groundwater. There is no proposed withdrawal of groundwater for use during operations. The impacts of dewatering during construction were discussed in Subsection 4.2.1.2, and were found to be SMALL. Any additional dewatering required during operations would be expected to be of a smaller scale than that required for construction. As discussed in Subsection 2.3.1.2.2.1, because surface water is abundant in the area, U.S. Environmental Protection Agency's (EPA) Sole Source Aquifer Program has not identified any sole source aquifers in Tennessee, and therefore there is no potential to impact Sole Source Aquifers. Based on these factors, operational impacts to groundwater hydrogeology would be SMALL.

5.2.1.3 Sufficiency of Water Supply for Facility Operations

5.2.1.3.1 Surface Water

As discussed in Subsection 5.2.1.2.1, the proposed facility withdraws an average of 0.9 percent of the average flow rate within the portion of the reservoir adjacent to the CRN Site. Of this, the most conservative scenario results in a consumptive use of approximately 7 percent of the minimum release from Melton Hill Dam. These are conservative estimates, as the water released from Melton Hill Dam is not the only source of water for the Watts Bar Reservoir. Although the continuous minimum release rate of 400 cfs from Melton Hill Dam is intended to ensure mixing of the thermal plume from the SMR, it is not necessary to provide adequate water supply for the SMR intake. Therefore, the Clinch River arm of the Watts Bar Reservoir has sufficient water available to support facility operations.

5.2.1.3.2 Groundwater

Because there is sufficient availability of surface water and no proposed use of groundwater, there are no impacts related to availability of groundwater for facility operations.

5.2.2 Water Use Impacts

This subsection presents an analysis of the water use impacts of SMR operation. These include the impact of operational water use on the availability of water for other users, and the impact of operations on water quality which could affect the use of that water by other users.

5.2.2.1 Water Availability

5.2.2.1.1 Surface Water

As discussed in Subsection 5.2.1.2.1, proposed facility operations require withdrawal of surface water to support the CWS and other plant systems. A portion of that water is consumed through evaporation and drift from the CWS, resulting in a localized net loss of water from the Clinch River arm of the Watts Bar Reservoir, and a regional net loss of water from the Tennessee River watershed. This net loss was evaluated for the potential to reduce the amount of water available to other users, including municipal and industrial users, recreational and navigational purposes, and aquatic ecology.

To evaluate the availability of water to support facility operations and potential impacts on other users, a Regional Surface Water Use Study was performed. Basin-wide water use was discussed in Subsection 2.3.2.1.1, and water use in the vicinity of the CRN Site was discussed in Subsection 2.3.2.1.3.

Potential local impacts to water availability on the Clinch River arm of the Watts Bar Reservoir, and in the Watts Bar Reservoir as a whole, were discussed in Subsection 5.2.1.2.1. That analysis demonstrated that the facility withdraws approximately 0.9 percent of the flow within the reservoir, and consumes approximately 0.6 percent of the average flow rate. In the most conservative scenario, the facility withdraws approximately 17 percent of the daily average flow in the portion of the reservoir adjacent to the CRN Site, and approximately 7 percent of the daily average flow is consumed. Based on this analysis, Subsection 5.2.1.2.1 concluded that hydrologic impacts of water withdrawal and consumption at the CRN Site on overall flow and pool levels in Watts Bar Reservoir would be SMALL. Because the hydrologic impact of water withdrawal and consumptive use of overall flow and pool levels would be SMALL, the impact on other local water users in the reservoir would also be SMALL.

Surface water is the primary water supply source for approximately 98.3 percent of the users in the Tennessee Valley watershed, including regional surface water users (Reference 5.2-3). Table 2.3.2-1 shows historical off-stream water use in the Tennessee River watershed from 1995 to 2010 and projected water use to 2035. Total water use peaked in 2005 and has decreased since then, mostly due to decline in water use for cooling at thermoelectric power plants.

TVA’s current reservoir operating policy was designed to meet the off-stream water needs of the Tennessee Valley out to the year 2030. The forecast of 2030 water needs was based upon a water use estimate prepared using year 2000 data. The estimates used to develop the reservoir operating policy were a total withdrawal in 2030 of 13,990 million gallons per day (mgd) (21,647 cfs) with a return of 13,010 mgd (20,131 cfs), for a net water demand of 980 mgd (1516 cfs). For the portion of the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site, the assumption used for the operating plan development was a net water demand 63 mgd (97 cfs) for 2030. (Reference 5.2-3)

As shown in Table 2.3.2-1, total water withdrawals are projected to decline approximately 21 percent by 2035. The current projection of water demand for the watershed for 2035 indicates a total withdrawal of 9449 mgd with a return of 8737 mgd, for a net water demand of 712 mgd. By category, water withdrawals are projected to change as follows: industrial withdrawals increase 31 percent to 1502 mgd, public supply withdrawals increase 30 percent to 938 mgd, and irrigation withdrawals increase 35 percent to 46 mgd. The 31 percent decline in thermoelectric water withdrawal is projected based on the anticipated retirement of older power plants, which utilize once-through cooling, and the introduction of new plants using closed-cycle cooling. The current 2035 net water demand projection for the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site is 26 mgd. (Reference 5.2-3)

The proposed SMR withdraws an average of 26 mgd (40 cfs) (44 mgd [68 cfs] maximum), which would increase the current projected total withdrawal within the Tennessee River Watershed to

9475 mgd (14,661 cfs) (9493 mgd [14,698 cfs] maximum). The proposed SMR withdrawal represents approximately 0.27 percent (0.46 percent maximum) of the current projected total withdrawal within the Tennessee River Watershed. The projected maximum consumptive water use from the CRN Site is 18 mgd (28 cfs). This increases the estimated projected net water demand to 730 mgd (1130 cfs) within the watershed and to 44 mgd (68 cfs) for the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site.

This proposed increase of net water demand represents approximately 2.5 percent of the current projected net water demand in the Tennessee River watershed. Both of these revised projections are within the initial projection estimates that were used in the development of TVA's reservoir operation system policy. Based on the above, the potential impacts of operation on other surface water users, both locally in the Clinch River watershed and regionally in the Tennessee River watershed, would be SMALL.

5.2.2.1.2 Groundwater

Groundwater is not used for safety-related systems or non-safety-related water supply purposes at the proposed CR SMR Project. There are no anticipated facility operation impacts to local groundwater resources (Reference 5.2-3).

5.2.2.2 Water Quality

As discussed in NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants Rev. 0, surface water quality impacts could occur from the concentration and discharge of chemicals added to the recirculating cooling water to prevent corrosion and biofouling, or from elevated temperatures in the discharge. The thermal impacts of the discharge are discussed in detail in Section 5.3. The other water quality impacts are discussed in this subsection.

Although cooling towers are considered to be closed-cycle cooling systems, concentrations of dissolved salts accumulate in the circulation system as a result of evaporative water loss. To maintain proper cooling, a certain percentage of the mineral-rich stream (blowdown) must be discharged and replaced with fresh water (makeup). In addition, cooling tower water chemistry must be maintained with anti-scaling compounds and corrosion inhibitors because cooling towers concentrate solids (minerals and salts) and organics that enter the system in makeup water. Similarly, a biocide must be added to the system to prevent the growth of fouling bacteria and algae.

The facility's wastewater discharges would be regulated by the Tennessee Department of Environment and Conservation (TDEC) through a NPDES permit. The anticipated constituents and their concentrations in the facility's non-radioactive liquid waste discharges are provided in Table 3.6-1, and the average and maximum flow rates for the discharges are discussed in Section 3.4 and Subsection 3.6.3.2. An NPDES permit includes discharge limits established to protect receiving waters, and monitoring to ensure compliance with those limits. Temperatures and chemical concentrations for all discharges would be in compliance with the terms and conditions of the NPDES permit. Biocides and chemicals used for water treatment are added in part per million concentrations, are used in accordance with a TDEC-approved Biocide/Corrosion Treatment Plan, and are largely consumed serving their purposes. TDEC takes the potential for these substances being in the discharge into consideration when establishing requirements for appropriate chemical parameter monitoring and acceptable limits in the NPDES permit. Therefore the impact from these discharges would be SMALL.

As shown in Figure 3.3-1, the projected blowdown flow rate for normal facility operations is an average of 4270 gpm, and a maximum of 12,800 gpm. An additional 445 gpm (average) and 4200 gpm (maximum) are discharged from miscellaneous power plant systems and fire protection system and 900 gpm (average and maximum) are discharged from the liquid radioactive waste system. The total discharge flow rate from the facility to the Clinch River arm of the Watts Bar Reservoir is 5615 gpm (average) and 17,900 gpm (maximum).

Subsection 2.3.1.1.2.4 presents the historical flow rate information for the Clinch River arm of the Watts Bar Reservoir. The release of water from Melton Hill Dam is the main source of water for flow in the Clinch River arm of the Watts Bar Reservoir at the CRN Site. The daily average releases from Melton Hill Dam for 2004 through 2013 are shown in Figure 2.3.1-5. For this period, the overall average release, and consequently the expected approximate average reservoir flow past the CRN Site, is approximately 4670 cfs. The minimum daily average release is 0 cfs. However, the development of the CR SMR Project includes implementation of a bypass structure at Melton Hill Dam to ensure a continuous release of at least 400 cfs.

On average, the CRN plant discharge is about 0.3 percent of the expected average reservoir flow past the plant, and about 3 percent of the minimum release from Melton Hill Dam. In the most conservative scenario, the maximum plant discharge represents about 10 percent of the reservoir flow past the plant when the maximum discharge occurs coincidentally with the minimum daily average release from Melton Hill Dam. However, even in this conservative situation, the characteristics and constituents of the plant discharge still are proposed to be managed within the water quality criteria specified in the plant NPDES permit. As such, water quality impacts would be SMALL.

5.2.3 References

Reference 5.2-1. Tennessee Valley Authority, "Watts Bar Reservoir Land Management Plan, Panel 4 Map," February, 2009.

Reference 5.2-2. Tennessee Valley Authority, Watts Bar Reservoir Website, Website: http://www.tva.com/sites/wattsbarres.htm, 2015.

Reference 5.2-3. Tennessee Valley Authority, "Clinch River Small Modular Reactor Site Regional Surface Water Use Study - Revision 2," April 24, 2015.

Reference 5.2-4. Tennessee Valley Authority, "Programmatic Environmental Impact Statement, Reservoir Operations Study," May, 2004.

Reference 5.2-5. Howard, Charles S., Henderson, Andrew R., and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Evaluation of Aquatic Habitats and Protected Aquatic Animals Technical Report - Revision 4," Tennessee Valley Authority, November 20, 2015.

Reference 5.2-6. Henderson, Andrew R. and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Stream Survey Report - Revision 2," Tennessee Valley Authority, November 20, 2015.

5.3 COOLING SYSTEM IMPACTS

Section 5.3 describes the range of impacts on the environment and human health from the operation of the Clinch River (CR) Small Modular Reactor (SMR) Project cooling system. The cooling system includes the cooling water intake system (Subsection 5.3.1), the cooling water discharge system (Subsection 5.3.2), and the system for discharging heat to the atmosphere (Subsection 5.3.3). In addition to the evaluation of physical and ecological impacts from these three components, impacts to public health are evaluated (Subsection 5.3.4) based on potential effects from microorganisms and noise.

5.3.1 Intake System

The design of the cooling water intake structure is described in Subsection 3.4.2.1. The hydrodynamic and physical impacts from operation of the intake structure are described in Subsection 5.3.1.1. The impacts on aquatic ecosystems from operation of the intake are described in Subsection 5.3.1.2.

5.3.1.1 Hydrodynamic Description and Physical Impacts

The proposed location of the intake structure is on the shoreline of the Clinch River arm of the Watts Bar Reservoir at approximately Clinch River Mile (CRM) 17.9. As discussed in Subsection 3.4.2.1, the intake structure is proposed to be a common intake for all SMRs and contain pumps, trash racks, and appropriate water screen technology to minimize effects on aquatic biota. The front face of the structure is to be located at the existing river bank. The river bank is to be excavated to provide a short intake channel, approximately 50 feet (ft) wide, to ensure sufficient water depth to provide water under conditions of low flow (Figures 3.4-2 and 3.4-3).

Hydrological conditions in the reservoir adjacent to the Clinch River Nuclear (CRN) Site are discussed in Subsections 5.2.1.1.1 and 5.2.1.2.1. On the average, the design withdrawal rate for the facility is approximately 0.9 percent of the average flow rate in the portion of Watts Bar Reservoir adjacent to the CRN Site. In the most conservative scenario, assuming a maximum water withdrawal rate by the plant and a minimum release from Melton Hill Dam (400 cubic feet per second [cfs]), the facility withdrawal rate would be approximately 17 percent of the daily average reservoir flow past the plant. Considering all of Watts Bar Reservoir, these estimates are conservative because the water released from Melton Hill Dam is not the only source of water for the reservoir. The Tennessee River below Fort Loudoun Dam comprises the main body of Watts Bar Reservoir and supports a much larger conveyance than that of the Clinch River arm of the Watts Bar Reservoir. Based on a comparison of the volume of water to be withdrawn by the CRN facility and the overall volume of water available in Watts Bar Reservoir, CRN facility operations would not significantly affect water levels or flow rates within the reservoir.

As discussed in Subsection 3.4.2.1, the maximum intake inlet velocity, trash rack flow-through velocity, and water screens flow-through velocity are to be designed to be less than 0.5 ft per second (s), in accordance with Clean Water Act (CWA) Section 316(b) regulations for protection of aquatic life. As discussed in detail in Subsection 5.3.1.2, this intake velocity is sufficiently low so that the majority of fish or other swimming organisms can avoid being trapped on the intake screens. Given the limited intake velocities and flow rates, the withdrawal zone created by the intake is expected to be weak and limited to the area immediately in front of the intake structure.

CWA Section 316(b) also requires that “for cooling water intake structures located in a lake or reservoir, the total design intake flow must not disrupt the natural thermal stratification or turnover pattern (where present)…” (40 CFR 125.84) As discussed in Subsection 2.3.1.1.2.7, a daily thermal gradient was documented in summer due to surficial warming during the hottest time of the day. However, the warmer surface water was then either flushed out by daily dam releases from Melton Hill Dam or its heat dissipated with nighttime atmospheric cooling. As a result, there is no established thermal stratification or stable thermocline to be disrupted in this reach of this reservoir. In addition, as discussed in Subsection 3.4.2.5, releases from Melton Hill Dam are currently episodic, occurring for only one hour each day. Once the project is operational, a bypass will be added to Melton Hill Dam to provide a continuous release of 400 cubic feet per second (cfs). As a result, there will be continuous flushing of the reservoir and greater mixing during all seasons. Therefore, any short-term diurnal stratification that is currently present would not be present once the project is operational.

As discussed in Subsection 5.2.1.2.1, the design intake flow for the facility is approximately 0.9 percent of the average flow in this portion of the reservoir. Therefore, the withdrawal by the intake of such a small proportion of water in a localized area of this large reservoir would not be expected to noticeably alter thermal patterns. There is no stable thermocline or substantial turnover pattern to be disrupted in this relatively shallow and well-mixed reach of the reservoir. In addition, as discussed in NUREG-1437, Revision 1 (2013), the U.S. Nuclear Regulatory Commission (NRC) has found that effects on thermal stratification in lakes at operating nuclear power plants are limited to the areas in the vicinity of the intake and discharge structures, and the NRC determined that these impacts have been SMALL.

For reasons discussed above, physical impacts from operation of the intake structure, including bottom scouring, induced turbidity, silt buildup, and alteration of thermal stratification patterns, are not expected to be significant. Therefore, hydrodynamic and physical impacts of water withdrawals during SMR operations would be SMALL.

5.3.1.2 Aquatic Ecosystems

This subsection discusses the potential impacts on the aquatic community of the Clinch River arm of the Watts Bar Reservoir from the operation of the intake structure for the CR SMR Project. The ecological characteristics of the potentially affected reservoir community adjacent to the CRN Site are described in Section 2.4. The operation of the cooling system and its use of the reservoir as the source of makeup water are described in Subsections 5.2.1.2.1 and 5.3.1.1. As noted in Subsection 5.3.1.1, operation of the CRN facility would not significantly affect water levels or flow rates in the reservoir. Thus, aquatic ecosystems and associated riparian habitats of the floodplain would not be affected by hydrological changes from facility operation.

For aquatic resources, the primary concerns related to the water intake are impacts associated with the relative amount of water drawn from the Clinch River arm of the Watts Bar Reservoir and the potential for organisms to be impinged on the intake screens of the intake structure or entrained within the circulating water system (CWS). Impingement occurs when organisms are trapped against the intake screens by the force of the water passing through the intake structure. Impingement can result in starvation, exhaustion, asphyxiation (water velocity forces may prevent proper gill movement or organisms may be removed from the water for prolonged periods of time), descaling, and other physical injuries. Entrainment occurs when organisms are incorporated into the intake water flow and drawn through the intake structure into the CWS. Organisms that become entrained normally are relatively small forms that float or swim freely in the water column, including plankton and early life stages of fish. As entrained organisms pass through the cooling system, they are subject to mechanical, thermal, and toxic stresses that often are lethal. (Reference 5.3-1)

As discussed in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, U.S. Nuclear Regulatory Commission (NRC) has determined that entrainment and impingement of fish and shellfish has not been a problem at operating nuclear facilities with cooling towers. This is due to the relatively low rates of water withdrawal required by facilities that utilize cooling towers in a closed-cycle cooling system. NRC did not identify any operating nuclear power plants with cooling towers operated in closed-cycle mode that reported reduced populations of aquatic organisms due to entrainment and impingement. Accordingly, NRC concluded that the effects of entrainment and impingement of aquatic organisms at nuclear facilities with a closed-cycle, cooling-tower-based heat dissipation system would be SMALL.

Closed-cycle, recirculating, cooling-water systems using fresh water can reduce water withdrawals by 96 percent to 98 percent of the amount that the facility would withdraw if it employed a once-through cooling system (Reference 5.3-1). This substantial reduction in water withdrawal capacity results in a corresponding reduction in entrainment and impingement of aquatic organisms.

The data from the U.S. Environmental Protection Agency (EPA) impingement studies suggested that a through-screen velocity of 0.5 feet per second (ft/s) would protect 96 percent of the fish tested. (Reference 5.3-1) The intake structure for the CR SMR Project is to be designed in accordance with Section 316(b) to limit through-screen velocity to no more than 0.5 ft/s and minimize the impact of the intake system on aquatic organisms. Thus, the design and construction of the intake structure is expected to prevent the impingement of the majority of fish or other swimming organisms that may come into contact with the intake structure.

The hydrological and ecological characteristics of the Clinch River arm of the Watts Bar Reservoir are additional factors limiting the potential for cooling system impacts on aquatic organisms from entrainment and impingement. As discussed in Subsection 5.2.1.2.1, based on the expected average water withdrawal through the intake structure, the design withdrawal rate for the facility is only approximately 0.9 percent of the annual average flow in the reservoir adjacent to the CRN Site. Under the most conservative scenario, based on the expected maximum withdrawal through the intake structure and a minimum daily average release from Melton Hill Dam, the facility withdrawal would be approximately 17 percent of the daily average flow in the reservoir adjacent to the CRN Site. Thus, the proportion of water withdrawn through the intake structure would be minimal under normal conditions and would be small even under the most conservative scenario. Also, the location of the intake structure on the shoreline of the reservoir is not near any known important spawning areas or other sensitive habitats. As discussed in Subsection 2.4.2, the reservoir adjacent to the CRN Site supports a community of relatively common species of aquatic organisms and is not known to provide habitat for listed species.

Subsection 2.4.2.1.1 includes a description of an investigation by Tennessee Valley Authority (TVA) in 2011 of ichthyoplankton in Watts Bar Reservoir adjacent to the CRN Site. The temporal occurrence, composition, and abundance of fish eggs and larvae in that part of the reservoir were characterized by data collected at an upstream location, immediately upstream of the location of the intake structure, and a downstream location.

The total numbers of fish eggs and larvae collected at the upstream and downstream locations and the percentage composition of the samples represented by each taxon are summarized in Table 2.4.2-3. The taxa identified in the samples are organized in the table by family. The families represented in the egg and larvae samples and the principal species from each family are discussed in Subsection 2.4.2.1.1. More than 53 percent of the eggs collected were from the freshwater drum (family Sciaenidae), followed by shad (Clupeidae), and temperate basses (Moronidae). More than 67 percent of the larvae collected were Clupeid species, followed by suckers (Catostomidae), temperate basses, sunfishes (Centrarchidae), and others contributing less than 2 percent (Table 2.4.2-3). The species abundance data were used with sample volume data to calculate species-specific densities of fish eggs and larvae in the water column. (Reference 5.3-2)

The data from the upstream location provide an indication of the ichthyoplankton densities at the proposed location of the intake structure. These density data are summarized in Table 5.3-1, which shows densities of fish eggs and larvae by family (in numbers/1000 cubic meter [m^3]) based on the locations across the channel where they were collected along the transect. The results are totaled and averaged for day and night and for a 24-hour (hr) period. The average annual density for a 24-hr period was 337.5 eggs/1000 m^3 and 91.0 larvae/1000 m^3. Thus, the average annual total density of both fish eggs and larvae for a 24-hr period was 428.5 organisms/1000 m^3.

This annual average total density was used with the average reservoir flow past the CRN Site and the average and maximum estimated water withdrawals through the intake structure to estimate the average and maximum rates of entrainment of fish eggs and larvae at the intake structure during operation of the CR SMR Project. The results predict an average entrainment rate of 0.88 percent and a maximum entrainment rate of 1.5 percent of the total number of fish eggs and larvae in the reservoir at the intake structure. This evaluation conservatively assumes that biotic entrainment equals hydraulic entrainment (calculated in Subsection 5.2.1.2.1 as an average of 0.9 percent) and does not account for any potential reductions in entrainment that may result from factors such as intake screens or larval behavior.

These results are consistent with the conclusion by NRC that the effects of entrainment of aquatic organisms at nuclear facilities with a closed-cycle, cooling-tower-based heat dissipation system are SMALL. Impingement would be minimized by the design of the intake structure. Entrainment of ichthyoplankton under normal conditions would be less than 1 percent, and it would not exceed 1.5 percent under the most conservative water withdrawal scenario. Based on the species present, the predominant fish eggs and larvae entrained would be common species. The minimal reductions in numbers of fish eggs and larvae associated with the operation of the intake structure would not reduce the populations of important species (listed species or those considered commercially or recreationally valuable) or of mussels that may depend on fish as hosts for their larvae. Based on the use of closed-cycle cooling, the proportion of water that would be withdrawn, the expected design and location of the intake, and the composition of the aquatic community, the impacts from entrainment, impingement, or other effects on fish and other organisms due to the operation of the cooling water intake system for the CR SMR Project would be SMALL.

5.3.2 Discharge System

This subsection describes the impacts of the discharge system during operation of the CR SMR Project. The hydrothermal discharge and its physical impacts are described in Subsection 5.3.2.1. The impacts on aquatic organisms from operation of the discharge are described in Subsection 5.3.2.2.

5.3.2.1 Thermal Discharges and Other Physical Impacts

The design of the discharge structure, described in Subsection 3.4.2.3, consists of a bottom-mounted, cylindrical, multi-port diffuser situated approximately perpendicular to the flow at approximately CRM 15.5. Plans are for ports located in the downstream, upper quadrant of the diffuser pipe to disperse the heated water into the flow of the reservoir. Discharges from the CR SMR Project will be permitted under the Tennessee Department of Environment and Conservation (TDEC) National Pollutant Discharge Elimination System (NPDES) program, which regulates the discharge of pollutants into waters of the state. Under NPDES regulations, waste heat is regarded as thermal pollution and is regulated, as are chemical pollutants.

Computer modeling was performed to evaluate the thermal effects of the discharge from the CR SMR Project on both a local and regional scale. The computer codes are commercially available software products which have been vetted by developers and are successfully applied on projects similar to the SMR project. The computer modeling simulated the geometry of the water body, the shapes of the SMR intake and discharge structures, the reservoir flow conditions, and the intake and discharge rates, to reproduce the transport and movement of mass, momentum, and thermal energy in the reservoir. The modeling included consideration of viscosity, buoyancy, flow advection, turbulent diffusion, and other physical parameters, and included site-specific calibration against actual field measurements.

The local-scale analysis focused on thermal effects in the immediate vicinity of the SMR discharge and included a computational model spanning the reach of reservoir from about CRM 13.5 to CRM 21.0. The regional-scale analysis focused on thermal effects in Watts Bar Reservoir at locations farther away from the SMR site. Of particular interest are potential impacts in the portion of the reservoir near the confluence of the Clinch River and Emory River (e.g., to assess potential impacts on the Kingston Fossil Plant), and the reach of the reservoir near the confluence of the Clinch River and the Tennessee River (e.g., to assess potential impacts on the main body of the reservoir). The regional-scale analysis included a computational model encompassing all of Watts Bar Reservoir.

Local-scale modeling was initially performed to evaluate alternatives for managing the SMR blowdown. The results of the analysis of those alternatives are presented in Subsection 9.4.2.2.2. The two preferred alternatives from the initial analysis each required installation of a new low-level outlet structure at Melton Hill Dam. The purpose of the bypass is to provide a continuous, minimum release from the dam during periods of idle operation of the existing hydroelectric generating units at the dam. With the bypass, sufficient flow is provided in the Clinch River arm of the Watts Bar Reservoir at all times to assimilate blowdown from the CR SMR Project. The hydrothermal impacts of the CR SMR Project discharge are the same for both preferred alternatives; the only difference being in the type of hydraulic equipment used to control the bypass release from the dam. The initial analysis was based on a preliminary estimate of 3944 gallons per minute (gpm) for the SMR blowdown flowrate and a bypass flow rate of 200 cfs. Following further development of the plant parameter envelope (PPE), provided in Tables 3.1-1 and 3.1-2, a supplemental analysis of the preferred alternatives was performed. The supplemental analysis was based on a blowdown flow rate of 12,800 gpm and a bypass flow rate of 400 cfs.

The baseline temperature of water in the Clinch River arm of the Watts Bar Reservoir is summarized in Subsection 2.3.1.1.2.7. The flow conditions in the reservoir are summarized in Subsections 2.3.1.1.2.4 and 2.3.1.1.2.6. The local-scale analysis was conducted for both steady and unsteady flow conditions. As discussed in Subsection 2.3.1.1.2.4, flow rates and directions in the Clinch River arm of the Watts Bar Reservoir are a function of the relative release rates from Melton Hill, Fort Loudoun, and Watts Bar Dams. Although the Reservoir Operations Study (ROS) operating policy for Melton Hill Dam requires a minimum daily average release rate of 400 cfs, this may be achieved with a very short (less than 1 hr) period of operation of the hydro generating units at the dam, followed by up to 46 hr of no water release, before water is again released for another short period of operation. As discussed in Subsection 2.3.1.1.2.6, this manner of operation can lead to reversal of flow direction, or sloshing, of the reservoir. To address this behavior, the local-scale modeling analysis also examined the assimilation of the blowdown from the SMR plant for unsteady conditions in the Clinch River arm of Watts Bar Reservoir created by infrequent operation of the existing hydro units at Melton Hill Dam.

In the supplemental analysis, for the steady, minimum flow situation, the thermal plume from the SMR diffuser was evaluated using CORMIX, a water quality model used to assess and perform environmental impact assessment of mixing zones resulting from wastewater discharges from point sources. Modeling was conducted to evaluate worst-case scenarios under both extreme winter conditions and extreme summer conditions while the CRSMR Project is operating at 100 percent power (800 megawatts electric [MWe]). The steady flow rate was assumed to be 400 cfs, corresponding to the minimum daily average release from Melton Hill Dam as specified by the TVA ROS operating policy. The results suggest that for steady flow in the reservoir at or above 400 cfs, the thermal effluent from the SMR plant under PPE conditions could be assimilated within regulatory limits at a minimum distance of 50 ft from the diffuser.

For regulatory limits enforced on an hourly basis, the mixing zone for the diffuser discharge needs to be large enough to capture unsteady events wherein the thermal plume from the SMR billows laterally and upstream during sloshing events. To evaluate the thermal plume for these conditions, the model for local-scale analyses is capable of simulating the three dimensional, unsteady behavior of the SMR thermal discharge in the reservoir. The computational domain for the local-scale model included the natural geometry of the Clinch River arm of the Watts Bar Reservoir between approximately CRM 13.5 and CRM 21.0 (7.5 miles [mi]). The model inputs include the bathymetry of the reservoir and the basic configurations of the CR SMR Project intake and diffuser, as well as time histories for the ambient flow and temperature in the reservoir and the flow and temperature of the SMR blowdown.

In the supplemental analysis, two of the unsteady scenarios analyzed using the local-scale model included the behavior of the thermal plume for operation of the CR SMR Project at full power under extreme winter conditions and under extreme summer conditions. In terms of reservoir flow, operating conditions of Watts Bar Reservoir leading to perhaps the most challenging conditions for assimilation of the SMR thermal discharge are an extreme winter event and an extreme summer event, respectively, as presented in Figures 5.3-1 and 5.3-2. These diagrams show the flow rates from Melton Hill Dam (MHH), Watts Bar Dam (WBH), and Fort Loudoun Dam (FLH), and the flow rate in the reservoir at the CR SMR Project discharge location through a representative 48 hr period. Figures 5.3-1 and 5.3-2 show that Melton Hill Dam releases water for power generation through the hydroelectric plant at approximately 5000 cfs for 1 hr at the beginning of the first day, then releases a continuous flow of 400 cfs (through the bypass), and then releases flow through the hydroelectric plant at approximately 5000 cfs again for 1 hr at the end of the second day. In both scenarios, the flow in the reservoir increases immediately in reaction to the higher release volume during the first 2 hr. Once the release from the hydroelectric unit is completed, the flow rate at the discharge drops, and by hour 3 it reverses, flowing upstream in the reservoir. In the winter scenario (Figure 5.3-1), the sloshing in the reservoir continues for approximately 24 hr, decreasing in magnitude throughout that period until the reservoir reaches a steady flow rate of 400 cfs in the downstream direction. In the summer scenario (Figure 5.3-2), the sloshing continues for almost the entire 48-hr period.

The reversal of flow in the reservoir temporarily reduces downstream dispersion and transport of the discharge from the CR SMR Project. This causes the thermal plume to occupy a wider area of the reservoir as it is transported laterally and upstream from the discharge during the reverse flow event.

The behavior of the thermal plume must comply with the general water quality criteria for the State of Tennessee, which are provided by TDEC. For effluent entering the reservoir from the SMR discharge, the water quality criteria at the boundary of the mixing zone require that:

- The maximum change in river water temperature (ΔTR) caused by the effluent shall not exceed 5.4 degrees Fahrenheit (°F) relative to an upstream control point.
- The maximum river water temperature (TR) caused by the effluent shall not exceed 86.9°F.
- The maximum water temperature-rate-of-change (TROC) in the river shall not exceed ±3.6°F/hr.

The hydrothermal modeling results for the CR SMR Project indicate that these regulatory limits would be approached only under worst-case conditions. Extreme winter conditions would challenge regulatory limits for the river temperature rise (ΔTR) and the river TROC. Extreme summer conditions would challenge regulatory limits for the maximum river TR.

Spatially, the criteria for water temperature would be applied along the boundaries of an instream mixing zone surrounding the plant discharge. The water quality criteria do not outline any detailed procedures as to how the size and shape of mixing zones should be defined. Under these circumstances, the exact dimensions of mixing zones typically are determined on a case-by-case basis using analyses and recommendations provided by the permittee. Beyond this, some guidelines for the size and shape of mixing zones can be found in regulatory literature and correspondence from EPA. EPA would review any NPDES permit for the CR SMR Project issued by TDEC.

Because of the oscillation of flow within the reservoir due to the unsteady flow conditions, the shape and extent of the thermal plume, and the magnitude of ΔTR, TROC, and maximum TR all change throughout the 48-hr flow cycles depicted in Figure 5.3-1 and Figure 5.3-2. For winter conditions, the point in time with the most extreme temperature impact is hour 13. From results of the local-scale model, the configuration of the thermal plume at hour 13 is shown in Figure 5.3-3, along with configurations at other points in time, as identified in Figure 5.3-1. The figure shows the distribution of the change in temperature from ambient conditions within the plume (ΔTR), as well as the average ΔTR calculated around the perimeter of a 150 ft diameter mixing zone. For summer conditions, the point in time when ΔTR, and subsequently TR, is perhaps the most extreme is hour 46. The configuration of the thermal plume at hour 46 is shown in Figure 5.3-4, along with the configuration at other points in time, as identified in Figure 5.3-1.

The analysis also evaluated the maximum upstream travel distance of the thermal plume in both extreme winter and summer conditions to verify that the plume likely would not reach the SMR intake in any measureable amount. Figure 5.3-5 shows the approximate zone of influence of the thermal plume during extreme winter conditions. The most extreme condition occurs at hour 6 of the 48-hr cycle. Figure 5.3-5 shows that the maximum upstream extent of the plume would be to approximately CRM 16.3, more than 1.5 mi downstream of the SMR intake. Figure 5.3-6 shows the approximate zone of influence of the thermal plume during extreme summer conditions. The most extreme condition occurs at hour 38 of the 48-hr cycle. Figure 5.3-6 shows that the maximum upstream extent of the plume would be to approximately CRM 16.6, approximately 1.3 mi downstream of the SMR intake.

The result of the supplemental local-scale simulations suggest that the blowdown from the CR SMR Project operating at full power requires not only a bypass flow of about 400 cfs from Melton Hill Dam, but also a mixing zone commensurate to a circular area with a diameter of approximately 150 ft. The actual mixing zone would be established during the NPDES permitting process and is therefore deferred to the combined license application (COLA). However, a significant portion (more than half) of the Clinch River arm of the Watts Bar Reservoir is expected to remain hydrothermally unobstructed, allowing for the passage of fish and other aquatic life even during the relatively infrequent periods of extreme operating conditions. Although regulatory requirements based on compliance at the boundary of a 150-ft diameter mixing zone are satisfied, local pockets of warm water can slosh into regions beyond the mixing zone. For extreme winter conditions, the temperature rise in these pockets can be high. For PPE bounding conditions in Table 3.1-2, these are considered to fall within the range of acceptability for thermal compliance because they are brief and provide a zone of passage for aquatic life. The results also indicate that the intake for the CR SMR Project is far enough upstream that there is essentially no threat of blowdown being recirculated into the intake.

To assess potential water quality and hydrothermal impacts of the CR SMR Project at a regional-scale, a CE-QUAL-W2 (W2) water quality model was developed for Watts Bar Reservoir. W2 is formulated to simulate the behavior of rivers and reservoirs with traits that vary primarily throughout the depth and in the direction of flow. The parameters of primary concern for the Watts Bar model include flow, stage, water temperature, dissolved oxygen (DO), and algae biomass. The model includes the main body of Watts Bar Reservoir, major tributary inflows, and industrial discharges that potentially have a significant impact on reservoir water quality, including the withdrawal and thermal discharge for the CR SMR Project.

The calibrated W2 models for 2004, 2008, and 2013 were used to conduct simulations of the effects of SMR operation on temperature, algae, and DO in the Clinch River and Tennessee River portions of Watts Bar Reservoir. These years were selected to represent a normal flow year (2004), a low flow year (2008), and a high flow year (2013). The year 2013 also represented a year in which data were available; preapplication studies of the reservoir were conducted in 2013 to support the SMR evaluation.

W2 modeling results were summarized at the 1.5 meters (m; 5 ft) depth, the normal monitoring depth required by TDEC. TDEC's criteria for the Fish and Aquatic Life stream classification (Rule 1200-04-03-.03) are stated as follows:

- DO: In lakes and reservoirs, the DO concentrations shall be measured at mid-depth in waters having a total depth of 10 ft or less, and at a depth of 5 ft in waters having a total depth of greater than 10 ft and shall not be less than 5.0 milligrams per liter (mg/L).
- Temperature: The maximum water temperature change shall not exceed 3 degrees Celsius (°C; 3°F) relative to an upstream control point. The temperature of the water shall not exceed 30.5°C (86.9°F) and the maximum rate of change shall not exceed 2°C (35.6°F)/hr. The temperature of recognized trout waters shall not exceed 20°C (68°F). There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions. The temperature in flowing streams shall be measured at mid-depth.
- The temperature of impoundments where stratification occurs will be measured at mid-depth in the epilimnion (see definition in Rule 0400-40-03-.04) for warm water fisheries and mid-depth in the hypolimnion (see definition in Rule 0400-40-03-.04) for cold water fisheries.
- A successful demonstration as determined by TDEC conducted for thermal discharge limitations under Section 316(a) of the CWA, (33 USC 1326) shall constitute compliance with this section.

TDEC's criteria for the Domestic Water Supply stream classification is stated as follows:

- Temperature: The maximum water temperature change shall not exceed 3°C (5.4°F) relative to an upstream control point. The temperature of the water shall not exceed 30.5°C (86.9°F) and the maximum rate of change shall not exceed ±2°C (±3.6°F)/hr. The temperature of impoundments where stratification occurs will be measured at a depth of 5 ft or mid-depth, whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

The results of the regional-scale modeling suggest that SMR effects would have de minimis impact on temperature, algae, and DO at sites further downstream in Watts Bar Reservoir. The modeling analyses suggest that the water temperature in these areas would perhaps be attenuated very slightly by the 400 cfs bypass at Melton Hill Dam (i.e., compared to the present conditions wherein there is no release).

In summary, hydrothermal modeling simulations were performed to evaluate impacts in the reservoir under various operational alternatives, including conditions with minimum, steady flow in the reservoir and conditions with unsteady flows in the reservoir. The results indicate that with a minimum steady flow of 400 cfs through the planned Melton Hill Dam bypass, the thermal effluent from the CR SMR Project operating under PPE conditions ideally could be assimilated within regulatory limits at a distance of about 50 ft from the diffuser. To allow for unsteady flow and PPE conditions, a mixing zone commensurate to a circular area of diameter of approximately 150 ft is expected to be sufficient. Because the discharge would be managed in accordance with requirements of the TDEC NPDES permit, and the modeling indicates compliance with the thermal water quality criteria, thermal impacts from operation of the CR SMR Project discharge would be SMALL, and mitigation beyond operation of the Melton Hill Dam bypass is not warranted.

5.3.2.2 Aquatic Ecosystems

Operation of the CR SMR CWS produces liquid effluent that is discharged to the Clinch River arm of the Watts Bar Reservoir and has thermal and chemical effects as described in Subsections 5.3.2.1 and 5.2.2.2, respectively. The majority of the waste heat produced by the SMRs would be discharged to the atmosphere through evaporation in the cooling towers. In a closed-cycle system, evaporation causes the accumulation of minerals in the water of the system. To limit this buildup of dissolved solids (minerals and salts), some water would be regularly removed from the system (blowdown) and replaced with makeup water from the reservoir. The discharge of this heated blowdown water can have thermal and chemical effects on biota in the receiving water body, the Clinch River arm of the Watts Bar Reservoir. This subsection discusses the potential impacts from the cooling water discharge on aquatic organisms in the reservoir. The ecological characteristics of the potentially affected reservoir community adjacent to the CRN Site are described in Section 2.4.

As discussed in NUREG-1437, Rev. 1, NRC has determined that thermal discharges from operating closed-cycle nuclear facilities with cooling towers have not been a problem with respect to heated effluents directly killing aquatic organisms. NRC studies also have evaluated other effects on biota resulting from cooling system discharges from operating closed-cycle nuclear facilities with cooling towers. The issues NRC evaluated included the following:

- Cold shock
- Thermal plume barriers to migrating fish
- Effects on the regional geographic distribution of aquatic organisms
- Premature emergence of aquatic insects
- Establishment and proliferation of nuisance species
- Low dissolved oxygen and gas supersaturation
- Accumulation of nonradiological contaminants in sediments or biota
- Exposure of aquatic organisms to radionuclides

For each of these issues, NRC determined that the effects of the cooling system discharge have been SMALL for operating closed-cycle nuclear facilities with cooling towers.

The results of the thermal discharge evaluation performed by TVA to evaluate the local and regional effects of the CR SMR Project discharge are consistent with the conditions assumed under NRC's evaluation. For example, as discussed in Subsection 5.3.2.1, modeling of the effects of the discharge from the CR SMR Project found that under worst-case conditions, the plant thermal effluent could be safely assimilated using a mixing zone commensurate to a circular area of diameter of approximately 150 ft. A 150-ft diameter mixing zone encompasses approximately 45 percent of the width of the Clinch River arm of the Watts Bar Reservoir in the area of the discharge, which leaves more than half of the width of the reservoir hydrothermally unobstructed for passage of fish. In extreme winter conditions, local pockets of warm water can slosh into regions beyond the mixing zone; however, these are of brief duration, and a zone of passage for fish would remain. Additional modeling was performed at a regional scale to evaluate the discharge in the context of the full extent of Watts Bar Reservoir, and it showed that the CR SMR Project discharge would have a negligible impact on temperature (outside of the area local to the mixing zone), algae, and dissolved oxygen in the reservoir. Accordingly, NRC's conclusions are applicable for the CRN Site, and the effects of the cooling system discharge would be SMALL.

Chemical impacts from the CR SMR Project cooling system discharge on water quality of the Clinch River arm of the Watts Bar Reservoir are discussed in Subsection 5.2.2.2. Because cooling towers concentrate minerals and salts as well as organic compounds that enter the system in makeup water, cooling tower water chemistry must be modified with the addition of anti-scaling compounds and corrosion inhibitors. Biocides are also added to the system to prevent the growth of bacteria and algae. It is anticipated that the facility's blowdown discharge would contain the nonradioactive liquid waste constituents and concentrations listed in Table 3.6-1. Radionuclides anticipated to occur in the discharge from the facility are discussed in Section 3.5 and listed in Table 3.5-1. The effluent from the liquid radioactive waste treatment system would be combined with the flow from the holding pond before entering the reservoir through the discharge structure. Chemical constituent levels in the cooling system discharge will be regulated by TDEC through an NPDES permit. The concentrations of constituents in the facility discharge would be limited by the NPDES permit to comply with state water quality standards for the protection of aquatic organisms.

On the basis of the NRC's determination of insignificant biological impacts associated with thermal discharges from operating closed-cycle nuclear facilities with cooling towers, the results of the modeling of the thermal plume from the discharge at the CRN Site, the regulation of the temperature effects of the discharge in accordance with requirements of the NPDES permit and CWA Section 316(a), and the regulation of the chemical concentrations in the discharge in accordance with requirements of the NPDES permit, impacts on aquatic organisms from operation of the CR SMR cooling water discharge would be SMALL.

5.3.3 Heat Discharge System

This subsection describes the impacts from operation of the heat-discharge system for the CR SMR Project. Subsection 5.3.3.1 discusses the physical effects from the transfer of heat to the atmosphere, and Subsection 5.3.3.2 discusses the potential for theses physical effects to impact terrestrial ecosystems.

5.3.3.1 Heat Dissipation to the Atmosphere

The cooling system design for the CR SMR Project includes linear mechanical draft cooling towers (LMDCT) for the transfer and dissipation of heat from SMR cooling water to the atmosphere. The planned LMDCT use circulating makeup water from the Clinch River arm of the Watts Bar Reservoir. Releases from cooling towers consist of a vapor plume that is visible when water vapor released from the towers condenses in cooler ambient air. Small water droplets associated with the towers' circulating water also are emitted and escape with the exhaust air. These droplets are referred to as drift and contain dissolved solids. Potential impacts from these releases on the CRN Site and immediate surroundings include:

- Aesthetics related to an elevated visible plume
- Ground level fogging and icing
- Deposition of dissolved solids in drift that escapes from the circulating water
- Cloud formation and shading
- Additional precipitation from the vapor plume
- An increase in humidity
- Interaction with other vapor plumes from existing sources in the vicinity of the CRN Site

Computer modeling of the CR SMR Project's LMDCT used the Electric Power Research Institute's (EPRI) Seasonal and Annual Cooling Tower Impact (SACTI) model for evaluating potential impacts to the CRN Site and its immediate surroundings. A description of the modeling and results of the study are presented below.

The SACTI model uses hourly meteorological data to calculate seasonal and annual impacts associated with the released vapor plume and drift deposition. Meteorological data used as input to the cooling tower model were from the CRN Site's meteorological monitoring program for the period from April 21, 2011 through July 9, 2013. Other SACTI model inputs include ceiling height and mixing height data, which were not collected as part of the onsite monitoring program. Ceiling height data used were from Lovell Field Airport in Chattanooga, as obtained from the National Climatic Data Center, which was determined to be the best source of available ceiling height data for the CRN Site. Mixing height data are not collected at all National Weather Service Stations. The Lovell Field Airport mixing height data are considered representative for the Appalachian Ridge and Valley Region of Tennessee. These data are provided by the EPA Support Center for Regulatory Atmospheric Modeling (SCRAM) database website for Tennessee. Ceiling height data used from Lovell Field were concurrent with the onsite meteorological data. The design of the facility's cooling towers is not yet final; thus, certain details, such as tower-specific performance curves and some design values, were not available. However, the current design for the CR SMR Project does use LMDCT. A representative set of cooling tower parameters was developed based on the required heat rejection for the CR SMR Project. Bounding cooling tower parameters were used where applicable. The representative data selected for the project's cooling tower evaluation were based on design parameters consistent with Case Study 1 of the SACTI User's Manual, as the heat rejection for Case Study 1 is similar to that of the CR SMR Project. SACTI Model Case Study 1 included two LMDCT with a total heat rejection of 1400 megawatts (MW). The CR SMR Project is designed for a total heat rejection of approximately 1640 MW. Where appropriate, cooling tower data for the project were prorated from the SACTI Model's Case Study 1 input data.

The cooling towers area on the site layout is located approximately 500 ft to the west of the power block area, at an elevation of approximately 810 ft above mean sea level (msl). The cooling towers are located 2950 ft (899 m) from the northern boundary of the CRN Site, 1400 ft (426 m) from the western boundary, 635 ft (193 m) from the southern boundary, and 2300 ft (701 m) from the eastern boundary. As shown in Table 3.1-2, Item 3.3.1, the design footprint of the cooling towers area occupies approximately 6 acres (ac).

Representative cooling tower parameters for the project are presented in Table 5.3-2. The modeled cooling tower configuration includes two towers consisting of nine cells each. Cooling tower cells are evenly spaced by 11.0 m. (Metric units are presented here to be consistent with the SACTI model input requirements.) Each tower modeled is 99.0 m long by 11.0 m wide. The release height of the cells above ground level is 19.8 m (65 ft, from Table 3.1-2, Item 3.3.8). The total cooling water flow rate would be up to 755,000 gpm (Table 3.1-2, Item 3.3.12). The circulating water system would operate at up to four cycles of concentration. Section 3.4 of this report provides additional information on the cooling system description, operating modes, and water intake and discharge characteristics.

Table 5.3-3 provides the drift droplet mass spectrum used for the SACTI modeling based on a Marley cooling tower, which is expected to have characteristics similar to the actual cooling towers that may be included in the eventual design. Excel drift eliminators are included to mitigate drift deposition and drift impacts. The two cooling tower housings were assumed to be 11.0 m apart, which is closer than the SACTI Model Case Study 1. Positioning the towers closer conservatively increases drift deposition by concentrating the releases from the towers. The cooling tower orientation was determined based on a sensitivity study of varying tower orientations and deposition rates. The sensitivity analysis demonstrated that an east-west lengthwise orientation generated the most conservative deposition rates.

Because the design of the cooling towers is not yet final, the density of total dissolved solids (TDS) in the CR SMR Project's cooling tower water is unknown. For the SACTI modeling, the TDS density was assumed equal to that of salt, 2.17 grams per cubic centimeter (gm/cm^3). This is considered an acceptable assumption given that an order-of-magnitude approach [in the SACTI Model] is utilized when analyzing depositions, so small differences in density are negligible with respect to the conclusions derived in the calculation." Other dissolved solids potentially found in the cooling water, such as ferric nitrate, ferric chloride, potassium nitrate, and magnesium nitrate are relatively comparable in density to salt.

SACTI modeling was performed using a polar receptor grid with radials at the 16 compass directions. Receptors along each radial were spaced at 10-m, 100-m, or 200-m increments depending on the parameter modeled. Modeling was conducted to evaluate the following:

- Groundlevel fogging and icing

- Additional precipitation and humidity
- Salt deposition
- Deposition of TDS
- Hours of plume shadowing
- Plume length frequencies

Results of the SACTI modeling are discussed below.

5.3.3.1.1 Groundlevel Fogging and Icing

Groundlevel fogging occurs when the visible vapor plume directly impacts groundlevel locations downwind of the tower. Icing is predicted under temperature conditions low enough for the freezing of plume water on groundlevel surfaces. The cooling tower analysis demonstrated that due to the relatively small size of these cooling towers in comparison to a cooling tower servicing a large power plant, and the temperature and climate of the area, there were no hours of fogging or icing calculated by the SACTI code at any distance from the towers. Therefore no fogging or icing impacts are expected on transportation areas around the CRN Site and impacts are categorized as SMALL.

5.3.3.1.2 Additional Precipitation and Humidity

Table 5.3-4 provides annual average water deposition rates from the SACTI model for distances out to 1000 m. The modeling predicted the greatest annual water deposition would occur at 100 m from the cooling towers for all directions. The greatest level of deposition on an annual average basis is 97,000 kilograms per square kilometer per month (kg/km2-mo), which occurs to the west of the towers. This value, which is equivalent to approximately 0.004 inches (in.) of water per month, is insignificant for the Oak Ridge area because the Oak Ridge National Weather Service Station reports approximately 3 in. of precipitation per month or more (Table 2.7.1-2). Thus, additional water deposition from the cooling towers would be negligible. No calculations for humidity levels are provided by the SACTI model. Some increase in relative humidity may occur close to the towers and in the elevated plume. However, with low levels of water deposition and no prediction of fogging or icing, impacts on groundlevel humidity are expected to be minimal. Based on this analysis, the effects of cooling tower operation on precipitation and humidity are expected to be SMALL.

5.3.3.1.3 Salt Deposition

The SMR project design includes efficient drift eliminators to mitigate the impacts of water droplets (drift) discharged from the top of the cooling towers. However, some water in the form of drift would still be discharged from the tower with the exhaust air. Once released, drift is carried downwind from the towers. Because drift consists of water originating from within the cooling towers, it has the same concentration of salts and other dissolved solids as the water circulating in the towers. As shown in Table 3.1-2, Item 3.3.6, the design of the cooling towers would utilize up to four cycles of concentration. Salt drift is of primary concern, because salt particles deposited in the surroundings may have adverse effects on the environment. Based on sodium (Na) and chloride (Cl) concentrations in the cooling tower's circulating water (as shown in Table 5.3-2), a salt (NaCl) concentration of 0.010086 grams of salt/gram of solution was modeled in the SACTI model.

NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,* provides a basis for interpreting salt deposition rates based on levels at which vegetation may be affected. Deposition rates of 1 to 2 kilograms per hectare per month (kg/ha/mo or kg/ha-mo), which is equivalent to 100 to 200 kg/km^2-mo, are generally not damaging to plants. Deposition rates of 10 to 20 kg/ha/mo (1000 to 2000 kg/km^2-mo) cause leaf damage in many species. These effects levels and the potential for impacts on terrestrial vegetation at the CRN Site are discussed further in Subsection 5.3.3.2.1.

Table 5.3-5 provides annual average downwind salt deposition rates from the SACTI model for distances out to 1000 m. The SACTI model predicted that the maximum salt deposition rate would occur at 100 m for all directions. At this distance, the greatest annual average deposition predicted is 6276 kg/km^2-mo to the west. The average salt deposition at 100 m based on all directions is predicted to be 2983 kg/km^2-mo.

At 200 m, annual average salt deposition rates are predicted by the model to be below 1000 kg/km^2-mo in all directions except for the west and west-northwest. At 300 m and beyond, annual average salt deposition rates are below 1000 kg/km^2-mo in all directions, and the greatest annual average deposition predicted is 605 kg/km^2-mo to the west of the towers. Salt deposition rates at 300 m also are below 1000 kg/km^2-mo in all seasons. At 600 m and beyond, the greatest annual average deposition rate is below 100 kg/ km^2-mo for all directions. A distance of 600 m from the cooling towers extends beyond the site boundary, to just over the other side of the river, in the south-southeast through northwest directions (clockwise).

Seasonal salt deposition values for distances out to 1000 m also are provided in Table 5.3-5. For the individual seasons at 600 m, salt deposition rates are below 100 kg/ km^2-mo except for the rate in the westerly direction from the tower during the summer season (111 kg/ km^2-mo). Based on this analysis, the effects of salt deposition from cooling tower operation are expected to be limited to the area of the cooling towers and would be SMALL.

5.3.3.1.4 TDS Deposition

Deposition of TDS other than salt was modeled and annual average values out to a distance of 1000 m are presented in Table 5.3-6. Maximum TDS deposition for all directions occurs at 100 m. At 100 m from the cooling towers, the greatest predicted deposition is 93,928 kg/km^2-mo to the west of the cooling towers, while the average deposition at 100 m is 44,972 kg/km^2-mo. At 300 m from the cooling towers, TDS deposition drops considerably. The maximum TDS deposition at 300 m is 5079 kg/km^2-mo, while the average at 300 m is 2545 kg/km^2-mo.

Seasonal TDS deposition values for distances out to 1000 m also are provided in Table 5.3-6. Similar to the salt analysis, the greatest TDS deposition occurs adjacent to the cooling towers, and deposition drops off rapidly with distance. Thus, the effects of TDS deposition from cooling tower operation are expected to be limited to the area of the cooling towers and would be SMALL.

5.3.3.1.5 Plume Shadowing

The frequency of annual plume shadowing, or shading, in hours per year (hr/yr) out to a distance of 1000 m is presented in Table 5.3-7. SACTI model results predict a maximum of 634 hr/yr of plume shadowing at 200 m to the northeast of the cooling towers. At 200 m to the northeast, the cooling tower plume would be over the SMR facilities. The maximum number of hours of plume shadowing at 400 m is 283 hr to the west-southwest and is equivalent to just over 3 percent of the year. The nearest residences are located at approximately 500 m to 600 m to the west-southwest and southwest of the cooling towers. At 600 m, the maximum number of hours of plume shadowing to the west-southwest is 237 hr/yr, or 2.7 percent of the year.

The plume modeling evaluates the hours of shadowing per year based on plume sectors, where each sector consists of a 22.5 degree arc. Thus, any specific point within these 22.5 degree sectors is likely to experience plume shadowing less than the percentages given here. In addition, plume shadowing varies seasonally. At 600 m, for example, maximum plume shadowing is predicted to occur 3.9, 3.7, 5.8, and 2.7 percent of the time during the winter, spring, summer, and fall seasons, respectively. Seasonal hours of plume shadowing for distances out to 1000 m are presented in Table 5.3-7. Because the predicted frequencies of plume shadowing beyond the CRN Site are low, impacts would be SMALL.

5.3.3.1.6 Plume Length Frequency

Annual plume length frequencies calculated by the SACTI model are presented in Table 5.3-8 for plume lengths up to 1000 m. Predicted visible plumes extend no more than 3200 m from the towers. Plumes at this distance occur to the south, south-southwest, north-northwest, north, north-northeast, and south-southeast directions. However, the frequency of a visible plume at this distance is very low, with the greatest value being 0.09 percent of the time (annually) in the south-southeasterly direction. For other wind directions, the predicted plume does not extend beyond 2100 m. For these cases, a visible plume at 2100 m is also infrequent.

On an annual average basis, visible plumes occur up to 5.4 and 5.0 percent of the time out to a distance of approximately 200 m to the east and east-southeast directions of the towers, respectively. For other directions, a plume out to 200 m occurs less than 3.4 percent of the time annually. Table 5.3-8 also provides seasonal plume length frequencies for distances out to 3200 m. Visible plumes are more frequent in winter and fall than in spring and summer. In winter, predicted visible plumes occur 5 percent of the time out to approximately 800 m in the east direction and 300 m in the east-southeast direction from the cooling towers. During summer, the

5 percent visible plume frequency level extends to only between 100 m and 200 m for any direction.

At 300 m, a visible plume is expected less than 3 percent of the time annually for the east and east-southeast directions and less than 2 percent of the time for any of the other directions. Based on these distances and directions, locations with overhead visible plumes occurring more than 3 percent of the time annually are predicted to be restricted to the CRN Site on or adjacent to the CR SMR Project.

Visible plume frequency calculations evaluated all hours of the year including night-time hours and periods of poor visibility (e.g., periods of precipitation and fog). During night-time hours and weather conditions producing poor visibility, visible plumes from the cooling tower would be obscured or hidden. Cooler temperature conditions, such as during the night-time hours, create greater occurrences of condensation and the likelihood of a visible plume. In addition, modeling indicates long visible plumes can be generated during periods when atmospheric conditions are close to or at saturation, conditions often associated with precipitation that can obscure a predicted visible plume. As a result, the SACTI model produces conservative results, and the occurrence of visible plumes from the project's cooling towers is expected to be less frequent than predicted by the model. Impacts on terrestrial ecosystems from the occurrence of visible plumes would be SMALL.

5.3.3.1.7 Plume Interaction with Existing Sources

The nearest large facility to the CRN Site is Hittman Transportation, located approximately 2 kilometers (km) north of the cooling towers. At this distance, the SACTI model results indicate that water and salt deposition decline significantly (Tables 5.3-4 and 5.3-5). This reduction in deposition rates is reflective of reduced concentrations of plume contaminants. Further, the frequency of a visible plume at 2 km in this direction is only about 15 hr/yr (Table 5.3-8). The impacts of the cooling towers on other facilities, as well their interaction with other nearby air pollution sources, will be addressed during consultation with TDEC regarding air quality permitting. Given the limited concentrations of salt and TDS in drift and the distance to other potential sources of vapor plumes, the potential for interaction of the SMR plume with other plumes would be negligible, and the impact would be SMALL.

5.3.3.1.8 Holding Pond

The planned CR SMR Project includes a holding pond to mix discharge streams from the cooling towers and miscellaneous demineralized water users for the facility. This provides that any discharge from the holding pond into the reservoir would be homogeneous in temperature and composition. The intent of the holding pond is not for heat removal from the facility discharge or for management of discharge flow rates, and cooling effects of the pond are not given credit in the hydrothermal analysis. The purpose of the pond is for discharge flow mixing only. Nevertheless, this mixing would act to further reduce temperatures and moderate flow rates, making this is a conservative modelling assumption for purposes of the hydrothermal analysis. Assuming the holding pond was to function under a “worst case” scenario as a cooling pond, NUREG-1555 states:

- The plume will exist as ground level fog, but will evaporate within 300 m or lift to become stratus for wind speeds greater than 2.2 meters per second (m/s).
- The plume will exist as fog over the pond, lifting to become stratus for winds less than or equal to 2.2 m/s.

An analysis of nearby areas of importance shows that the closest such area is Interstate 40, which is located 900 m from the CRN Site’s nearest boundary. Because this area is greater than 300 m from the location of the holding pond, potential “worst case” scenario impacts from the holding pond would be SMALL.

5.3.3.2 Terrestrial Ecosystems

The terrestrial ecosystems at the CRN Site that could be affected by operation of the SMR system for discharging heat to the atmosphere are described in Subsection 2.4.1. Heat dissipation systems at nuclear power facilities potentially can impact terrestrial ecological communities through effects such as those evaluated and discussed in Subsection 5.3.3.1 (salt deposition; increased precipitation, humidity, fogging, and icing; and plume shading), as well as noise, and bird collisions with cooling towers.

5.3.3.2.1 Salt Deposition

As discussed in NUREG-1437, Rev. 0, salts from cooling tower operation are deposited on plants by droplet and particulate fallout, rainfall, and wind. In most humid environments, rain would wash salts off of vegetation, but exposure can become substantial during periods between rainfall events. Plants damaged by salt drift and deposition may show acute symptoms, such as discolored or necrotic tissue, stunted growth, or deformities. Chronic symptoms are less apparent but may include reduced growth, chlorosis, or increased susceptibility to insects or disease. Foliar uptake of salt is affected by the characteristics of the leaves, salt concentration, temperature, humidity, and the length of time the leaf is wet. Salt on foliage is absorbed in solution, so rainfall, dew, and humidity can enhance salt uptake. Because moisture and other plant and environmental factors affect salt deposition, uptake, and injury to plants, exposures likely to cause effects are difficult to predict.

Salt deposition also can damage vegetation through salinization of soil. However, in areas where rainfall is sufficient to leach salts from the soil, salinization usually does not occur. Consequently, NRC generally considers the risk to vegetation from soil salinization to be low.

As noted by NRC in NUREG-1437, Rev. 0 and NUREG-1555, the tolerances of native plants, crops, and ornamentals to salt deposition from drift are not precisely known. Accordingly, NRC recommends an order-of-magnitude approach to evaluating such effects, and NUREG-1555 identifies the following salt (NaCl) deposition thresholds for evaluating the potential for effects on vegetation:

- 1 to 2 kg/ha/mo (100 to 200 kg/km^2-mo): salt deposition generally not damaging to plants
- 10 to 20 kg/ha/mo (1000 to 2000 kg/km^2-mo): threshold range for visible leaf damage from salt deposition on leaves in any month during the growing season
- Hundreds or thousands of kg/ha/year: could cause damage sufficient to suggest the need for changes of tower-basin salinities or a re-evaluation of tower design, depending on the extent of the area impacted and the uniqueness of the terrestrial ecosystems expected to be exposed to drift deposition

The distance at which the SACTI model predicts the greatest salt deposition rate from the cooling towers is 100 m; the greatest annual average deposition is 6276 kg/km^2-mo to the west (Table 5.3-5). The average salt deposition for all directions at 100 m is 2983 kg/km^2-mo. A radius of 100 m from the cooling towers is within the developed area of the facility immediately surrounding the cooling towers. Thus, salt deposition is predicted to exceed the 1000 to 2000 kg/ km^2-mo threshold range for effects within that radius. As a result, there is the possibility that vegetation on slopes established immediately adjacent to the cooling towers to the west and south may be adversely affected by salt deposition.

At 200 m from the cooling towers, annual average salt deposition rates are predicted by the model to be below 1000 kg/ km^2-mo in all directions except for the west and west-northwest (Table 5.3-5). Thus, within this developed area of the facility, salt deposition is predicted to be within the threshold for adverse effects in almost all directions. However, the potential for impacts to vegetation on the slopes adjacent to the cooling towers may extend to the toe of the slope in the westerly direction.

At 300 m from the cooling towers and beyond, the model predicts that the maximum salt deposition drops below 1000 kg/km^2-mo (Table 5.3-5). The greatest annual average deposition predicted at 300 m is 605 kg/km^2-mo to the west of the towers. Seasonal salt deposition rates at 300 m are below 1000 kg/km^2-mo in all seasons. Thus, beyond 200 m from the cooling towers and throughout the remainder of the CRN Site, salt deposition is predicted to remain below the 1000 to 2000 kg/km^2-mo threshold range for adverse effects.

At 600 m and beyond, maximum annual average salt deposition for all directions is below 100 kg/km^2-mo, a level at which vegetation damage does not occur. For the individual seasons, salt deposition values also are below 100 kg/km^2-mo at 600 m except for the westerly direction from the towers during the summer season. In summer at 600 m to the west, the predicted salt deposition is 111 kg/ km^2-mo, which is within the 100 to 200 kg/ km^2-mo range where damage to vegetation generally does not occur.

Based on studies of operating nuclear power facilities with cooling towers, discussed in NUREG-1437, Rev. 1, most deposition of drift and salt from cooling towers occurs in relatively close proximity to the towers. Deposition rates generally have been below those known to cause measurable adverse effects on plants, and no deposition effects on plant communities or crops have been observed from the operation of cooling towers at most nuclear power facilities. The SACTI modeling for the operation of the cooling towers at the CRN Site similarly predicts only a minor potential for vegetation to be impacted, and the area potentially affected would be limited to the area between the cooling towers and the reservoir on the west side of the CRN Site. Whether localized impacts to vegetation occur in this area would be determined by the sensitivity to salt deposition of the vegetation established in the area and local climatic conditions, such as the frequency with which rainfall washes salt deposits from foliage. Given that the potentially affected vegetation would be vegetation established on slopes during facility development in a limited area adjacent to the cooling towers, and the minimal occurrence of deposition effects at other facilities operating cooling towers, the impacts of salt deposition at the CRN Site would be SMALL. Mitigation may be warranted if vegetation established on slopes to prevent soil erosion is adversely affected by salt deposition.

5.3.3.2.2 Increased precipitation, humidity, fogging, and icing

As discussed in Subsections 5.3.3.1.1 and 5.3.3.1.2, the SACTI model indicated that operation of the cooling towers would not produce additional fogging or icing at any distance from the towers, and additional water deposition from the cooling towers would be negligible. Some increase in relative humidity may occur close to the towers, but effects on groundlevel humidity are expected to be minimal. As discussed in NUREG-1437, Rev. 1, impacts from increased humidity at nuclear power facilities have not been observed. Thus, the effects of cooling tower operation on terrestrial vegetation or other biota at the CRN Site from precipitation, humidity, fogging, or icing are expected to be SMALL.

5.3.3.2.3 Noise

The principal source of noise associated with the heat discharge system is the operation of the mechanical draft cooling towers. Wildlife on the CRN Site and the adjacent Grassy Creek Habitat Protection Area would be exposed to elevated noise levels, which would have the potential to alter behavioral patterns. As discussed in Section 2.8, the ambient noise assessment performed prior to construction and preconstruction activities on the CRN Site concluded that sound levels onsite ranged between daytime levels of 46 to 48 A-weighted decibels (dBA) and nighttime levels of 41 to 49 dBA. As presented in Table 3.1-2, Item 3.3.10, the cooling towers at the CR SMR Project are expected to operate at less than 70 dBA at a distance of 1000 ft.

Subsection 4.3.1.4 discusses the potential effects of noise on wildlife in the context of noise generated by construction activities. As discussed in that section, construction-related noise is attenuated by natural factors such as vegetation, topography, and temperature, and it quickly decreases over relatively short distances. Prediction of the effects of noise on wildlife is limited by the paucity of information linking sound levels to effects on species. A study by the Federal Highway Administration that summarized information from the available literature on the effects of noise on wildlife populations indicated that birds have been studied the most. The review found that some studies indicated that bird numbers and breeding were adversely affected by proximity to roads and their associated noise, while other studies found the opposite effect, with reports of many bird species using roadside habitats despite the noise. The sensitivity of birds seems to vary by species, with some affected, some not affected, and others more common even near noisy interstate highways. For mammals, the review found that studies indicate large mammals may avoid noise, but the effect seems to be small to moderate, and small mammals occur in significant numbers in highway rights-of-way and do not seem to be adversely affected by road noise. (Reference 5.3-3) The threshold noise level at which birds and small mammals are frightened or startled is 80 to 85 dBA (893 NRC 2011). This noise level is expected to occur at less than 1000 ft from the cooling towers, and undeveloped areas of habitat potentially affected occur only in a small area immediately south and west of the cooling towers between the facility and the reservoir.

More sensitive species may be permanently displaced to more distant habitats as a result of elevated noise levels from cooling tower operation, while more tolerant species likely would remain nearby if available habitats are otherwise suitable. Wildlife displaced by noise can find refuge in available undisturbed habitats in the vicinity of the CRN Site. Based on the similarity of cooling tower operational noise and highway noise levels, the rapid attenuation of noise expected to occur beyond the cooling tower area, the ability of mobile wildlife to move away from the noise, and the habituation and limited sensitivity of many wildlife species to the noise levels likely to occur in habitat areas, the impacts of noise on wildlife from cooling tower operation are expected to be SMALL.

5.3.3.2.4 Bird Collisions with Cooling Towers

As shown in Table 3.1-2, Item 3.3.8, the height of the mechanical draft cooling towers is expected to be 65 ft above finished grade. As discussed in NUREG-1437, Rev. 1, NRC has determined that natural draft cooling towers, which are much taller (usually taller than 330 ft), cause some bird mortality from collisions. However, mechanical draft cooling towers are much smaller (usually less than 100 ft) and cause negligible mortality to birds. Therefore, adverse effects on bird populations from collisions with the mechanical draft cooling towers at the CR SMR Project would be SMALL.

5.3.4 Impacts to Members of the Public

This subsection describes two issues associated with operation of the cooling system for the CR SMR Project that potentially could impact human health: propagation of etiologic agents (pathogenic microorganisms) and noise.

5.3.4.1 Etiologic Agent (Microorganism) Impacts

As discussed in NUREG-1555, etiologic agents, including organisms formerly referred to as thermophilic microorganisms, can increase in occurrence and numbers due to the presence of heat in aquatic systems or can resist moderately high temperatures long enough to be released into a cooler water body where they can grow. When such microorganisms are etiologic agents capable of causing human disease (pathogens), they can pose a risk to public health if cooling towers and thermal discharges can harbor them or accelerate their growth once they are released into the environment.

Etiologic agents of concern in the context of cooling systems include bacteria such as *Vibrio* species (spp.), *Salmonella* spp., *Legionella* spp., *Shigella* spp., *Plesiomonas shigelloides*, and *Pseudomonas* spp.*;* thermophilic fungi; noroviruses; free-living amoebae of the genera *Naegleria and Acanthamoeba*; the protozoan *Cryptosporidium;* and toxin-producing algae such as *Karenia brevis*. Data from the Centers for Disease Control and Prevention (CDC) show that there were three outbreaks of waterborne illness from treated recreational waters and one from untreated recreational water in Tennessee between 2009 and 2010. The organisms responsible were *Cryptosporidium* spp., *Shigella* spp., *Escherichia coli*, and an unidentified species. (Reference 5.3-4) In the years 2011 to 2012, there were no reported waterborne illnesses in Tennessee (Reference 5.3-5). Data regarding waterborne pathogens and toxic algae were not available specifically for the Watts Bar Reservoir.

Characteristics of these etiologic agents associated with aquatic environments and cooling systems are described below:

> *Vibrio* spp., *V. cholerae* and *V. parahaemolyticus*, are human pathogens that cause severe diarrhea, but through different mechanisms. Cholera is transmitted to humans through water or food. *V. vulnificus* is an emerging pathogen of humans that causes wound infections, gastroenteritis, or primary septicemia. (Reference 5.3-6) V. cholerae has an optimal growth temperature range of 18°C (64.4°F to 37°C (98.6°F) (Reference 5.3-7).
>
> *Salmonella* spp. live in the intestinal tracts of humans and animals. *Salmonella* spp. are the cause of two types of salmonellosis: enteric fever (typhoid), resulting from bacterial invasion of the bloodstream, and acute gastroenteritis, resulting from a foodborne infection/intoxication. (Reference 5.3-8) *Salmonella* spp. enter the natural environment (water, soil, plants) through human or animal excretion. *Salmonella* spp. do not appear to multiply significantly in the natural environment, but they can survive several weeks in water and several years in soil if conditions are favorable. (Reference 5.3-9)
>
> *Shigella* spp. can cause a gastrointestinal disease called shigellosis, with symptoms that include diarrhea, fever, and stomach cramps. *Shigella* spp. can occur in water or food. Infection can occur from eating contaminated food, swimming in or drinking contaminated water, or contact with flies that carry the bacterium. Water may become contaminated from sewage or an infected person swimming or bathing.(Reference 5.3-10)

Plesiomonas shigelloides has been found in many aquatic ecosystems, including freshwater (ponds, streams, rivers), estuarine, and marine. The pathogen has been isolated from warm-blooded and cold-blooded animals, including freshwater fish and shellfish, and from many types of animals, including cattle, goats, swine, cats, dogs, monkeys, vultures, snakes, and toads. Symptoms from an infection are usually mild, although a more severe, dysenteric form of gastroenteritis may occur. Under laboratory conditions, *P. shigelloides* is able to grow at temperatures between 8°C (46.4°F) and 45°C (113°F), with an optimal range from 25°C (77°F) to 35°C (95°F). (Reference 5.3-11)

All of the *Pseudomonas* spp. are free-living bacteria found in soil and water. They are also found on the surfaces of plants and animals. *P. aeruginosa* exploits an existing break in the host defenses in order to infect the compromised tissues. It can infect almost all tissues, causing urinary tract infections, respiratory system infections, dermatitis, soft tissue infections, bacteremia, bone and joint infections, gastrointestinal infections, and a variety of systemic infections. (Reference 5.3-12) Its optimum temperature for growth is 37°C (98.6°F), and it is able to grow at temperatures as high as 42°C (107.6°F).

Karenia brevis is a dinoflagellate responsible for red tides in the Gulf of Mexico. It is a marine species and would not be found in the Clinch River arm of the Watts Bar Reservoir. (Reference 5.3-13)

Legionella spp. can cause Legionnaire's disease, which is contracted from inhaling infected water droplets. The bacteria can be found in hot tubs, hot water tanks, large plumbing systems, decorative fountains, and cooling towers. (Reference 5.3-14) Symptoms of Legionnaire's disease are similar to pneumonia, including cough, shortness of breath, high fever, muscle aches and headaches (Reference 5.3-15). *L. pneumophila* can withstand temperatures of 50°C (122°F) for several hours, but it remains dormant below 20°C (68°F) (Reference 5.3-16).

Naegleria fowleri is an amoeba found in warm freshwater and soil. Specifically, it is usually found in bodies of warm freshwater, such as lakes and rivers, geothermal water such as hot springs, warm water discharge from industrial plants, swimming pools that are poorly maintained with minimal or no chlorination, and water heaters. An infection can occur if the amoeba is inhaled through the nose; it cannot be contracted by drinking contaminated water. *N. fowleri* causes primary amoebic meningoencephalitis, a brain infection that leads to the destruction of brain tissue. Initial symptoms include headache, fever, nausea, or vomiting. Later symptoms include stiff neck, confusion, lack of attention to people and surroundings, loss of balance, seizures, and hallucinations. The disease usually causes death within about 5 days (range 1 to 12 days). *N. fowleri* infections are rare. In the 10 years from 2005 to 2014, 35 infections were reported in the United States. Of those cases, 31 people were infected by contaminated recreational water, three people were infected after performing nasal irrigation using contaminated tap water, and one person was infected by contaminated tap water. *N. fowleri* grows best at higher temperatures of up to 115°F (46°C) and can survive for short periods at higher temperatures. (Reference 5.3-17)

Acanthamoeba can cause *Acanthamoeba* keritItis, an eye infection that can result in permanent vision impairment or blindness. Other symptoms include eye pain, eye redness, blurred vision, sensitivity to light, sensation of something in the eye and excessive tearing. *Acanthamoeba* can be found in freshwater bodies, soil, and air. People who wear contact lenses are the most susceptible to this infection. (Reference 5.3-18)

Cryptosporidium parvum is an obligate intracellular parasite. It can cause cryptosporidiosis, with symptoms that include mild to severe diarrhea, with severity increasing in young, old, and immuno-compromised individuals. Human exposure usually occurs by the ingestion of water contaminated with fecal material from an infected animal or food that was irrigated or washed with contaminated water. Swimming pools and other recreational waters are another vehicle for transmission of *Cryptosporidium* oocysts. The oocysts are difficult to eliminate with disinfectants like chlorine and can remain infectious for up to a year in both freshwater and seawater. Treated human wastewater can contain oocysts and could contaminate recreational waters downstream of a sewage treatment plant. (Reference 5.3-11)

Freshwater algal blooms can be harmful either by creating toxins or by generally impacting water quality such that they degrade aesthetic, ecological, or recreational value. Harmful algal blooms (HABs) are most often caused by cyanobacteria, but other types of algae can also cause toxicity. In addition to the production of neurotoxic, hepatotoxic, dermatotoxic, or other bioactive compounds, HABs can cause fish kills by depleting the oxygen in the water column. HABs can be naturally occurring or result of human activity. HABS usually are associated with significant increases in nutrient levels. (Reference 5.3-19)

Subsection 5.3.2.1 describes the potential effects of the hydrothermal discharge from the cooling system on water temperatures in the Clinch River arm of the Watts Bar Reservoir. The discharge will be managed in accordance with requirements of the TDEC NPDES permit, and the modeling indicates compliance with the thermal water quality criteria; therefore, thermal impacts from operation of the CR SMR Project discharge would be SMALL.

The maximum temperature measured in the Clinch River arm of the Watts Bar Reservoir during monitoring activities was 31.3°C (88.3°F) (at the monitoring location near CRM 16, approximately 0.5 mi upstream from the discharge location). Due to the complexity of the human-manipulated hydrology of this portion of the reservoir, temperatures can at times exceed TDEC's regulations without the additional discharge associated with the CR SMR Project. As discussed in Subsection 5.3.2.1, modeling of the effects of the discharge (incorporating a continuous 400 cfs bypass of the Melton Hill Dam) indicated that the thermal component of the discharge would be assimilated within 50 ft of the discharge structure.

No data are available concerning the occurrence of etiologic agents and thermophilic microorganisms in the Clinch River arm of the Watts Bar Reservoir near the CR SMR Site. As stated in NUREG-1437, Supplement 34, thermophilic microorganisms generally occur in water with temperatures between 77°F (25°C) and 176°F (80°C). Optimal growth has been reported at between 122°F (50°C) and 150°F (65.5°C). TDEC requires a water temperature of lower than 86.9°F (30.5°C); it is unlikely that populations of thermophilic or other etiologic agents would increase in the reservoir due to discharges from the CR SMR Project. Because the temperatures in the reservoir have at times exceeded TDEC's criteria in the absence of a discharge from the CR SMR Project, etiologic agents would not experience conditions that are substantially different from those that have previously occurred without causing their proliferation. The mixing zone where elevated temperatures from the discharge would occur would be a small area within the reservoir, and its temperatures would be at the low end of the range preferred by thermophilic etiologic agents. In addition, the few incidences of disease from etiologic agents reported in Tennessee would suggest that hydrothermal discharges on multiple reservoirs has had little or no effect on the proliferation of these agents. Based on these lines of evidence, the potential for etiologic agents associated with cooling system operation to impact public health is SMALL.

5.3.4.2 Noise

This subsection is focused on the potential human health effects associated with operation of the cooling system for the CR SMR Project. NUREG-1555 notes that the principal sources of noise from nuclear power facility operations include natural draft and mechanical draft cooling towers. Other sources may include auxiliary equipment such as pumps to supply cooling water. The main source of noise associated with the cooling system at the CR SMR Project is operation of the mechanical draft cooling towers.

The distance from the perimeter of the cooling tower block to the nearest property boundary is approximately 690 ft. The nearest offsite residence is located approximately 1900 ft southwest from the edge of the cooling tower block, across the Clinch River arm of the Watts Bar Reservoir from the CRN Site. The cooling towers are expected to produce noise levels of less than 70 dBA at a distance of 1000 ft during operation, as presented in Table 3.1-2, Item 3.3.10. For industrial and commercial areas, TVA uses a 60 dBA equivalent noise level as a design goal at the property line. NUREG-1437, Rev 1 indicates that noise levels below 65 dBA are considered acceptable outside a residence. It also notes that cooling towers emit noise of a broadband nature, which is largely indistinguishable from and is less obtrusive than noise of a specific tonal nature (such as transformer or loudspeaker noise). Noise produced by the cooling towers would be attenuated with distance and intervening vegetation. Considering that noise levels from the cooling towers are expected to be less than 70 dBA at 1000 ft from the towers and the nearest residence is almost twice that distance, noise levels at the nearest residence are expected to be attenuated to 65 dBA or less. Therefore, impacts to members of the public from noise associated with operation of the cooling system would be SMALL.

5.3.5 References

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Table 5.3-1
Average annual densities of fish eggs and larvae (number/1000 m^3) collected at the upstream sample location (CRM 18.0) near the proposed intake for the CR SMR Project from February 2011 through January 2012

Fish Eggs								
	Day				**Night**			
Family	**RDB**	**Midchannel**	**Midchannel (bottom tow)**	**LDB**	**RDB**	**Midchannel**	**Midchannel (bottom tow)**	**LDB**
Sciaenidae	3.5	14.9	23.4	26.0	12.5	13.0	1671.1	6.3
Clupeidae	13.4	31.0	49.4	309.6	5.3	11.7	22.2	36.6
Moronidae	4.3	24.2	26.5	154.4	3.6	13.9	21.8	56.0
Unidentifiable	4.3	11.9	11.0	65.2	5.8	8.1	10.6	27.6
Total	25.6	82.0	110.3	555.7	27.1	46.7	1725.7	126.5
Avg	193.4				481.5			
24-hr Avg	337.5							
Fish Larvae								
Clupeidae	44.2	51.8	45.9	81.9	64.1	64.7	65.3	137.4
Catostomidae	0.9	0.4	0.0	0.9	0.9	1.3	0.0	1.8
Moronidae	8.7	11.0	11.5	21.7	6.2	9.4	8.3	13.6
Centrarchidae	5.6	5.1	0.9	2.6	4.5	2.7	2.8	22.1
Atherinopsidae	3.0	1.3	0.9	0.4	1.8	-	-	1.4
Cyprinidae	-	-	-	-	3.1	4.0	1.4	0.9
Sciaenidae	1.7	0.8	1.8	0.9	0.4	0.9	0.5	0.5
Percidae	-	-	-	0.9	-	0.4	-	0.9
Unidentifiable	-	0.4	0.4	-	0.9	-	-	-
Polyodontidae	-	-	-	0.4	-	-	-	-
Total	64.2	70.9	61.3	109.6	81.9	83.5	78.2	178.5
Avg	76.5				105.5			
24-hr Avg	91.0							

Notes:
Average Annual Density of Eggs and Larvae: 337.5 + 91.0 = 428.5/1000 m^3 = 0.4285/m^3
RDB = right descending bank
LDB = left descending bank
- = no fish eggs or larvae collected
Source: (470 Tennessee Valley Authority 2012)

Table 5.3-2
Cooling Tower Design Inputs for SACTI Model

Parameter	Design Value
Total Heat Rejection for All Units (MBtu/hr)	5593
Total Heat Rejection for All Units (MWt)	1640
Height of Cells Above Ground Level (m)	19.8
Cell Exit Diameter (m)	9.14
Cell Spacing (m)	11.0
Each Tower Length (m)	99.0
Each tower Width (m)	11.0
Maximum Number of Cells All Units	18
Sodium Concentration (ppm)	990
Chloride Concentration (ppm)	1527
Salt Concentration (g salt/g solution)[1]	0.010086
Total Dissolved Solids Concentration (g TDS/g solution)[1]	0.068
Salt Density (g/cm^3)	2.17
Cycles of Concentration	4
Air Flow Rate All Cells (kg/s)	16,186.8
Drift Rate All Cells (g/s)	200.7

[1] Based on four cycles of concentration

Notes:
cm^3 = cubic centimeter
g = grams
kg = kilograms
m = meters
MBtu/hr = million British thermal units per hour
MWt = megawatts thermal
ppm = parts per million
s = second
SACTI = Seasonal and Annual Cooling Tower Impact
TDS = total dissolved solids

Table 5.3-3
Cooling Tower Droplet Mass Spectrum[1]

Mass in Range Modeled	Droplet Size Provided by Marley (microns)	Droplet Size Used in SACTI (microns)
0.12	<10	5 - 10
0.08	10 - 15	10 - 15
0.20	15 - 35	15 - 35
0.20	35 - 65	35 - 65
0.20	65 - 115	65 - 115
0.10	115 - 170	115 - 170
0.05	170 - 230	170 - 230
0.04	230 - 375	230 - 375
0.008	375 - 525	375 - 525
0.002	>525	525 - 1000

[1] The size distribution provided by Marley (SPX Cooling Technologies) did not include bounding values at the upper and lower ends of the spectrum. Limits were added as needed for the SACTI modeling. Limits were set to half the lowest value and approximately twice the upper value as provided by Marley.

Table 5.3-4 (Sheet 1 of 3)
Water Deposition in kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	40000	28000	33000	49000	97000	75000	53000	35000	37000	22000	21000	32000	62000	53000	48000	31000	45000
200	5300	3800	4500	7400	14000	10000	7300	4500	5600	2800	2800	6600	12000	12000	8300	4600	7000
300	3400	2600	3200	4700	8100	5900	4000	3000	3800	1700	1700	4600	8800	8200	6200	3500	4600
400	2000	1500	2400	3000	4500	3300	3000	1800	2100	1000	1200	2900	5200	5000	4800	2000	2900
500	870	610	940	1200	2000	1400	1200	770	760	430	460	960	1800	1700	1600	800	1100
600	230	180	280	450	820	580	350	190	230	110	150	400	830	780	530	230	400
700	230	180	270	430	800	570	330	190	230	110	140	390	810	770	510	230	390
800	230	180	250	320	480	340	300	190	230	110	120	330	600	570	480	230	310
900	230	180	250	310	440	300	300	190	230	110	110	320	570	540	480	230	300
1000	220	180	240	230	320	230	280	180	220	110	110	220	390	370	430	230	250
Winter																	
100	12000	10000	16000	19000	40000	47000	44000	37000	35000	27000	22000	28000	45000	28000	24000	14000	28000
200	2600	2700	4300	7800	9900	10000	9200	6300	6800	3900	3900	9900	18000	13000	8300	3700	7600
300	2500	2700	3400	6100	7200	7600	6100	4900	5400	2500	2400	8600	16000	11000	7600	3400	6100
400	1300	1400	2900	3400	3600	4100	4900	2800	3000	1500	1600	5400	9000	6900	6100	1800	3700
500	300	310	910	970	1100	1300	1600	1100	870	590	610	1500	2600	2100	1900	540	1100
600	170	170	310	580	730	720	520	320	340	170	220	720	1400	1100	680	230	530
700	170	170	290	560	720	700	500	320	340	170	200	710	1400	1100	660	230	520
800	170	170	270	380	440	390	470	320	340	170	160	580	1000	860	630	230	410
900	160	170	270	360	410	340	470	320	330	170	160	560	980	830	630	230	400
1000	160	170	240	250	260	250	400	310	320	160	160	400	670	560	580	230	320

Table 5.3-4 (Sheet 2 of 3)
Water Deposition in kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Spring																	
100	24000	22000	26000	46000	91000	79000	56000	38000	25000	21000	19000	31000	56000	42000	34000	30000	40000
200	4600	3800	3800	7100	16000	12000	6800	4300	5200	2400	2300	6500	12000	11000	7500	4300	6800
300	3000	2500	3100	4900	10000	7000	3600	2500	4000	1500	1400	4100	8200	8000	6000	3500	4600
400	1600	1400	1800	3100	5200	3500	2600	1500	1900	940	1100	2100	4700	4400	4300	1800	2600
500	530	540	710	1300	2100	1600	1100	700	540	380	430	810	1600	1500	1400	720	990
600	190	190	280	460	1000	740	300	150	200	100	120	410	770	770	490	220	400
700	190	190	270	450	970	720	290	150	200	100	110	400	750	760	480	220	390
800	190	190	250	350	530	390	270	150	200	100	91	310	610	590	450	220	310
900	190	190	240	340	460	330	270	150	200	99	89	300	580	570	450	220	290
1000	190	180	230	250	340	240	230	150	190	94	82	180	370	340	420	220	230
Summer																	
100	74000	48000	51000	79000	16000 0	94000	57000	30000	47000	20000	19000	31000	79000	85000	75000	48000	62000
200	6600	4500	4900	7600	16000	9400	5500	2900	4300	2200	2300	4300	8200	11000	7800	4900	6400
300	3300	2200	2700	3600	7400	3800	2000	1700	2600	1200	1400	2500	3800	5900	4000	2700	3200
400	2200	1400	2200	2600	4900	2600	1700	1100	1700	800	940	1600	2600	3500	3100	1700	2200
500	1300	840	1000	1400	2700	1500	940	610	850	360	370	630	1300	1600	1400	950	1100
600	230	160	220	290	760	390	190	100	160	72	100	180	380	490	340	180	260
700	230	160	210	280	750	380	180	100	160	72	100	170	370	480	330	180	260
800	230	160	200	240	480	270	160	100	160	72	95	150	240	290	300	180	210
900	220	160	200	230	440	250	160	100	160	72	94	150	220	260	290	180	200
1000	220	150	200	200	360	210	160	97	150	71	94	120	190	230	260	180	180

Table 5.3-4 (Sheet 3 of 3)
Water Deposition in kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Fall																	
100	45000	28000	39000	45000	89000	74000	55000	34000	42000	22000	24000	36000	68000	55000	57000	31000	47000
200	7100	4400	5100	7000	12000	9500	8300	5000	6300	2700	3100	6200	13000	11000	10000	5500	7300
300	4700	3400	3700	4500	7000	5100	4700	3300	3400	1500	1600	4000	8700	8500	7500	4800	4800
400	2800	1900	2700	2800	4200	3100	3100	1900	2000	990	1200	2800	5200	5500	6200	2700	3100
500	1300	730	1100	1200	1700	1300	1200	730	810	430	450	1000	1700	1800	2100	970	1200
600	340	220	360	480	740	490	420	200	240	120	160	350	840	830	650	320	420
700	340	220	340	480	710	480	400	200	240	120	150	350	810	820	630	320	410
800	340	220	310	340	450	310	360	200	240	120	120	300	590	590	590	320	340
900	340	210	300	320	420	290	360	200	240	110	120	300	560	560	590	320	330
1000	330	210	290	220	300	230	350	190	240	110	110	220	400	410	500	320	280

Table 5.3-5 (Sheet 1 of 3)
Salt Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	2977	2067	2249	3259	6276	4781	3538	2593	2652	1634	1235	1950	3671	3334	3155	2364	2983
200	684	478	504	744	1425	1084	809	595	626	375	284	468	884	802	730	547	690
300	272.31	194.4	216.61	317.85	604.91	457.07	326.94	238.82	260.56	148.66	123.64	220.73	421.72	376.25	330.37	230.02	296.3
400	252.03	178.13	196.47	275.72	511.77	386.52	299.66	220.44	234.99	138.59	106.68	183.07	340.42	313.36	300.06	207.68	259.1
500	180.17	125.95	137.87	197.34	374.29	282.96	213.85	156.8	161.83	97.93	75.62	123.34	233.75	213.47	201.16	146.06	182.65
600	29.81	21.9	30.64	45.17	90.81	67.86	44.81	25.69	29.69	16.51	20.35	33.34	70.46	59.27	49.37	25.94	41.35
700	29.81	21.9	27.77	41.84	85.11	63.74	40.37	25.69	29.69	16.51	17.38	30.64	65.23	56.57	44.99	25.94	38.95
800	29.81	21.9	22.69	31.16	55.74	41.34	33.47	25.69	29.69	16.51	12.3	23.56	44.69	40.87	37.28	25.94	30.79
900	29.48	21.67	22.67	30.52	53.62	39.81	33.45	25.31	29.12	16.12	12.29	23.15	43.33	39.65	37.26	25.63	30.19
1000	28.79	21.2	22.19	28.11	50.26	37.74	32.38	24.52	27.97	15.34	12.1	20.32	38.19	34.69	35.32	25	28.38
Winter																	
100	733	709	721	626	1862	2474	2743	2569	2140	1797	1144	1477	2109	1342	1086	899	1527
200	189.89	182.55	201.11	222.67	494.75	619.48	686.32	626.19	552.19	432.56	288.36	408.33	634.79	411.73	313.73	239.86	406.53
300	99.09	97.37	115.26	156.99	276.78	321.27	308.33	273.99	262.64	181.7	138.18	247	406.09	269.04	207.14	125.61	217.9
400	82.75	78.56	99.36	100.24	189.21	239.44	279.11	246.07	226.49	166.59	110.3	191.79	296.2	204.35	176.33	101.4	174.26
500	49.29	47.71	59.66	59.42	129.47	164.97	187.09	166.2	142.06	112.75	77.84	111.33	175.22	118.48	99.41	63.51	110.28
600	14.26	12.97	25.19	39.13	61.38	62.82	50.76	35.06	37.65	23.76	28.6	43.13	83.07	55.67	45.41	17.45	39.77
700	14.26	12.97	21.8	34.14	57.09	57.11	45.39	35.06	37.65	23.76	23.52	40.27	77.37	54.95	40.63	17.45	37.09
800	14.26	12.97	16.31	20.27	30.34	32.06	38.07	35.06	37.65	23.76	15.28	30.32	52.75	39.98	32.39	17.45	28.06
900	13.68	12.62	16.27	19.25	28.74	30.18	38.02	34.48	36.15	22.95	15.28	29.62	50.74	38.67	32.39	17.1	27.26
1000	12.51	11.91	15.2	16.17	24.46	27.52	35.1	33.29	33.12	21.3	15.02	24.89	41.63	30.74	30.28	16.4	24.35

Table 5.3-5 (Sheet 2 of 3)
Salt Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Spring																	
100	1651	1505	1659	3075	5636	4930	3797	2982	1654	1529	1125	1718	3352	2459	2116	2261	2590
200	417	373	373	705	1320	1132	845	665	422	347	252	424	806	627	510	522	609
300	177.73	156.19	172.66	304.72	591.65	481.04	335.64	256.63	196.87	138.78	110.41	201.12	383.46	307.78	252.31	220.67	267.98
400	156.23	141.03	146.97	265.74	481.7	403.27	310.66	238.66	163.94	129.72	96.49	156.12	312.6	246.45	221.2	197.02	229.24
500	104.44	96.28	102.55	189.03	348.5	295.42	222.76	174.45	104.89	90.96	67.87	110.53	213.31	164.63	141.22	138.73	160.35
600	22.32	21.02	26.69	43.48	94.39	72.77	41.88	24.63	23.4	15.7	18.32	36.1	60.46	52.03	39.47	24.11	38.55
700	22.32	21.02	23.97	39.52	85.91	67.68	38.32	24.63	23.4	15.7	15.49	31.01	55.37	48.06	36.14	24.11	35.79
800	22.32	21.02	18.85	31.24	55.48	44.54	32.47	24.63	23.4	15.7	10.37	22.85	42.56	37.1	30.29	24.11	28.56
900	22.14	20.74	18.83	30.71	52.71	42.12	32.46	24.35	22.85	15.05	10.34	22.19	41.45	36.05	30.27	23.92	27.89
1000	21.75	20.18	18.41	27.91	49.15	39.53	31.2	23.8	21.73	13.76	10.12	18.75	35.14	29.41	29.01	23.55	25.84
Summer																	
100	5931	3772	3827	5969	11270	6677	3962	2386	3746	1574	1237	2151	5384	6092	5426	3780	4574
200	1282	826	826	1289	2457	1455	869	521	811	350	272	482	1178	1351	1180	834	999
300	473.49	303.53	315.64	484.57	940.68	554.23	322.39	196.88	305.3	133.12	111.03	198.38	460.88	535.58	455.98	313.66	381.58
400	454.62	292.13	303.95	459.37	863.82	506.41	306.04	187.58	292.58	124.4	102.23	176.34	415.61	484.08	429.71	299.45	356.14
500	342.72	218.84	220.36	338.39	643.26	379.37	227.6	139.3	216.65	91.4	71.72	124.9	308.34	352.57	311.47	222.11	263.06
600	42.78	28.53	32.01	48.74	111.44	66.28	37.52	17.81	27.39	11.96	12.82	22.94	58.77	62.63	52.81	30.28	41.54
700	42.78	28.53	30.65	46.42	107.97	63.39	34.18	17.81	27.39	11.96	11.95	21.78	54.72	59.17	48.82	30.28	39.86
800	42.78	28.53	28.44	41.43	81.09	47.53	29.02	17.81	27.39	11.96	10.47	17.76	39.9	45.57	41.45	30.28	33.84
900	42.49	28.53	28.43	41.12	79.03	46.79	29	17.62	27.2	11.96	10.46	17.68	38.82	44.43	41.42	30.28	33.45
1000	41.91	28.51	28.42	40.12	76.68	45.62	28.99	17.23	26.82	11.95	10.46	16.57	37.8	43.28	40.13	30.28	32.8

Table 5.3-5 (Sheet 3 of 3)
Salt Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Fall																	
100	3239	2032	2564	2799	5371	4574	3491	2394	3055	1675	1455	2452	3528	3034	3718	2222	2975
200	773	478	574	647	1224	1036	810	567	727	383	333	565	868	736	867	532	695
300	315.64	204.73	250.53	291.03	537.77	443.28	340.02	233.33	282.41	147.03	141	245.78	436.76	373.14	395.32	243.2	305.06
400	291.19	183.79	222.74	238.83	440.42	365.52	298.68	212.9	260.74	139.01	121	215.48	327.33	296.49	361.72	214.52	261.9
500	205.31	126.99	158.34	172.85	321.64	267.04	212.64	147.21	184.75	99.75	87.7	148.71	226.36	198.72	241.24	144.41	183.98
600	38.67	23.77	39.25	48.92	90.26	68.54	51.36	27.39	32.35	15.86	23.94	32.84	84.49	67.56	61.28	31.32	46.11
700	38.67	23.77	34.85	46.79	83.89	65.7	45.46	27.39	32.35	15.86	20.3	31.43	78.12	65.42	55.52	31.32	43.55
800	38.67	23.77	26.77	29.37	50.39	39.01	35.58	27.39	32.35	15.86	14.01	24.79	45.2	40.69	45.65	31.32	32.55
900	38.32	23.42	26.74	28.57	48.51	37.97	35.54	26.81	32.23	15.74	13.98	24.59	43.8	39.21	45.62	30.51	31.97
1000	37.61	22.72	26.21	25.61	45.04	36.05	35.26	25.66	31.99	15.51	13.7	22.26	39.04	34.66	42.2	28.89	30.15

Table 5.3-6 (Sheet 1 of 3)
TDS Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	45567	31660	33854	49028	93928	71518	53352	39631	40548	24927	18407	29266	54604	49715	47381	36160	44972
200	7091	4965	5447	7939	15752	12025	8816	6189	6632	3967	3317	5176	9939	8542	7927	5669	7462
300	2445	1753	1739	2613	5079	3854	2767	2138	2448	1376	1059	1886	3627	3176	2721	2037	2545
400	2030	1441	1658	2383	4549	3434	2593	1781	1926	1113	968	1645	3166	2857	2567	1700	2238
500	1141	823	977	1389	2623	1967	1450	1003	1118	624	568	1004	1970	1743	1565	986	1309
600	389.08	302	422.04	493.52	921.96	688.79	577.52	349.87	458.92	218.35	290	443.66	920.53	786.06	760.77	386.18	525.58
700	327.31	258.57	269.83	393.86	679.22	500.26	360.64	287.89	385.54	175.99	158.96	367.81	726.6	649.62	504.45	319.67	397.89
800	291.22	227.25	247.28	339.65	537.23	388.18	313.67	250.66	330.13	153.97	135.36	330.42	623.8	582.33	461.71	276.27	343.07
900	257.96	199.34	232.78	296.1	458.88	336.07	304	222.96	286.61	138	131.76	290.28	535.19	489.04	434.97	243.86	303.61
1000	176.15	136.59	194.81	217.28	353.65	267.48	266.46	155.71	192.26	95.25	112.01	208.35	377.5	335.12	360.95	177.82	226.71
Winter																	
100	11058	10748	10587	8584	26948	36256	41488	39366	32548	27406	16995	21648	30445	19237	15761	13711	22674
200	2176	1979	2515	2776	6151	7270	7656	6731	6357	4798	3700	4240	6644	4080	3826	2612	4594
300	1034	935	1054	1527	2551	2830	2715	2699	2807	1867	1256	2098	3578	2322	1839	1262	2023
400	748	708	983	1235	2079	2382	2587	2061	1954	1366	1140	1813	3069	2069	1716	918	1677
500	490	466	646	867	1415	1525	1495	1233	1254	807	684	1221	2129	1478	1220	597	1095
600	311	289	478	604	857	793	786	595	751	374	450	743	1353	991	939	373	668
700	246	241	320	493	616	604	532	476	571	281	238	646	1158	861	658	307	516
800	204	203	294	434	481	495	494	425	475	249	206	604	1074	810	613	257	457
900	174.89	165.25	270.94	356.34	397.63	404.61	472.53	382.32	411.05	229.48	200.31	505.61	872.43	667.02	555.96	223.83	393.14
1000	128.34	123.23	223.74	240.01	277	286.47	413.49	251.15	282.72	147.48	170.94	340.32	557.58	418.35	455	166.21	280.13

Table 5.3-6 (Sheet 2 of 3)
TDS Deposition kg/km²-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Spring																	
100	25464	23146	24803	46300	83983	73295	57233	45535	25309	23167	16717	25471	49839	36383	31583	34623	38928
200	4462	4016	4108	7457	14538	12585	9028	6780	4587	3748	2970	5053	8870	6619	5554	5358	6608
300	1791	1595	1374	2492	5047	4170	2756	2153	1965	1302	923	1833	3288	2710	2119	1898	2339
400	1303	1178	1278	2292	4438	3714	2598	1884	1403	1057	847	1560	2912	2437	1951	1608	2029
500	781	700	796	1348	2592	2076	1436	1023	866	600	505	965	1800	1507	1235	936	1198
600	374.87	326.61	389.08	478.44	956.6	679.25	486.05	264.47	461.56	222.47	257.18	420.29	787.39	716.35	691.07	363.23	492.18
700	330.68	272.61	228.56	397.2	754.05	524.15	292.89	231.02	388.61	161.2	134.44	337.63	652.93	612.78	476.03	309.13	381.49
800	302.22	254.26	208.16	356.78	639.6	436.62	253.09	202.23	332.06	132.9	112.68	297.17	592.25	572.29	439.96	264.37	337.29
900	259.25	229.89	196.56	313.89	525.84	375.32	250.06	177.9	285.4	120.95	108.5	267.72	527.61	490.05	413.01	230.11	298.25
1000	150.02	137.25	168.02	225.34	391.87	297.67	226.94	131.94	189.43	90.94	94.05	196.18	370.03	324.41	332.75	168.6	218.46
Summer																	
100	90590	57771	58105	90664	170044	100891	59892	36386	57193	24086	18514	32821	81225	92137	82039	57931	69393
200	12894	8319	8388	13202	26019	15436	9302	5271	8152	3522	2848	5358	13151	14158	12401	8429	10428
300	3766	2492	2429	3784	7581	4456	2672	1584	2421	1096	906	1647	3802	4339	3616	2597	3074
400	3500	2250	2380	3617	7114	4153	2518	1473	2265	968	839	1441	3456	4009	3434	2325	2859
500	1833	1180	1266	1901	3795	2237	1321	788	1202	513	465	812	1886	2152	1904	1240	1531
600	313.35	217.92	297.67	331.25	859.55	520.47	361.36	176.47	245.96	114.52	161	250.35	482.77	521.41	542.28	270.55	354.18
700	272.6	207.98	220.85	283.26	637.06	366.82	223.74	147.93	220.82	113.39	110.6	200.72	350.91	430.55	319.44	248.61	272.2
800	241.45	188.62	211.15	256.07	501.45	271.91	179.21	119.03	187.62	97.29	99.04	173.6	269.51	376.26	272.87	226.56	229.48
900	227.2	177.32	202.92	232.62	453.58	255.6	178.56	107.27	162.23	82.41	97.47	155.71	246.26	312.52	268.98	210.03	210.67
1000	182.52	122.27	170.63	199.57	388.78	230.33	159.73	88.27	128.37	64.62	80	122.83	217.84	252.17	237.88	142.72	174.28

Table 5.3-6 (Sheet 3 of 3)
TDS Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
									Fall								
100	49710	31099	38497	41865	80049	68501	52347	36592	46948	25655	21726	37041	52056	44795	55892	33807	44786
200	8134	5010	6419	7255	14272	11881	9110	6051	7569	3954	3936	6012	10613	8502	9453	5724	7744
300	3038	1855	2027	2416	4577	3738	2946	2243	2722	1323	1218	2029	3878	3183	3246	2295	2671
400	2409	1506	1915	2134	4012	3252	2686	1752	2128	1106	1104	1828	3226	2756	3112	1829	2297
500	1390	891	1175	1337	2431	1937	1578	1015	1190	607	656	1071	2122	1801	1898	1124	1389
600	576	386	559	601	1017	800	746	425	427	185	330	413	1187	990	936	568	634
700	470.25	319.48	331.4	426.92	699.03	528.8	441.3	342.63	398.9	166.25	170.43	333.92	846.59	752.23	612.53	431.85	454.53
800	424.55	264.95	293.37	327.73	508.87	363.46	373.25	298.11	358.08	155.11	138.76	292.56	648.12	620.01	568.97	369.82	375.36
900	376.13	221.94	276.44	292.33	442.95	317.05	356.28	262.24	316.64	136.19	135.09	269.49	561.92	526.12	544.46	321.55	334.8
1000	248.37	166.39	229.06	206.83	339.51	256.16	299.57	173.01	184.13	86.11	115.41	197.11	402.5	366.68	452.65	243.26	247.92

Table 5.3-7
Hours of Plume Shadowing

Dist(m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
200	40	65	125.4	421.4	618.5	505.1	419.9	361.4	393.3	469.7	633.7	541.6	535	218.1	71	37.7	341
400	16	22	59.1	282.6	241.8	205.9	134.1	104	114	141.3	216.9	200.6	163.6	187.5	30	18	133.6
600	12	16	41.1	237.1	134.1	139.6	56.8	50	58	72	131.9	133.2	103.9	57.7	22	16	80.1
800	7	12.1	33.1	169	101.5	96.6	39	36	49	52	104.9	111.2	74.6	48.9	19	12	60.4
1000	5	8	29.1	131.5	81.8	73.5	24	30	44	50	85.8	91.7	65.9	37.8	13	6	48.6
Winter																	
200	4	3	10.1	30.7	42.4	134.7	191	180.5	211.3	263.8	343.5	139.5	38.9	34.2	14.8	5.7	103
400	2	1	2	7.6	28.4	98.6	72.6	62	67	88.3	140	92.4	29.6	9	6	3	44.4
600	2	1	0	4.5	21.4	84.3	32.8	36	34	45	86	69.2	26.4	7	6	2	28.6
800	1	1	0	4.5	17.4	61.9	20	27	29	31	68	59.2	25.4	7	4	1	22.3
1000	0	0	0	4.5	17.4	48.8	11	24	29	31	56.8	54.2	23.2	7	2	0	19.3
Spring																	
200	20	31	60.6	142.7	246.7	152.8	72	70	67	75	86	179.5	265.3	83.7	37.1	16	100.3
400	7	10	27	104.2	106.9	32.7	18	12	19	23	24	39	81.3	58.4	15	9	36.7
600	6	8	18	80.1	50.2	12.7	7	4	11	10	12	24	50.4	30.3	9	8	21.3
800	2	5	15	57.2	36.2	9.7	8	4	9	10	9	20	33.2	27.2	9	6	16.3
1000	1	3	13	50.6	25.5	6.7	5	2	9	10	8	16	27.7	21.1	6	3	13
Summer																	
200	9	12.8	27.1	192.8	210.2	47.6	32.5	30	26	25	27	43.4	158.1	78.5	8	6	58.4
400	4	7	11.9	139.4	22.5	11.5	6.5	7	7	5	7	8	13	113.1	4	3	23.1
600	1	4	9.1	126	4	4.5	1	4	5	2	6	6	6	13.4	2	3	12.3
800	1	4.1	6.1	84.8	3	3.5	1	3	5	1	6	6	3	8.7	2	3	8.8
1000	1	3	6.1	57	1	2	1	3	3	1	5	5	2	4.7	2	2	6.2
Fall																	
200	7	18.2	27.5	55.1	119.3	170.1	124.4	81	89	105.9	177.2	179.3	72.7	21.8	11.1	10	79.3
400	3	4	18.2	31.5	83.9	63.1	37	23	21	25	45.9	61.2	39.7	7	5	3	29.5
600	3	3	14	26.5	58.4	38.1	16	6	8	15	27.9	34	21.2	7	5	3	17.9
800	3	2	12	22.5	44.9	21.5	10	2	6	10	21.9	26	13	6	4	2	12.9
1000	3	2	10	19.4	38	16	7	1	3	8	16	16.4	13	5	3	1	10.1

Table 5.3-8 (Sheet 1 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	4.49	3.88	5.34	5.77	7.94	6.21	5.28	3.73	5.94	3.43	4.94	9.14	12.24	9.44	8.23	4	100
200	1.53	1.35	1.71	2.57	2.95	1.94	1.29	1.23	1.73	0.82	0.85	3.1	5.44	4.99	3.3	1.71	36.51
300	0.74	0.7	0.61	1.33	1.44	0.9	0.22	0.47	0.65	0.39	0.34	1.72	2.97	2.6	1.31	0.99	17.38
400	0.61	0.54	0.61	0.78	0.66	0.32	0.22	0.39	0.55	0.31	0.34	1.21	1.88	1.71	1.31	0.86	12.29
500	0.37	0.31	0.61	0.78	0.66	0.32	0.22	0.2	0.29	0.23	0.34	1.21	1.88	1.71	1.31	0.49	10.93
600	0.37	0.31	0.61	0.78	0.66	0.32	0.22	0.2	0.29	0.23	0.34	1.21	1.88	1.71	1.31	0.49	10.93
700	0.32	0.24	0.61	0.78	0.66	0.32	0.22	0.13	0.19	0.16	0.34	1.21	1.88	1.71	1.31	0.39	10.46
800	0.32	0.24	0.61	0.78	0.66	0.32	0.22	0.13	0.19	0.16	0.34	1.21	1.88	1.71	1.31	0.39	10.46
900	0.32	0.24	0.56	0.69	0.42	0.16	0.13	0.13	0.19	0.16	0.32	1.16	1.73	1.52	1.14	0.39	9.26
1000	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1200	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1300	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1400	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1500	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1600	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1700	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1800	0.27	0.21	0.36	0.48	0.29	0.09	0.07	0.07	0.17	0.15	0.24	0.95	1.22	1.03	0.66	0.33	6.59
1900	0.27	0.21	0.36	0.48	0.29	0.09	0.07	0.07	0.17	0.15	0.24	0.95	1.22	1.03	0.66	0.33	6.59
2000	0.27	0.21	0.36	0.48	0.29	0.09	0.07	0.07	0.17	0.15	0.24	0.95	1.22	1.03	0.66	0.33	6.59
2100	0.27	0.21	0.14	0.19	0.08	0.05	0.03	0.07	0.17	0.15	0.12	0.4	0.59	0.48	0.41	0.33	3.7
2200	0.27	0.21	0	0	0	0	0	0.07	0.17	0.15	0	0	0	0	0	0.33	1.2
2300	0.17	0.14	0	0	0	0	0	0.03	0.12	0.09	0	0	0	0	0	0.19	0.73
2400	0.17	0.14	0	0	0	0	0	0.03	0.12	0.09	0	0	0	0	0	0.19	0.73
2500	0.17	0.14	0	0	0	0	0	0.03	0.12	0.09	0	0	0	0	0	0.19	0.73
2600	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
2700	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
2800	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
2900	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33

Table 5.3-8 (Sheet 2 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
3000	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
3100	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
3200	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
Winter																	
100	2.82	2.47	4.7	6.07	6.35	5.5	5.98	4.23	5.43	2.92	3.79	10.44	14.9	11.57	9.54	3.29	100
200	1.69	1.62	2.42	4.35	3.69	3.17	2.63	2.4	2.73	1.25	1.53	7.14	11.44	9	6.51	2.16	63.74
300	0.99	0.99	0.92	2.47	2.02	1.36	0.56	1.11	1.46	0.61	0.61	4.32	6.98	5.33	3.22	1.53	34.48
400	0.85	0.75	0.92	1.81	1.13	0.59	0.56	0.92	1.25	0.52	0.61	3.31	5.07	3.92	3.22	1.41	26.82
500	0.49	0.45	0.92	1.81	1.13	0.59	0.56	0.49	0.75	0.35	0.61	3.31	5.07	3.92	3.22	0.94	24.61
600	0.49	0.45	0.92	1.81	1.13	0.59	0.56	0.49	0.75	0.35	0.61	3.31	5.07	3.92	3.22	0.94	24.61
700	0.42	0.31	0.92	1.81	1.13	0.59	0.56	0.35	0.56	0.28	0.61	3.31	5.07	3.92	3.22	0.78	23.83
800	0.42	0.31	0.92	1.81	1.13	0.59	0.56	0.35	0.56	0.28	0.61	3.31	5.07	3.92	3.22	0.78	23.83
900	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.35	0.56	0.28	0.59	3.17	4.58	3.64	3.03	0.78	21.63
1000	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1100	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1200	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1300	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1400	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1500	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1600	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1700	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1800	0.42	0.31	0.56	1.24	0.59	0.16	0.14	0.21	0.49	0.23	0.42	2.51	3	2.56	1.97	0.7	15.54
1900	0.42	0.31	0.56	1.24	0.59	0.16	0.14	0.21	0.49	0.23	0.42	2.51	3	2.56	1.97	0.7	15.54
2000	0.42	0.31	0.56	1.24	0.59	0.16	0.14	0.21	0.49	0.23	0.42	2.51	3	2.56	1.97	0.7	15.54
2100	0.42	0.31	0.21	0.49	0.16	0.07	0.09	0.21	0.49	0.23	0.26	1.08	1.48	1.32	1.36	0.7	8.91
2200	0.42	0.31	0	0	0	0	0	0.21	0.49	0.23	0	0	0	0	0	0.7	2.37
2300	0.21	0.12	0	0	0	0	0	0.07	0.38	0.12	0	0	0	0	0	0.4	1.29
2400	0.21	0.12	0	0	0	0	0	0.07	0.38	0.12	0	0	0	0	0	0.4	1.29
2500	0.21	0.12	0	0	0	0	0	0.07	0.38	0.12	0	0	0	0	0	0.4	1.29
2600	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73

Table 5.3-8 (Sheet 3 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
2700	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
2800	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
2900	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
3000	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
3100	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
3200	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
Spring																	
100	3.65	3.28	4.92	5.84	8.44	6.96	5.15	3.82	6.75	3.93	5.42	9.18	12	8.88	8.1	3.69	100
200	1.37	1.33	1.55	2.73	3.4	1.89	0.9	0.95	1.68	0.75	0.73	2.09	4.97	4.72	2.99	1.66	33.7
300	0.51	0.62	0.58	1.48	1.81	1.03	0.22	0.28	0.43	0.39	0.3	0.97	2.45	2.22	1.04	0.82	15.15
400	0.37	0.47	0.58	0.78	0.91	0.43	0.22	0.17	0.34	0.34	0.3	0.56	1.49	1.45	1.04	0.75	10.19
500	0.21	0.3	0.58	0.78	0.91	0.43	0.22	0.09	0.11	0.22	0.3	0.56	1.49	1.45	1.04	0.32	9.02
600	0.21	0.3	0.58	0.78	0.91	0.43	0.22	0.09	0.11	0.22	0.3	0.56	1.49	1.45	1.04	0.32	9.02
700	0.15	0.21	0.58	0.78	0.91	0.43	0.22	0.04	0.07	0.19	0.3	0.56	1.49	1.45	1.04	0.2	8.63
800	0.15	0.21	0.58	0.78	0.91	0.43	0.22	0.04	0.07	0.19	0.3	0.56	1.49	1.45	1.04	0.2	8.63
900	0.15	0.21	0.54	0.71	0.47	0.17	0.11	0.04	0.07	0.19	0.28	0.52	1.42	1.31	0.93	0.2	7.31
1000	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1100	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1200	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1300	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1400	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1500	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1600	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1700	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1800	0.13	0.17	0.35	0.49	0.37	0.11	0.06	0.04	0.06	0.19	0.26	0.5	1.06	0.88	0.48	0.17	5.32
1900	0.13	0.17	0.35	0.49	0.37	0.11	0.06	0.04	0.06	0.19	0.26	0.5	1.06	0.88	0.48	0.17	5.32
2000	0.13	0.17	0.35	0.49	0.37	0.11	0.06	0.04	0.06	0.19	0.26	0.5	1.06	0.88	0.48	0.17	5.32
2100	0.13	0.17	0.06	0.15	0.13	0.09	0.04	0.04	0.06	0.19	0.11	0.17	0.5	0.26	0.24	0.17	2.49
2200	0.13	0.17	0	0	0	0	0	0.04	0.06	0.19	0	0	0	0	0	0.17	0.75
2300	0.09	0.11	0	0	0	0	0	0	0.04	0.15	0	0	0	0	0	0.09	0.49

Table 5.3-8 (Sheet 4 of 6)
Annual Plume Length Frequency

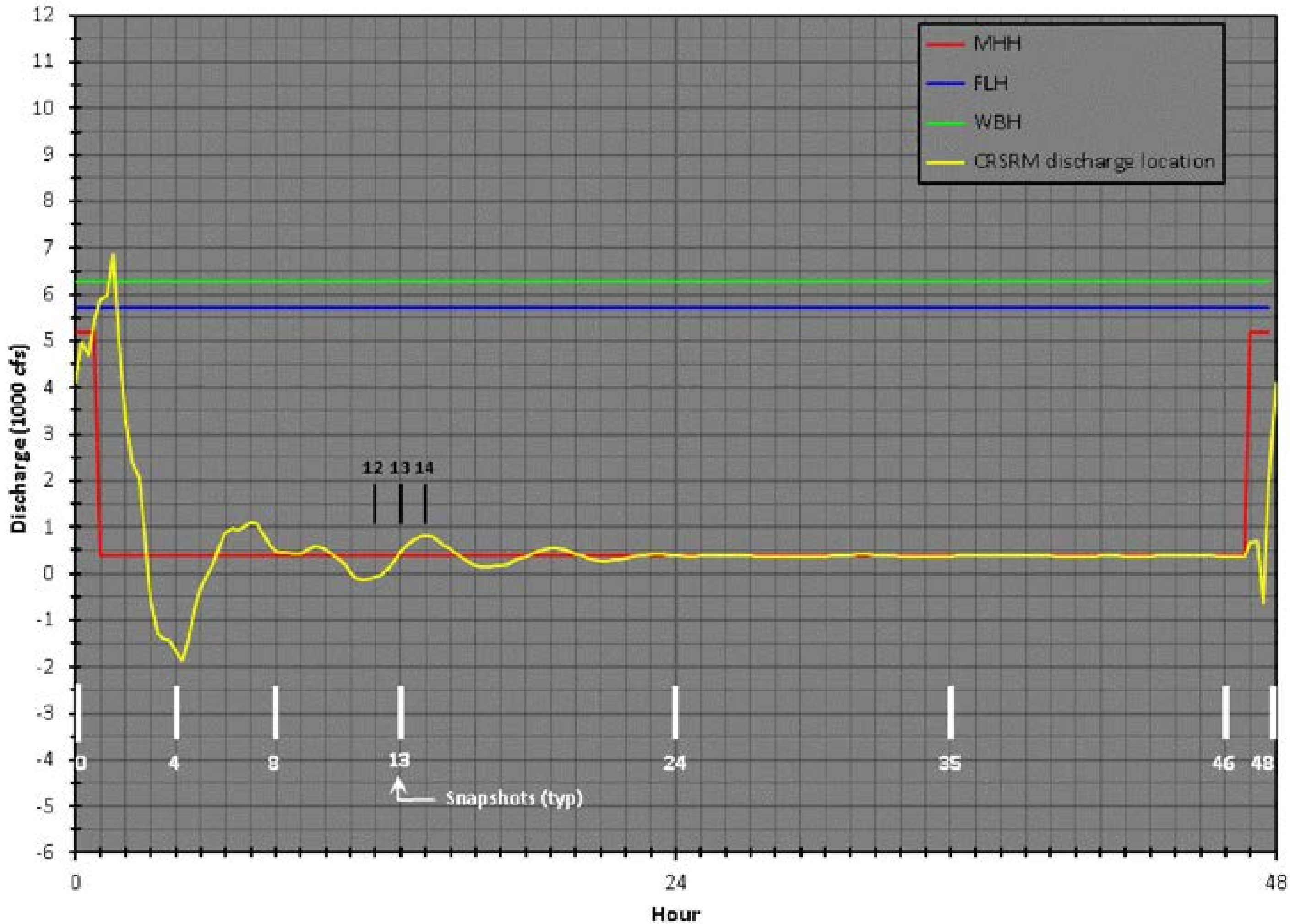
Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
2400	0.09	0.11	0	0	0	0	0	0	0.04	0.15	0	0	0	0	0	0.09	0.49
2500	0.09	0.11	0	0	0	0	0	0	0.04	0.15	0	0	0	0	0	0.09	0.49
2600	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
2700	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
2800	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
2900	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
3000	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
3100	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
3200	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
Summer																	
100	6.43	5.72	6.12	5.94	8.98	5.69	4.02	3.15	5.62	3.58	5.53	8.86	10.6	8.09	7.31	4.34	100
200	0.91	0.87	0.84	0.98	1.7	0.9	0.46	0.6	0.91	0.48	0.38	1.07	1.13	1.55	0.8	0.89	14.47
300	0.29	0.2	0.21	0.19	0.65	0.42	0.08	0.15	0.27	0.17	0.1	0.39	0.36	0.52	0.17	0.21	4.38
400	0.17	0.12	0.21	0.04	0.21	0.1	0.08	0.15	0.21	0.1	0.1	0.19	0.1	0.27	0.17	0.17	2.38
500	0.08	0.04	0.21	0.04	0.21	0.1	0.08	0.1	0.06	0.1	0.1	0.19	0.1	0.27	0.17	0.1	1.92
600	0.08	0.04	0.21	0.04	0.21	0.1	0.08	0.1	0.06	0.1	0.1	0.19	0.1	0.27	0.17	0.1	1.92
700	0.06	0.04	0.21	0.04	0.21	0.1	0.08	0.08	0.04	0.04	0.1	0.19	0.1	0.27	0.17	0.1	1.81
800	0.06	0.04	0.21	0.04	0.21	0.1	0.08	0.08	0.04	0.04	0.1	0.19	0.1	0.27	0.17	0.1	1.81
900	0.06	0.04	0.21	0.02	0.08	0.06	0.08	0.08	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.1	1.29
1000	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1100	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1200	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1300	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1400	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1500	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1600	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1700	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1800	0.04	0.04	0.15	0.02	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.16	0.06	0.06	0.04	0.06	0.95
1900	0.04	0.04	0.15	0.02	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.16	0.06	0.06	0.04	0.06	0.95

Table 5.3-8 (Sheet 5 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
2000	0.04	0.04	0.15	0.02	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.16	0.06	0.06	0.04	0.06	0.95
2100	0.04	0.04	0.11	0	0	0	0	0.04	0.04	0.04	0	0.02	0.02	0	0	0.06	0.4
2200	0.04	0.04	0	0	0	0	0	0.04	0.04	0.04	0	0	0	0	0	0.06	0.25
2300	0.04	0.04	0	0	0	0	0	0.02	0.02	0.02	0	0	0	0	0	0.04	0.18
2400	0.04	0.04	0	0	0	0	0	0.02	0.02	0.02	0	0	0	0	0	0.04	0.18
2500	0.04	0.04	0	0	0	0	0	0.02	0.02	0.02	0	0	0	0	0	0.04	0.18
2600	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
2700	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
2800	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
2900	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
3000	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
3100	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
3200	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
									Fall								
100	4.82	3.78	5.56	5.19	7.63	6.59	6.27	3.8	5.81	3.13	4.73	8.16	11.9	9.69	8.24	4.68	100
200	2.34	1.69	2.27	2.55	3.17	2.06	1.48	1.18	1.8	0.9	0.9	2.85	5.34	5.53	3.54	2.34	39.92
300	1.32	1.13	0.82	1.39	1.34	0.88	0.07	0.46	0.6	0.42	0.42	1.72	2.83	2.92	1.14	1.62	19.08
400	1.18	0.93	0.82	0.65	0.44	0.19	0.07	0.44	0.53	0.35	0.42	1.16	1.4	1.61	1.14	1.27	12.6
500	0.81	0.53	0.82	0.65	0.44	0.19	0.07	0.16	0.35	0.28	0.42	1.16	1.4	1.61	1.14	0.72	10.75
600	0.81	0.53	0.82	0.65	0.44	0.19	0.07	0.16	0.35	0.28	0.42	1.16	1.4	1.61	1.14	0.72	10.75
700	0.75	0.47	0.82	0.65	0.44	0.19	0.07	0.07	0.14	0.16	0.42	1.16	1.4	1.61	1.14	0.61	10.09
800	0.75	0.47	0.82	0.65	0.44	0.19	0.07	0.07	0.14	0.16	0.42	1.16	1.4	1.61	1.14	0.61	10.09
900	0.75	0.47	0.77	0.56	0.33	0.14	0.05	0.07	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.61	9.18
1000	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1100	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1200	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1300	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76

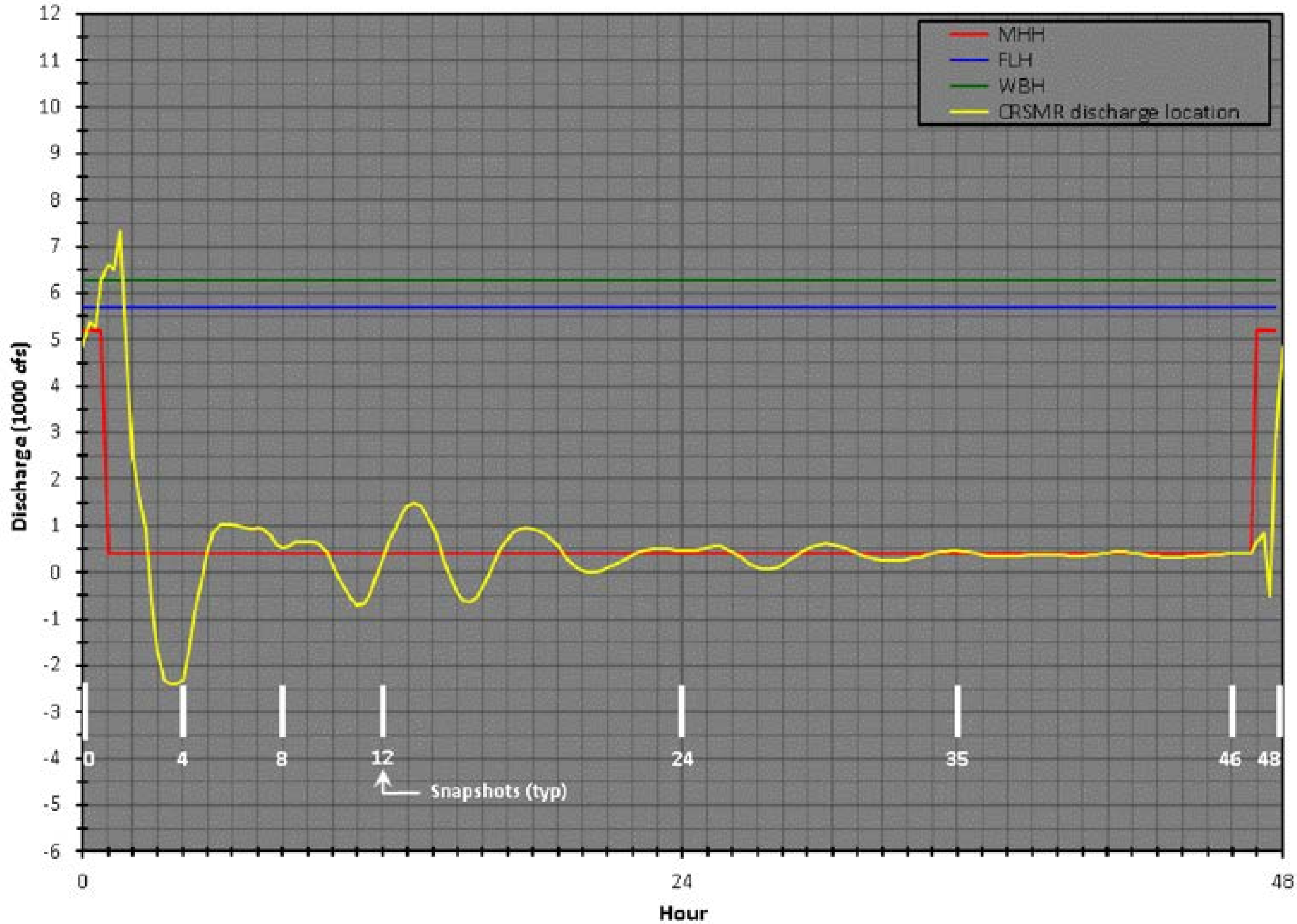
Table 5.3-8 (Sheet 6 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
1400	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1500	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1600	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1700	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1800	0.56	0.4	0.42	0.28	0.19	0.05	0.02	0.02	0.14	0.16	0.26	0.93	1.04	0.9	0.35	0.49	6.2
1900	0.56	0.4	0.42	0.28	0.19	0.05	0.02	0.02	0.14	0.16	0.26	0.93	1.04	0.9	0.35	0.49	6.2
2000	0.56	0.4	0.42	0.28	0.19	0.05	0.02	0.02	0.14	0.16	0.26	0.93	1.04	0.9	0.35	0.49	6.2
2100	0.56	0.4	0.21	0.18	0.05	0.02	0	0.02	0.14	0.16	0.14	0.46	0.53	0.51	0.18	0.49	4.06
2200	0.56	0.4	0	0	0	0	0	0.02	0.14	0.16	0	0	0	0	0	0.49	1.77
2300	0.37	0.3	0	0	0	0	0	0.02	0.09	0.09	0	0	0	0	0	0.28	1.16
2400	0.37	0.3	0	0	0	0	0	0.02	0.09	0.09	0	0	0	0	0	0.28	1.16
2500	0.37	0.3	0	0	0	0	0	0.02	0.09	0.09	0	0	0	0	0	0.28	1.16
2600	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
2700	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
2800	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
2900	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
3000	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
3100	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
3200	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53



Notes:
Snapshots are provided in Figure 5.3-3
MHH = Melton Hill Hydro plant
FLH = Fort Loudoun Hydro plant
WBH = Watts Bar Hydro plant
CR SMR = Clinch River Small Modular Reactor

Figure 5.3-1. River Flows for PPE Extreme Winter Conditions, Full Power



Note:
Snapshots are provided in Figure 5.3-4

Figure 5.3-2. River Flows for PPE Extreme Summer Conditions, Full Power

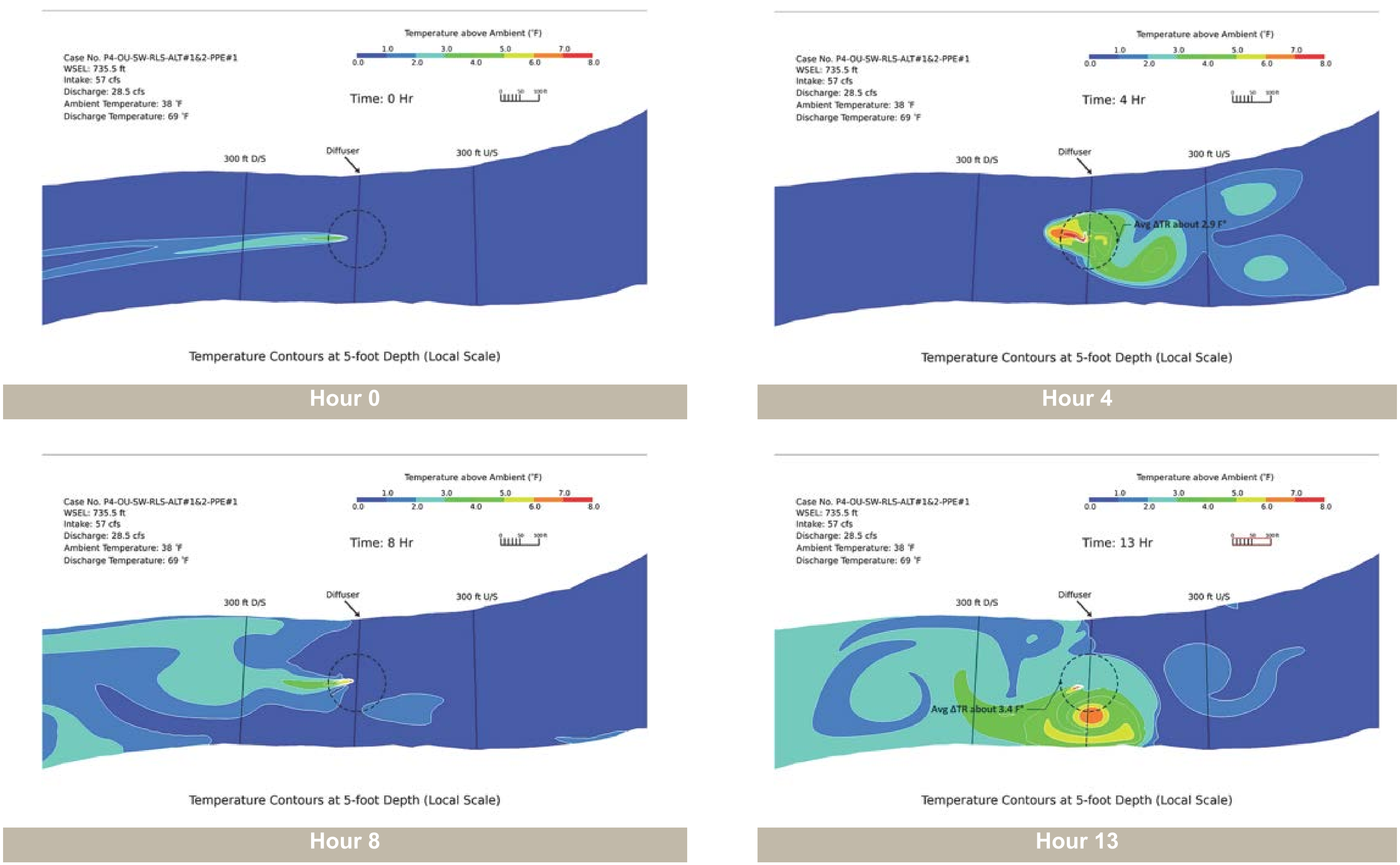


Figure 5.3-3. (Sheet 1 of 2) Temperatures at 5-Foot Depth for PPE Extreme Winter Conditions, Full Power

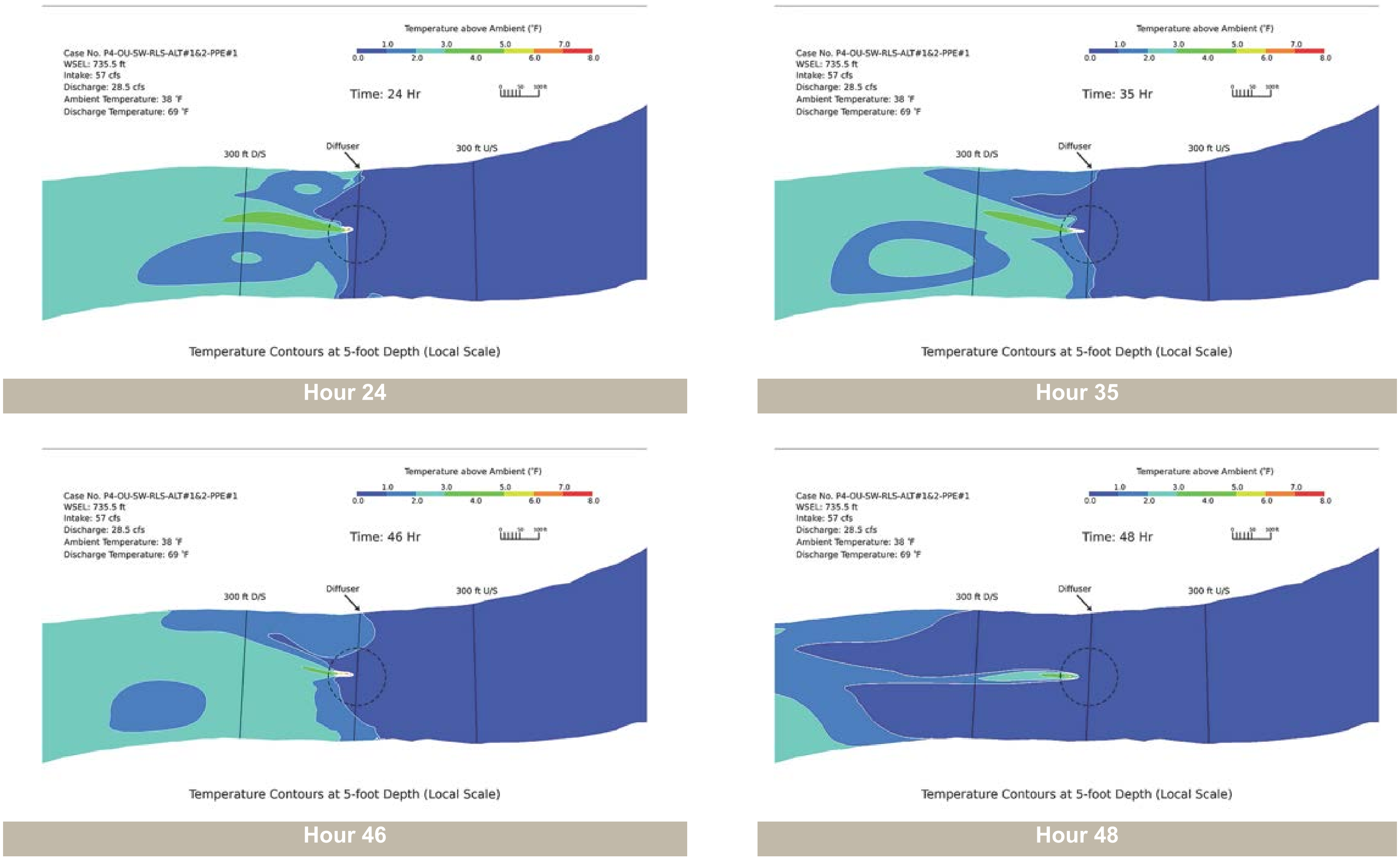


Figure 5.3-3. (Sheet 2 of 2) Temperatures at 5-Foot Depth for PPE Extreme Winter Conditions, Full Power

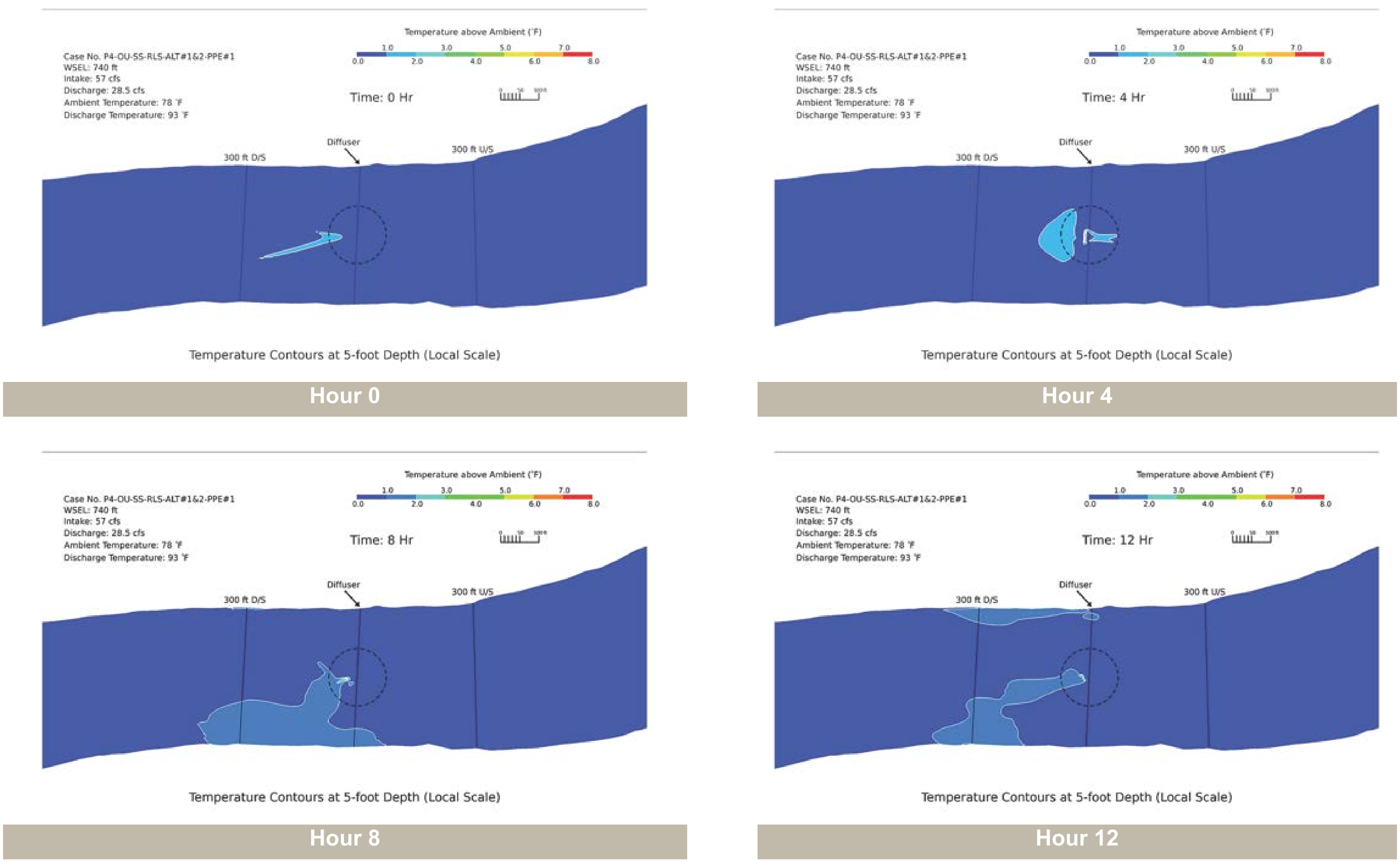


Figure 5.3-4. (Sheet 1 of 2) Temperatures at 5-Foot Depth for PPE Extreme Summer Conditions, Full Power

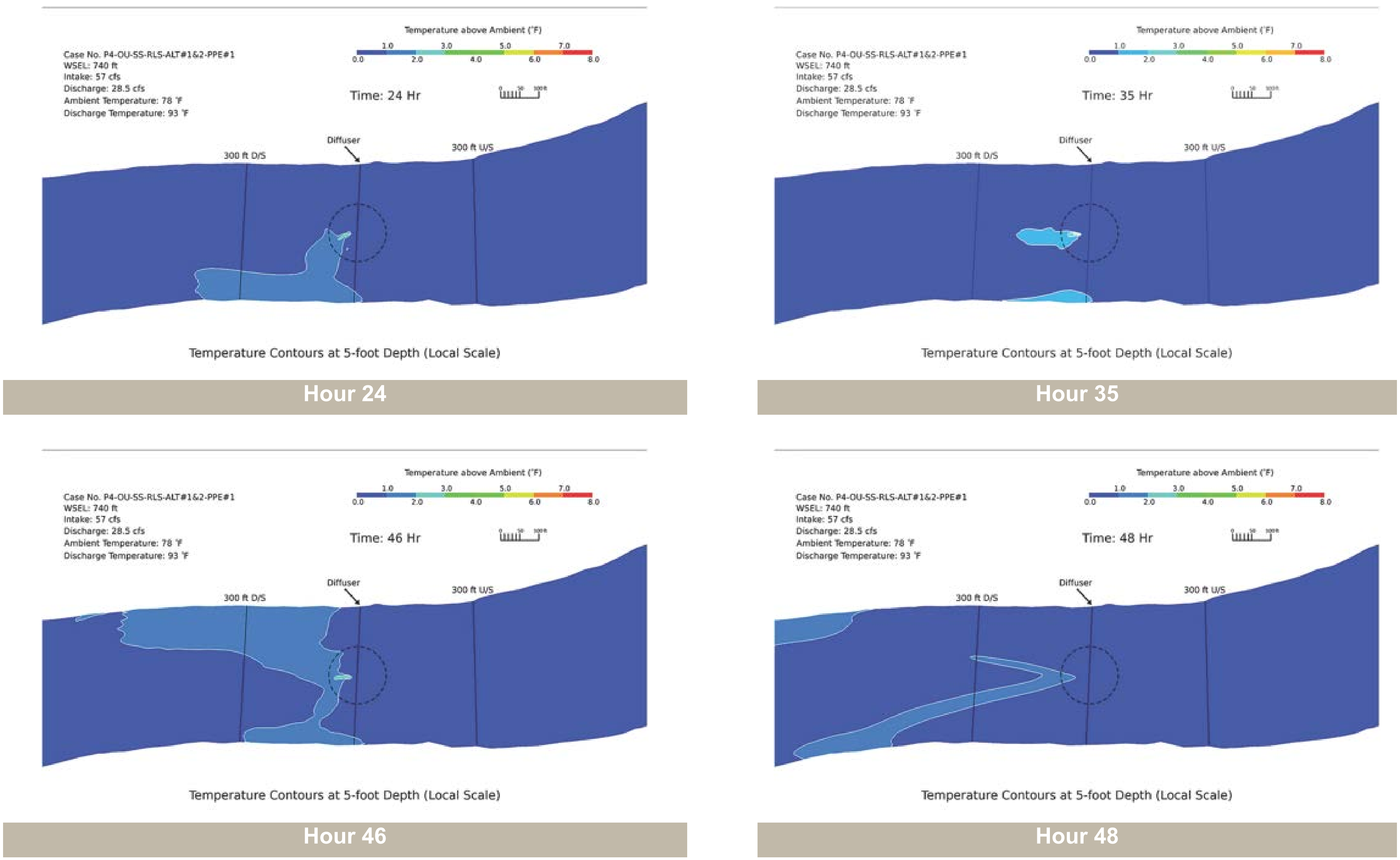
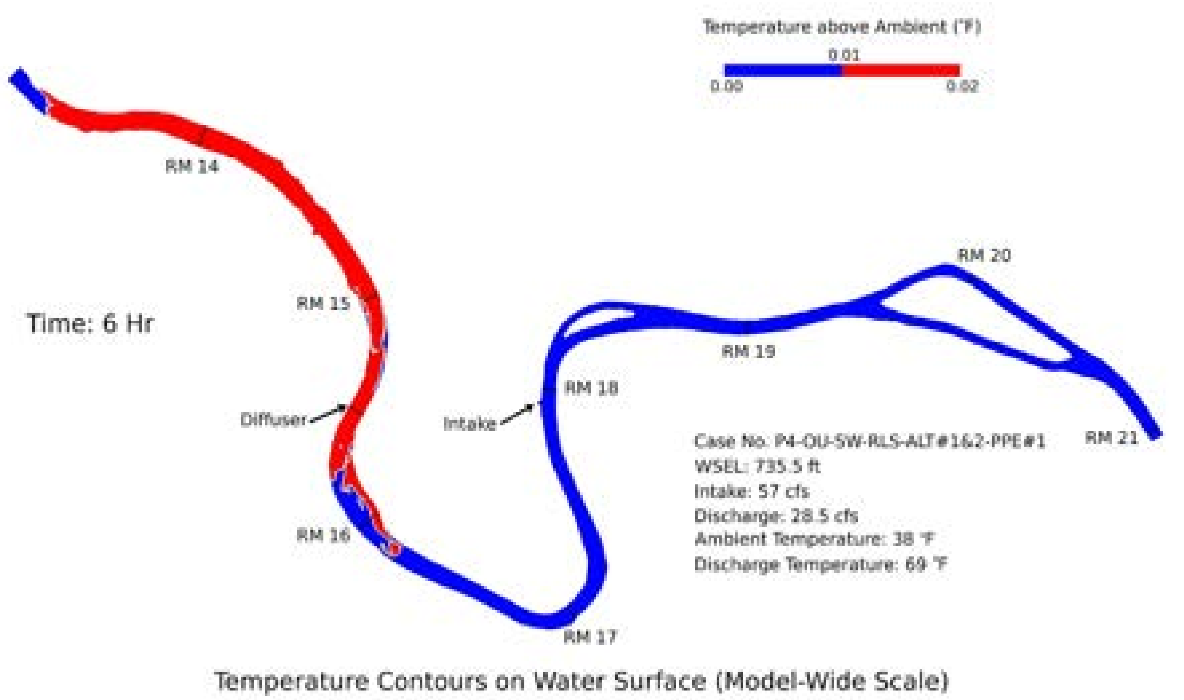


Figure 5.3-4. (Sheet 2 of 2) Temperatures at 5-Foot Depth for PPE Extreme Summer Conditions, Full Power



Hour 6

Figure 5.3-5. Approximate Zone of Influence of SMR Thermal Effluent at Water Surface for PPE Extreme Winter Conditions, Full Power

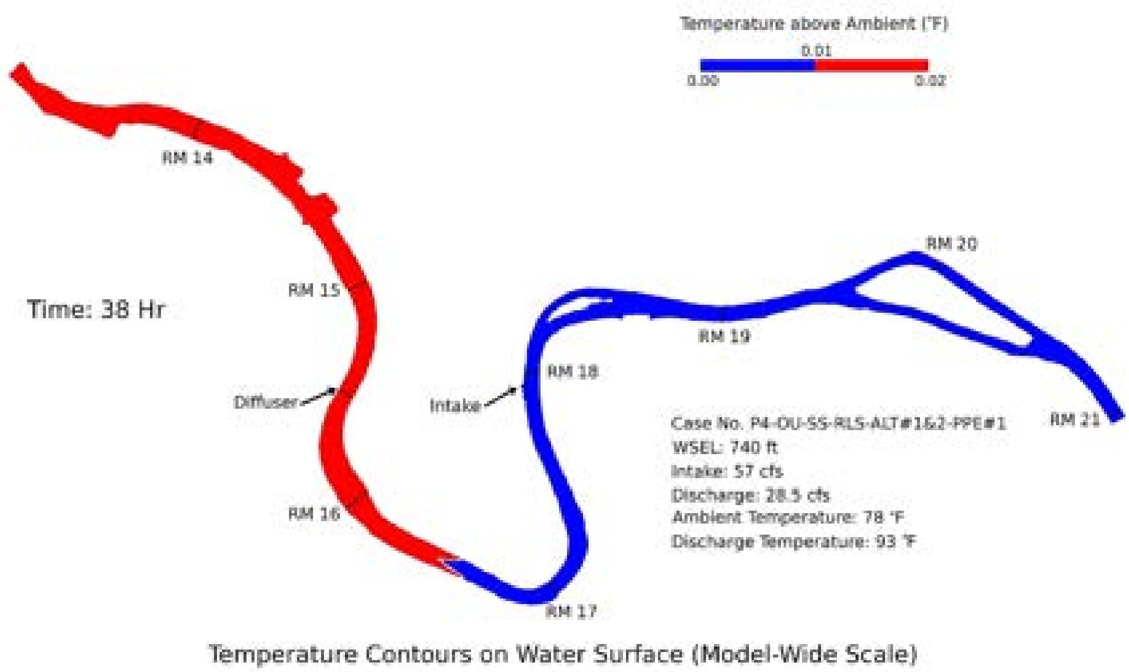


Figure 5.3-6. Approximate Zone of Influence of SMR Thermal Effluent at Water Surface for PPE Extreme Summer Conditions, Full Power

5.4 RADIOLOGICAL IMPACTS OF NORMAL OPERATION

This section describes the radiological impacts of normal operations of the Clinch River (CR) Small Modular Reactor (SMR) Project on members of the public and the biota of terrestrial and aquatic ecosystems. As discussed in Section 3.9, the SMRs would be manufactured in a factory and shipped to the Clinch River Nuclear (CRN) Site. The number of SMR units would vary depending on the SMR design selected. In most SMR designs, the reactor containment vessel is underground. Because a final SMR design has not yet been selected, a plant parameter envelope, described in Section 3.1, was developed for use in evaluating potential environmental impacts from normal operations of the CR SMR Project.

Subsection 5.4.1 describes the environmental pathways by which radiation and radiological effluents from the facility may be transmitted to living organisms in and around the CRN Site. Subsection 5.4.2 estimates individual and collective doses to members of the public from gaseous and liquid effluents from normal SMR operations, as well as from increased ambient background radiation levels from the facility. Subsection 5.4.3 evaluates the impacts of these doses by comparing them to regulatory limits. Subsection 5.4.4 evaluates the impact to non-human biota.

5.4.1 Exposure Pathways

Living organisms in the vicinity of the CR SMR Project may be exposed to radiological releases from normal facility operations. Small quantities of radioactive gases and liquids are expected to be released to the environment during normal operation of SMRs at the CRN Site. Radiological exposure due to operation of the SMRs is highly dependent on the pathways by which a receptor may become exposed to radiological releases from the facility. The major pathways of concern are those that could result in the highest offsite radiological dose. The relative importance of a pathway depends on the type and amount of radioactivity released, its environmental transport mechanism, and usage of the land surrounding the CRN Site (e.g., residence, gardens, etc.). Factors such as the relative location of homes and the local production of milk cattle and vegetable gardens are taken into consideration when evaluating pathways of radiological exposure. In addition, the environmental transport mechanisms for gaseous effluents are dependent on the meteorological characteristics of the area.

Radioactive gaseous effluent pathways include direct radiation, deposition on plants and soil, and inhalation by humans and animals. Radioactive liquid effluent pathways include consumption of fish, drinking of water from downstream sources, and direct exposure from radionuclides that may be deposited in the Clinch River arm of Watts Bar Reservoir. An additional exposure pathway is direct radiation from the SMRs during normal operation.

Radiation doses to humans from the potential release of radionuclides during operation of the SMRs have been evaluated for gaseous emissions released to the atmosphere and for liquid effluents released into the Clinch River arm of the Watts Bar Reservoir. The critical pathways to humans for routine releases at the CRN Site are radiation exposure from submersion in air, inhalation of contaminated air, drinking milk from an animal that feeds on open pasture near the CRN Site, eating vegetables and meat raised near the CRN Site, eating fish caught in the Clinch River arm of Watts Bar Reservoir, and drinking water from downstream sources. Other less significant pathways considered include: external irradiation from radionuclides deposited on the ground surface, activities on the shoreline of the Clinch River arm of the Watts Bar Reservoir, and direct radiation from the SMRs. The relative importance of the potential pathways to humans has been evaluated by calculating the doses from routine operations for each pathway. Calculation assumptions, methodology, results, and conclusions are presented in the following subsections.

The release of small amounts of radioactive effluents is permitted as long as releases comply with the requirements in Title 10 of the Code of Federal Regulations (10 CFR) Part 20 and 40 CFR Part 190. The design and operation of the SMRs at the CRN Site will also limit gaseous and liquid effluent releases such that doses to the public would be as low as reasonably achievable (ALARA) in accordance with the objectives of 10 CFR 50, Appendix I.

The exposure pathways considered and the calculation methods used to estimate doses to the maximally exposed individual (MEI) and to the population surrounding the CRN Site were based on U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50*, Appendix I and on NRC RG 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*. The MEI is defined as a member of the general public at an assumed location that results in the maximum possible calculated dose. The exposure pathway parameters are provided in Tables 5.4-1, 5.4-2, and 5.4-3 for the liquid pathways and Table 5.4-4 for the gaseous pathways. The projected population distribution in the year 2067 within 50 mile (mi) of the CRN Site is provided in Table 5.4-5. The source terms used in estimating exposure pathway doses were based on the total projected bounding site release activity levels provided in Tables 3.5-1 and 3.5-2 releases for all units and individual units, respectively. The source terms for gaseous releases are provided in Tables 3.5-3 and 3.5-4 for all units and individual units, respectively. There are no unusual animals, plants, agricultural practices, game harvests, or food processing operations within the surrounding region requiring special consideration.

5.4.1.1 Liquid Pathways

The pathways evaluated for exposure to liquid effluents from normal facility operations include ingestion of contaminated fish or invertebrates and ingestion of contaminated drinking water. Exposure to liquid effluents from normal operations also may occur through shoreline, swimming, and boating activities occurring downstream of the facility discharge location on the Clinch River arm of the Watts Bar Reservoir.

Liquid effluent discharge is assumed to be fully mixed with the flow in the Clinch River arm of the Watts Bar Reservoir. As described in Subsection 5.2.1.1.1, the overall average release from

Melton Hill Dam for 2004 through 2013, and consequently the expected approximate average river flow past the CRN Site during operations, is approximately 4670 cubic feet per second (cfs). For the purpose of this analysis, the mean flow rate over the course of a year is assumed to be 4000 cfs. The use of this flow is conservative because mixing the discharge into a smaller volume yields higher activity concentrations. In addition, transit time from liquid discharge to receptor is conservatively assumed to be zero. Thus, other than the distribution times built into the LADTAP II computer code, no decay time is applied to reduce the activity of the radioactive liquid effluent between discharge and exposure.

5.4.1.2 Gaseous Pathways

The exposure pathways evaluated for gaseous effluents from normal facility operations include external exposure to (submersion in) gases in the air, external exposure to ground contaminated by gaseous deposition, and inhalation of airborne activity. Exposure to gaseous effluents also may occur through ingestion of contaminated milk, meat, and vegetables.

5.4.1.3 Direct Radiation from SMRs

An NRC evaluation of operating nuclear plants in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, states:

> “Direct radiation from sources within a light water reactor (LWR) plant is due primarily to nitrogen-16, a radionuclide produced in the reactor core by neutron activation of oxygen-16 from the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of LWRs are generally undetectable and less than 1 mrem/year at the site boundary.”

Thus, data from operating reactors indicate that direct radiation doses from large operating pressurized water reactors are negligible. The statement from NUREG-1437, Rev. 1 can be extrapolated to conclude that direct radiation doses from multiple SMRs with a total electric power generation not greater than 1000 megawatts electric are also expected to be less than 1 millirem per year (mrem/yr). Similarly, based on dose rate modeling results for the AP1000, a reactor much larger in size than the SMRs, direct radiation from the containment and other buildings would be negligible at the site boundary (Reference 5.4-1).

5.4.2 Radiation Dose Modeling

This subsection describes the methodology, data, and results of the evaluation of radiation doses to members of the public. LADTAP II and GASPAR II are the computer models used to evaluate doses to members of the public from liquid and gaseous effluents, respectively, released from normal operations of the SMRs at the CRN Site. The annual consumption and usage rates for the average individual and the MEI were taken from NRC RG 1.109 Tables E-4 and E-5, respectively. LADTAP II and GASPAR II use the maximum rates in calculating individual doses and the average rates in calculating population doses.

Production rates for agricultural commodities within 50 mi of the CRN Site were determined for use in the LADTAP II and GASPAR II models. Vegetable production rates within 50 mi of the CRN Site are assumed to be equal to the state production rates multiplied by the fraction of the state harvested land area that falls within the 50-mi radius. Similarly, milk and meat production rates within 50 mi of the CRN Site are assumed to be equal to the state production rates multiplied by the respective fractions of the state milk and meat animals that reside within the 50-mi radius. Food production rates are assumed to increase proportionally with population increases within 50 mi of the CRN Site. This is conservative because the guidance in NUREG-1555, Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan, requires the use of only present production rates for calculating population doses. Table 5.4-6 shows the annual production rate of foods in Tennessee, and Table 5.4-7 shows the vegetable, milk and meat production rates within 50 mi of the facility.

No dose modeling was conducted to evaluate the dose from the direct radiation pathway. As discussed in Subsection 5.4.1.3, the direct radiation doses from the SMRs are expected to be negligible. However, it was conservatively assumed that the total direct radiation dose from all SMR units on the CRN Site would be 1 mrem/yr at the site boundary.

5.4.2.1 Liquid Pathways

The LADTAP II computer program, as described in NUREG/CR-4013, LADTAP II – Technical Reference and User Guide, was used to calculate doses to the MEI and to the general population surrounding the CRN Site from normal operations of the SMRs at the CRN Site. This program implements the radiological exposure models described in NRC RG 1.109 to estimate the dose resulting from radioactive releases in liquid effluents.

LADTAP II was used to evaluate both internal and external doses to the MEI and the general population from radionuclides in liquid effluents based on the following pathways:

- Internal exposure from ingestion of aquatic foods
- Internal exposure from ingestion of drinking water
- Internal exposure from ingestion of milk and meat from livestock consuming water and pasture feed from farms irrigated by contaminated water
- Internal exposure from ingestion of vegetables and fruits from farms irrigated by contaminated water
- External exposure to shoreline sediments
- External exposure from boating and swimming

Input parameters for LADTAP II are detailed in Tables 5.4-1 through 5.4-3. Table 5.4-1 presents the fish and invertebrate consumption rates and aquatic recreation usage rates used for the average individual and the MEI. The values are taken from NRC RG 1.109 Tables E-4 and E-5, respectively.

Table 5.4-2 provides population consumption rates of aquatic food obtained from the Clinch River arm of Watts Bar Reservoir for the projected 2067 population within 50 mi of the CRN Site. These consumption rates are based on the assumption that 50 percent of the fish and invertebrate consumed by the population within 50 mi comes from the Clinch River arm of Watts Bar Reservoir. Table 5.4-2 identifies the portion of the consumption that represents aquatic food obtained by sport fishers and the portion that represents commercially caught aquatic food, and it provides details on how these values were calculated.

Table 5.4-3 identifies the primary liquid pathway parameters used in the LADTAP II program to estimate radioactive exposures due to liquid effluents from the SMRs at the CRN Site. An explanation of each of the parameters is provided in the table footnotes.

5.4.2.2 Gaseous Pathways

The GASPAR II computer program was used to calculate doses from gaseous pathways to offsite receptors from normal operations of the SMRs at the CRN Site. This program, described in NUREG/CR-4653, *GASPAR II – Technical Reference and User Guide,* implements the radiological exposure models described in NRC RG 1.109 for radioactivity releases in gaseous effluents. As discussed in Subsection 2.7.6, routine dilution and deposition estimates were calculated using the XOQDOQ-82 modeling program, which is the dispersion model for evaluating routine releases recommended by NRC in NUREG/CR-2919, *XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations*. Site-specific, validated meteorological data for June 2011 through May 2013 were used as input to the model. The site-specific dilution and deposition estimates were used by the GASPAR II computer program to calculate radiation doses.

By using projections of food production and consumption rates coupled with the projected population within a 50-mi radius of the CRN Site, GASPAR II evaluated both external and internal exposures to gaseous effluents from the operation of SMRs at the CRN Site based on the following pathways:

- External exposure to gases
- External exposure to ground contaminated by gases
- Inhalation of gases
- Ingestion of milk contaminated from the grass-to-cow-to-milk pathway
- Ingestion of contaminated vegetables and meats

Table 5.4-4 identifies the gaseous pathway parameters used in the GASPAR II computer program, including current and projected milk, meat, and vegetable production within 50 mi of the CRN Site. Annual consumption rates for the average individual and the MEI were obtained from NRC RG 1.109 Tables E-4 and E-5, respectively. Table 5.4-5 presents the projected total 2067 population within a 50-mi radius of the CRN Site as a function of direction and distance.

5.4.3 Impacts to Members of the Public

This subsection summarizes the impacts to individuals from radioactive effluents released in the course of normal operation of the SMRs at the CRN Site. Impacts to the public are evaluated by comparing estimated dose to regulatory acceptance criteria. Doses to the MEI and collective doses to the public were evaluated.

Doses to the MEI from liquid effluent from all units are shown in Table 5.4-8 (per SMR unit) and 5.4-9 (all units), and doses from gaseous effluent are shown in Tables 5.4-10 (per SMR unit) and 5.4-11 (all units). Collective doses to the population from liquid and gaseous effluents are shown in Tables 5.4-12 and 5.4-13, respectively. Gaseous effluent doses to the thyroid of the MEI from iodines and particulates are shown in Table 5.4-14.

Table 5.4-15 summarizes the estimated doses to the MEI per operating unit of the CR SMR Project and compares them to the ALARA design objectives from 10 CFR Part 50, Appendix I to determine compliance with dose rates protective of the general public. All of the doses are less than or equal to the corresponding regulatory dose limits in 10 CFR Part 50, Appendix I; thus, the criteria are met.

Annual doses to the MEI from the SMRs at the CRN Site are summarized in Table 5.4-16. The sum of the direct radiation dose, liquid effluent dose, and gaseous effluent dose yields an annual total body dose of 11.0 mrem/yr. (As discussed in Subsections 5.4.1.3 and 5.4.2, the direct radiation dose would be negligible but is assumed to be 1 mrem/yr.) Similarly, the sum of direct, liquid, and gaseous contributions for the thyroid and the bone pathways yields a total dose of 25 mrem/yr and 24 mrem/yr respectively. The U.S. Environmental Protection Agency (EPA) radiation protection standards in 40 CFR Part 190 provide criteria that apply to the annual dose equivalent received by members of the general public exposed to planned discharges of radioactive materials from the operation of nuclear power plants. The most restrictive portion of the standards specified in this regulation states that the annual dose equivalent shall not exceed 25 mrem/yr to the whole body. The regulation also provides standards limiting the annual dose equivalent to the thyroid (75 mrem/yr) and any other organ (25 mrem/yr). As shown in Table 5.4-16, the total body annual dose, estimated to be 11.0 mrem/yr, is below the limit of 25 mrem/yr. Similarly, total doses to the thyroid and bone also are below their respective limits. This annual dose was compared to EPA's environmental radiation protection standards for individual members of the public from 40 CFR 190.10 to determine compliance. All of the doses are less than the corresponding regulatory dose limits; thus the criteria are met. As indicated in NUREG-1555, demonstration of compliance with the limits of 40 CFR 190 is considered to also indicate compliance with the 100 mrem limit in 10 CFR 20.1301.

Annual collective doses to the public based on the population within 50 mi of the CRN Site also were estimated based on the operation of all SMR units. Table 5.4-17 shows the total body and thyroid doses from all liquid and gaseous pathways expressed in units of person-rems per year (person-rem/yr). For comparison, Table 5.4-17 also includes the annual collective background radiation dose calculated from the estimated population within 50 mi of the CRN Site in 2067 and the average natural background dose in the United States of approximately 311 mrem/yr. The total of the doses to the population for the total body (68 person-rem/yr) and thyroid (100 person-rem/yr) are negligible compared to the background dose of 820,000 person-rem/yr.

Because the doses to members of the public from operation of the SMRs at the CRN Site are calculated to be within the regulatory limits for protection of the MEI and the contribution to the collective population dose is estimated to be negligible compared to background, the radiological impacts to members of the public from normal operation of the CR SMR Project would be SMALL.

5.4.4 Impacts to Biota Other than Members of the Public

This subsection examines radiation exposure pathways to biota other than members of the public to determine if these pathways could result in doses to biota greater than the doses predicted for humans. This assessment uses surrogate biota species that provide representative information on the various dose pathways potentially affecting broader classes of living organisms, including the important terrestrial and aquatic species identified in Section 2.4. Surrogates are used because important attributes are well defined and are accepted as a method for judging doses to biota. As described in NUREG/CR-4013 the use of surrogate biota in this analysis includes the use of algae as a surrogate for aquatic plants and the use of invertebrates as a surrogate for freshwater mollusks and crayfish. Other surrogates used in this analysis include fish, muskrat, raccoon, heron, and duck. There are no unusual plants, animals, or pathways in the vicinity of the CRN Site that would require specific evaluation.

Doses to surrogate biota from liquid effluents were calculated using the LADTAP II program and the parameters included in the computer program. As described in NUREG-CR/4013, pathways evaluated for aquatic biota include internal exposure from bioaccumulation and external exposure from swimming and the shoreline. Exposure pathways for terrestrial biota include ingestion of aquatic biota and external exposure from swimming and the shoreline. Liquid effluent doses to biota from the operation of SMRs at the CRN Site are shown in Table 5.4-18. Doses range from 1.3 millirad per year (mrad/yr) for the raccoon to 8.9 mrad/yr for the heron.

Because the GASPAR II program does not perform biota dose calculations, the human doses calculated for the gaseous pathway were assumed to be applicable to biota. Because biota are closer to the ground than are humans, the ground deposition doses calculated by the GASPAR II computer program were doubled. This is consistent with the approach used for biota in LADTAP II. The nearest terrestrial biota were assumed to be exposed to gaseous effluents at a distance of 0.25 mi from the SMR release point. It was also assumed that the internal dose and the external plume dose received by the biota are the same as the doses received by humans.

This is reasonable because the plume dose is independent of the size of the receptor, and it is conservative because the internal dose for humans is based on a much longer retention period than would be expected for biota. As shown in Table 5.4-19, the highest of the total body doses for the child, teen, and adult was identified as the biota dose for the inhalation, vegetable consumption, plume immersion, and ground deposition pathways. The total biota dose from all four pathways is 84 millirads per year (mrad/yr).

The total doses to surrogate biota from liquid and gaseous effluents released from normal operations of the SMRs at the CRN Site are shown in Table 5.4-20. The total dose to each of the biota was calculated by summing the annual doses from gaseous and liquid pathways in mrad/yr. The total doses also were converted to units of mrad/day for comparison to criteria for the protection of biota.

Use of exposure guidelines, such as 40 CFR Part 190, which apply to members of the public in unrestricted areas, is considered very conservative when evaluating calculated doses to biota. As noted in NUREG-1555, Subsection 5.4.4, the International Council on Radiation Protection states "… if man is adequately protected then other living things are also likely to be sufficiently protected" and uses human protection to infer environmental protection from the effects of ionizing radiation.

As stated in NUREG-1555, "species in most ecosystems experience rather high mortality rates from natural causes." From an ecological viewpoint, population stability is considered more important to the survival of a species than individual mortality. In addition, no biota have been discovered that show significant changes in morbidity or mortality due to radiation exposures predicted for nuclear power plants.

The National Academy of Sciences-National Research Council's Committee on the Biological Effects of Ionizing Radiation concludes that the evidence indicates that no other living organisms have been identified that are likely to be significantly more radiosensitive than members of the public (Reference 5.4-2). The Department of Energy (DOE) Order 458.1, Radiation Protection of the Public and the Environment, identifies dose rate criteria to protect aquatic and terrestrial biota from adverse effects due to radiation released from DOE operations (Reference 5.4-3). These criteria, provided in DOE Standard 1153-2002, are 1 rad/day for aquatic animals and 0.1 rad/day for terrestrial animals. Existing effects data support the application of these dose limits to representative individuals within the population of animals (Reference 5.4-4). As shown in Table 5.4-20, total doses to the surrogate aquatic animals are 0.0045 mrad/day for fish and 0.021 mrad/day for invertebrates. For surrogate terrestrial biota, total body doses range from 0.23 mrad/day for the raccoon to 0.25 mrad/day for the heron. The highest of these doses (0.021 mrad/day for aquatic biota and 0.25 mrad/day for terrestrial biota) are significantly less than their respective dose rate criteria (1 rad/day and 0.1 rad/day). The permissible dose rates given in 40 CFR Part 190 are considered screening levels and higher species-specific dose rates could be acceptable with additional study or data. Because the doses to surrogate biota presented in Table 5.4-20 are significantly below the dose rate criteria specified by DOE, the impact to biota other than members of the public due to operation of the CR SMR Project would be SMALL.

5.4.5 Occupational Doses

The annual occupational dose to operational workers, including outage activities, is dependent on the specific plant design chosen, and is determined in accordance with applicable criteria in 10 CFR 20 and 10 CFR 50 Appendix I. The occupational dose is provided at COLA once the design has been selected.

5.4.6 References

Reference 5.4-1. U.S. Nuclear Regulatory Commission, Westinghouse AP1000 Design Control Document Rev. 19 (Chapter 12), Website: http://pbadupws.nrc.gov/docs/ML1117/ML11171A500.html, June 21, 2011.

Reference 5.4-2. National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. Report of the Advisory Committee on the Biological Effects of Ionizing Radiation," INIS-XA-N--248, Washington, DC, November, 1972.

Reference 5.4-3. U.S. Department of Energy, "Radiation Protection of the Public and the Environment," DOE O 458.1, February 11, 2011.

Reference 5.4-4. U.S. Department of Energy, "DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," DOE-STD-1153-2002, Washington, DC, 2002.

Table 5.4-1
Liquid Pathway Parameters – Aquatic Food and Activities

Parameter	MEI			Average			
	Child	Teen	Adult	Child	Teen	Adult	Average Rate
Fish consumption[1] (kg/yr)	6.9	16	21	2.2	5.2	6.9	5.9[2]
Invertebrate consumption[1] (kg/yr)	1.7	3.8	5	0.33	0.75	1.0	0.85[2]
Shoreline recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Swimming recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Boating recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Population distribution[5]	NA	NA	NA	0.18	0.11	0.71	NA

1 MEI rates from NRC RG 1.109 Table E-5. Average individual rates from NRC RG 1.109 Table E-4.
2 Average rate of fish and invertebrate consumption calculated by weighting age-specific consumption by population distribution and summing across the age groups.
3 Water recreation from NRC RG 1.109 Tables E-4 and E-5 as listed for shoreline activities. Time spent swimming and boating is assumed for each to be identical to time spent on shoreline activities.
4 Average rate of recreational shoreline, swimming, and boating activities calculated by weighting age-specific recreational rates by population distribution and summing across the age groups.
5 NRC RG 1.109 Page 1.109-33.

Notes:
hr/yr = hours per year
kg/yr = kilograms per year
MEI = maximum exposed individual
NA = not applicable

Table 5.4-2
Aquatic Food Consumption from Clinch River arm of Watts Bar Reservoir for 2067 Population within 50 Miles (kg/yr)

Parameter	Fish	Invertebrate
Average person[1]	5.9[1]	0.85[1]
50-mi population - total[2]	7,800,000	1,130,000
50-mi population - sport[3]	1,870,000	271,000
50-mi population - commercial[4]	5,930,000	861,000

1 Aquatic food consumption for the average person from NRC RG 1.109 Table E-4. Average rate of fish and invertebrate consumption calculated by weighting age-specific consumption by population distribution and summing across the age groups.
2 Total consumption of fish by the 2067 population within 50 mi of the CRN Site. As source of 50% of fish and invertebrate consumed by the population within 50 mi of the site is Clinch River arm of the Watts Bar Reservoir, the total population consumption is determined by multiplying the average person rate (5.9 and 0.85) by the 2067 50-mi population and by 50%.
3 Population consumption of food obtained by sport is determined by multiplying the total consumption by the percentage of the population that eats sport food, estimated at 24 percent.
4 Commercial population consumption is the remaining consumption rate (total minus sport population value).

Notes:
kg/yr = kilograms per year

Table 5.4-3
Liquid Pathway Parameters

Parameter	Value
Release source terms	Tables 3.5-1 and 3.5-2
Discharge rate (Clinch River flow)[1]	4000 cfs[1]
Dilution factor for discharge	1[1]
Transit time to receptor	0[2]
Impoundment reconcentration model	None[3]
50-mi population in 2010	1,723,327[4]
50-mi population in 2067[5]	2,658,157[4]
50-mi shoreline usage	34,000,000 person-hours/yr[6]
50-mi swimming usage	34,000,000 person-hours/yr[6]
50-mi boating usage	34,000,000 person-hours/yr[6]
Fish and invertebrate consumption	Table 5.4-2
Drinking water consumption	730 liters per year[7]
Current – 50-mi drinking water population	162,000[8]
2067 – 50-mi drinking water population	249,000[8]
2067 – milk production using Clinch River as Irrigation	30,800 kilograms per year[9]
2067 – meat production using Clinch River as Irrigation	26,200 kilograms per year[9]
2067 – produce production using Clinch River as Irrigation	113,000 kilograms per year[9]

1 Liquid discharge from the surrogate plant is assumed to be fully mixed with Clinch River arm of Watts Bar Reservoir. A conservative mean flow rate of 4000 cfs is assumed. It is conservative because it is lower than the flow data collected over 47 years for the Clinch River arm of Watts Bar Reservoir near Oak Ridge and at Melton Hill Dam.

2 Transit time to the liquid effluent receptor is conservatively assumed to be zero; no decay is assumed other than the distribution times built into LADTAP II.

3 Liquid effluent is released directly into Clinch River Arm of the Watts Bar Reservoir. Effluent is assumed to be immediately, completely mixed.

4 The total population within 50 mi of the CRN Site is projected to increase from the current 1,723,327 to 2,658,157 in 2067. This is a projected increase of 54 percent.

5 Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.

6 Time spent by the average individual on shoreline activities taken from NRC RG 1.109 Table E-4. The time spent boating and swimming each is assumed identical to that spent on shoreline activities. Person-hours per year was determined by multiplying the average rate of 12.8 hours per year (hr/yr) by the projected 2067 population of 2,658,157.

7 Adult maximum exposed individual annual drinking water consumption from NRC RG 1.109 Table E-5.

8 Current and 2067 drinking water populations determined by multiplying the 50-mi population by the percentage of persons served by Clinch River arm of Watts Bar Reservoir (9.4 percent).

9 Irrigated food production within 50 mi determined by multiplying the projected 2067 food production within 50 mi by the percentage of irrigated state land within 50 mi (2.41 percent) and by the percentage of irrigation occurring with water from the Clinch River arm of Watts Bar Reservoir within 50 mi (0.67 percent).

Table 5.4-4
Gaseous Pathway Parameters – GASPAR II Information

Parameter	Value
Release source terms	Tables 3.5-3 and 3.5-4
Population distribution - current	Tables 2.5.1-2 and 2.5.1-4
Population distribution – projected 2067	Table 5.4-5
Dispersion and deposition factors	Section 2.7
Meteorology	Section 2.7
Maximum dispersion direction	WNW
Current - 50-mi milk production[1] (kg/yr)	124,000,000
Current - 50-mi meat production[1] (kg/yr)	106,000,000
Current - 50-mi vegetable/fruit production[1] (kg/yr)	454,000,000
Projected 2067 - 50-mi milk production[2,3] (kg/yr)	191,000,000
Projected 2067 - 50-mi meat production[2,3] (kg/yr)	163,000,000
Projected 2067 - 50-mi vegetable/fruit production[2,3] (kg/yr)	700,000,000

1 Current production: Production in Tennessee multiplied by percent of Tennessee food produced within 50 mi.
2 Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.
3 Projected 2067 production: Current production within 50 mi multiplied by the population ratio of 1.54 (ratio of 2067 population/current population).

Notes:
kg/yr = kilograms per year
WNW = west northwest

Table 5.4-5
Total Population Distribution Within 50 Miles of the CRN Site in 2067[1,2]

Direction	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
N	0	0	0	0	110	2850	2594	570	5499	12,272
NNE	0	0	0	0	0	8678	10,509	12,234	35,396	11,082
NE	5	0	0	0	0	1555	51,540	30,575	25,463	12,290
ENE	8	9	1	0	0	1670	104,860	711,355	81,037	31,999
E	8	14	130	57	116	9101	130,456	207,087	67,225	108,807
ESE	6	39	112	203	475	12,098	26,220	229,719	32,360	14,583
SE	8	42	85	307	357	22,492	11,132	21,153	4038	10,641
SSE	7	59	67	234	396	3916	35,921	17,961	2693	707
S	13	29	38	150	213	2446	14,716	24,197	19,100	10,242
SSW	14	31	41	150	147	1242	5357	26,006	49,143	21,631
SW	13	51	69	132	265	965	3895	5502	12,679	44,254
WSW	16	68	172	151	373	7989	4829	7185	7015	9876
W	18	107	161	183	742	18,819	15,343	5587	52,483	12,930
WNW	21	89	248	87	220	5303	6069	8407	11,606	13,108
NW	20	25	50	14	84	1771	7498	4907	3914	24,543
NNW	0	1	0	0	156	2077	8465	840	11,546	35,117
Total	157	564	1174	1668	3654	102,972	439,404	1,313,285	421,197	374,082
								Grand Total	2,658,157	

1 Projected total 2067 population distribution; sum of transient and permanent projected populations.
2 Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.

Notes:
E = East
N = North
S = South
W = West

Table 5.4-6
Food Production in Tennessee

Food	State Production	Max Year
Red Meat	6.76E+08 lbm	2012
Broilers	1.02E+09 lbm	2008
Milk	9.48E-08 lbm	2008
Tomatoes	8.50E+05 cwt	2012
Snap Beans	1.95E+05 cwt	2012
Soybeans	4.67E+07 bu	2012
Corn	1.28E+08 bu	2012
Wheat	2.14E+07 bu	2012
Apples	6.40E+06 lbm	2012

Table 5.4-7
Vegetable, Milk, and Meat Production within 50 Miles in 2067

Food	Production in TN (kg/yr)[1]	Percent of TN Food Produced within 50 mi		Production within 50 mi (Kg/yr)		
				Present	2067	Irrig 2067[2]
Milk	4.30E+08	Milk Cows	28.81%	1.24E+08	1.91E+08	3.08E+04
Red Meat	3.06E+08	Beef Cows	12.75%	3.91E+07	-	-
Broilers	4.62E+08	Broilers	41.39%	6.65E+07	-	-
Meat Total	-	-	-	1.06E+08	1.63E+08	2.62E+04
Vegetables/Fruit[3]	5.17E+09	Harvested Land	8.79%	4.54E+08	7.00E+08	1.13E+05

1 Production in TN –State values are from Table 5.4-1.
2 Production within 50 mi (Irrig 2067) – the percentage of state irrigation occurring within 50 mi and by 0.67%, the percentage of irrigation occurring with water from the Clinch River.
3 Vegetable production rates are for non-leafy vegetables only. Although there is no significant production of leafy vegetables, the same production rates are conservatively assumed to be applicable to leafy vegetables.

Table 5.4-8
Liquid Effluent Doses per Unit Units to MEI (mrem/yr)

Pathway	Total Body	GI-LLI	Liver	Kidney	Lung	Skin	Thyroid	Bone
Fish	8.5E-03	1.3E-02	1.1E-02	7.0E-03	1.1E-03	0	3.0E-03	2.2E-02
Invertebrate	2.6E-03	4.6E-02	5.4E-03	1.5E-02	1.8E-04	0	1.9E-03	6.5E-03
Drinking	2.9E-03	4.3E-03	4.2E-03	4.6E-03	3.7E-03	0	1.8E-02	2.0E-03
Shoreline activities	1.2E-05	1.2E-05	1.4E-05	1.4E-05	1.4E-05	7.9E-05	1.4E-05	1.4E-05
Swimming	1.4E-06	1.4E-06	1.7E-06	1.7E-06	1.7E-06	0	1.7E-06	1.7E-06
Boating	7.2E-07	7.2E-07	8.4E-07	8.4E-07	8.4E-07	0	8.4E-07	8.4E-07
Irrigated Vegetables	3.4E-03	7.2E-03	8.5E-03	8.3E-03	4.5E-03	0	1.8E-02	1.9E-02
Irrigated Milk	2.0E-03	2.1E-03	6.0E-03	4.0E-03	2.8E-03	0	2.3E-02	9.1E-03
Irrigated Meat	6.5E-04	2.5E-04	6.8E-04	2.9E-03	3.4E-04	0	7.6E-04	2.0E-03
Total Dose	2.0E-02	9.7E-02	3.5E-02	4.2E-02	1.3E-02	7.9E-05	6.4E-02	6.0E-02
Age group[1]	Adult	Adult	Child	Child	Child	Teen	Child	Child

[1] The age group receiving the maximum dose for each organ shown.

Notes:
GI-LLI = Gastrointestinal – Lower Large Intestine
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-9
Liquid Effluent Doses from All Units to MEI (mrem/yr)

Pathway	Total Body	GI-LLI	Liver	Kidney	Lung	Skin	Thyroid	Bone
Fish	9.2E-02	4.5E-02	1.1E-01	3.2E-02	1.2E-02	0	3.2E-02	1.6E-01
Invertebrate	2.3E-02	2.3E-01	5.2E-02	7.7E-03	2.0E-03	0	7.7E-03	3.4E-02
Drinking	1.3E-02	1.7E-02	2.1E-02	1.8E-01	1.5E-02	0	1.8E-01	1.9E-02
Shoreline activities	1.1E-04	1.1E-04	1.3E-04	1.3E-04	1.3E-04	7.0E-04	1.3E-04	1.3E-04
Swimming	8.8E-06	8.8E-06	1.0E-05	1.0E-05	1.0E-05	0	1.0E-05	1.0E-05
Boating	4.4E-06	4.4E-06	5.1E-06	5.1E-06	5.1E-06	0	5.1E-06	5.1E-06
Irrigated Vegetables	2.2E-02	3.2E-02	6.8E-02	1.8E-01	2.2E-02	0	1.8E-01	2.1E-01
Irrigated Milk	1.4E-03	1.5E-02	5.1E-02	2.5E-01	1.4E-02	0	2.5E-03	1.1E-02
Irrigated Meat	3.5E-02	9.9E-02	4.2E-02	5.0E-03	1.7E-03	0	5.0E-01	1.4E-01
Total Dose	1.7E-01	4.4E-01	3.1E-01	6.6E-01	6.8E-02	7.0E-04	6.6E-01	5.4E-01
Age group[1]	Adult	Adult	Child	Child	Child	Teen	Child	Child

[1] The age group receiving the maximum dose for each organ shown.

Notes:
GI-LLI = Gastrointestinal – Lower Large Intestine
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-10 (Sheet 1 of 2)
Gaseous Effluent Doses per Unit to MEI

Location	Pathway		Dose per Unit (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Site Boundary (0.21 mi WNW)	External	Plume	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.3E+00	1.4E+01
		Ground	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	1.0E+00
		Total	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.2E+00	1.5E+01
	Inhalation	Adult	1.5E+00	1.5E+00	2.9E-01	1.5E+00	1.5E+00	1.2E+01	2.0E+00	0
		Teen	1.5E+00	1.5E+00	3.5E-01	1.6E+00	1.6E+00	1.5E+01	2.4E+00	0
		Child	1.3E+00	1.3E+00	4.3E-01	1.4E+00	1.4E+00	1.8E+01	2.1E+00	0
		Infant	7.6E-01	7.5E-01	2.1E-01	8.5E-01	8.3E-01	1.6E+01	1.3E+00	0
	All	Adult	8.5E+00	8.6E+00	7.3E+00	8.6E+00	8.6E+00	1.9E+01	9.2E+00	1.5E+01
		Teen	8.5E+00	8.6E+00	7.4E+00	8.6E+00	8.7E+00	2.2E+01	9.5E+00	1.5E+01
		Child	8.4E+00	8.4E+00	7.5E+00	8.5E+00	8.5E+00	2.5E+01	9.2E+00	1.5E+01
		Infant	7.8E+00	7.8E+00	7.3E+00	7.9E+00	7.9E+00	2.3E+01	8.5E+00	1.5E+01
Residence (0.66 mi WNW)	External	Plume	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.9E-01	1.8E+00
		Ground	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.5E-01
		Total	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.2E-01	1.9E+00
	Inhalation	Adult	1.8E-01	1.9E-01	3.5E-02	1.9E-01	1.9E-01	1.5E+00	2.5E-01	0
		Teen	1.9E-01	1.9E-01	4.2E-02	2.0E-01	2.0E-01	1.8E+00	2.9E-01	0
		Child	1.6E-01	1.6E-01	5.2E-02	1.8E-01	1.8E-01	2.2E+00	2.5E-01	0
		Infant	9.5E-02	9.4E-02	2.6E-02	1.1E-01	1.0E-01	1.9E+00	1.6E-01	0
Vegetable Garden (1.15 mi WNW)	Veg	Adult	5.7E-01	5.7E-01	2.3E+00	5.8E-01	5.6E-01	1.5E+00	5.5E-01	0
		Teen	8.5E-01	8.5E-01	3.7E+00	8.7E-01	8.5E-01	2.1E+00	8.3E-01	0
		Child	1.9E+00	1.9E+00	8.9E+00	1.9E+00	1.9E+00	4.2E+00	1.9E+00	0
Meat Animal (0.70 mi WNW)	Meat	Adult	4.4E-01	4.6E-01	2.0E+00	4.4E-01	4.4E-01	5.1E-01	4.4E-01	0
		Teen	3.6E-01	3.7E-01	1.6E+00	3.6E-01	3.6E-01	4.1E-01	3.6E-01	0
		Child	6.5E-01	6.6E-01	3.1E+00	6.6E-01	6.5E-01	7.3E-01	6.5E-01	0

Table 5.4-10 (Sheet 2 of 2)
Gaseous Effluent Doses per Unit to MEI

Location	Pathway		Dose per Unit (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
MEI	All	Adult	2.1E+00	2.1E+00	5.2E+00	2.1E+00	2.1E+00	4.4E+00	2.2E+00	1.9E+00
		Teen	2.3E+00	2.3E+00	6.3E+00	2.3E+00	2.3E+00	5.2E+00	2.4E+00	1.9E+00
		Child	3.6E+00	3.6E+00	1.3E+01	3.7E+00	3.6E+00	8.0E+00	3.7E+00	1.9E+00
		Infant	1.0E+00	1.0E+00	9.3E-01	1.0E+00	1.0E+00	2.8E+00	1.1E+00	1.9E+00
		Max	3.6E+00	3.6E+00	1.3E+01	3.7E+00	3.6E+00	8.0E+00	3.7E+00	1.9E+00
		Group	Child	Child	Child	Child	Child	Child	Child	All

Note: In the first four rows for the MEI, MEI doses are obtained by conservatively summing the residence total external dose with the residence inhalation, vegetable, and meat maximum doses even though they are not all at the same location.

Table 5.4-11 (Sheet 1 of 2)
Gaseous Effluent Doses from All Units to MEI

Location	Pathway		Dose for All Units (mrem/yr)							
			Total Body	**GI-Tract**	**Bone**	**Liver**	**Kidney**	**Thyroid**	**Lung**	**Skin**
Site Boundary (0.21 mi WNW)	External	Plume	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.1E+01	8.4E+01
		Ground	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	3.3E+00
		Total	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	8.8E+01
	Inhalation	Adult	4.8E+00	5.0E+00	9.4E-01	5.0E+00	5.1E+00	4.1E+01	6.6E+00	0
		Teen	4.9E+00	5.0E+00	1.2E+00	5.2E+00	5.3E+00	5.2E+01	7.7E+00	0
		Child	4.3E+00	4.3E+00	1.4E+00	4.7E+00	4.7E+00	6.2E+01	6.7E+00	0
		Infant	2.5E+00	2.5E+00	7.3E-01	2.8E+00	2.8E+00	5.5E+01	4.2E+00	0
	All	Adult	4.8E+01	4.8E+01	4.4E+01	4.8E+01	4.8E+01	8.4E+01	5.0E+01	8.8E+01
		Teen	4.8E+01	4.8E+01	4.4E+01	4.8E+01	4.8E+01	9.5E+01	5.1E+01	8.8E+01
		Child	4.7E+01	4.7E+01	4.4E+01	4.8E+01	4.8E+01	1.0E+02	5.0E+01	8.8E+01
		Infant	4.5E+01	4.5E+01	4.4E+01	4.6E+01	4.6E+01	9.8E+01	4.8E+01	8.8E+01
Residence (0.66 mi WNW)	External	Plume	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.1E+00	1.1E+01
		Ground	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	5.1E-01
		Total	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	1.1E+01
	Inhalation	Adult	6.0E-01	6.2E-01	1.1E-01	6.3E-01	6.4E-01	5.1E+00	8.2E-01	0
		Teen	6.1E-01	6.3E-01	1.4E-01	6.5E-01	6.6E-01	6.4E+00	9.6E-01	0
		Child	5.4E-01	5.4E-01	1.7E-01	5.8E-01	5.9E-01	7.6E+00	8.2E-01	0
		Infant	3.1E-01	3.1E-01	8.9E-02	3.5E-01	3.4E-01	6.8E+00	5.2E-01	0
Vegetable Garden (1.15 mi WNW)	Veg	Adult	1.1E+00	1.1E+00	3.7E+00	1.1E+00	1.0E+00	4.0E+00	1.0E+00	0
		Teen	1.5E+00	1.5E+00	5.8E+00	1.6E+00	1.5E+00	5.2E+00	1.4E+00	0
		Child	3.1E+00	3.0E+00	1.4E+01	3.2E+00	3.1E+00	1.0E+01	3.0E+00	0
Meat Animal (0.70 mi WNW)	Meat	Adult	7.0E-01	7.5E-01	2.7E+00	7.0E-01	6.9E-01	9.0E-01	6.8E-01	0
		Teen	5.5E-01	5.8E-01	2.3E+00	5.6E-01	5.5E-01	7.0E-01	5.4E-01	0
		Child	9.6E+00	9.8E+00	4.3E+00	9.8E+00	9.6E+00	1.2E+00	9.6E-01	0

Table 5.4-11 (Sheet 2 of 2)
Gaseous Effluent Doses from All Units to MEI

Location	Pathway		Dose for All Units (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
MEI	All	Adult	7.8E+00	7.9E+00	1.2E+01	7.9E+00	7.8E+00	1.5E+01	8.0E+00	1.1E+01
		Teen	8.1E+00	8.1E+00	1.4E+01	8.2E+00	8.1E+00	1.8E+01	8.4E+00	1.1E+01
		Child	1.0E+01	1.0E+01	2.3E+01	1.0E+01	1.0E+01	2.4E+01	1.0E+01	1.1E+01
		Infant	5.8E+00	5.8E+00	5.5E+00	5.8E+00	5.8E+00	1.2E+01	6.0E+00	1.1E+01
		Max	1.0E+01	1.0E+01	2.3E+01	1.0E+01	1.0E+01	2.4E+01	1.0E+01	1.1E+01
		Group	Child	Child	Child	Child	Child	Child	Child	All

Note: In the first four rows for the MEI, MEI doses are obtained by conservatively summing the residence total external dose with the residence inhalation, vegetable, and meat maximum doses even though they are not all at the same location.

Table 5.4-12
Liquid Effluent Doses Per Unit to Population Within 50 Miles[a] (person-rem/yr)

Pathway	Total Body	Thyroid
Sport fish	7.1E-01	1.7E-01
Commercial fish	7.8E-01	1.5E-01
Sport invertebrate	1.3E-01	6.3E-02
Commercial invertebrate	3.9E-01	1.7E-01
Drinking water	3.8E-01	1.2E+00
Shoreline activities	3.4E-02	3.4E-02
Swimming	4.1E-03	4.1E-03
Boating	2.0E-03	2.0E-03
Irrigated milk	2.2E-04	9.3E-04
Irrigated meat	1.7E-04	2.1E-04
Irrigated non-leafy vegetables	5.3E-04	4.0E-04
Irrigated leafy vegetables	6.7E-05	3.2E-04
Total Dose	2.4E+00	1.8E+00

[1] Annual liquid effluent dose for the 50-mi population determined by LADTAP II.

Notes:
person-rem/yr = person-rems per year

Table 5.4-13
Gaseous Effluent Dose per Unit to Population Within 50 Mi[1] (person-rem/yr)

Pathway	Total Body	Thyroid
Plume	8.0E-01	8.0E-01
Ground	5.7E-01	5.7E-01
Inhalation	1.4E+00	8.1E+00
Vegetable	7.7E+00	7.6E+00
Cow milk	1.8E+00	4.7E+00
Meat	2.6E+00	2.8E+00
Total Dose	1.5E+01	2.5E+01

1 Annual gaseous effluent dose for the 50-mi population determined by GASPAR II.

Notes:
person-rem/yr = person-rems per year

Table 5.4-14
Gaseous Effluent Thyroid Doses Per Unit to MEI from Iodines and Particulates[1] (mrem/yr)

Pathway	Adult	Teen	Child	Infant
Plume	0	0	0	0
Ground	1.3E-01	1.3E-01	1.3E-01	1.3E-01
Inhalation	1.3E+00	1.7E+00	2.0E+00	1.8E+00
Vegetable	9.9E-01	1.2E+00	2.3E+00	0
Meat	7.2E-02	5.3E-02	7.9E-02	0
Total Dose	2.5E+00	3.1E+00	4.5E+00	2.0E+00

1 Annual gaseous effluent thyroid doses for the MEI determined by GASPAR II.

Notes:
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-15
Compliance of MEI Annual Doses Per Unit with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose	Limit[5]
Liquid Effluent[1]			
Total Body (mrem)	Clinch River	2.0E-02	3
Maximum Organ – GI-LLI (mrem)	Clinch River	9.7E-02	10
Gaseous Effluent			
Gamma Air[2] (mrad)	Site Boundary	9.5E+00	10
Beta Air[2] (mrad)	Site Boundary	1.2E+01	20
Total Body[3] (mrem)	Residence	9.0E-01	5
Skin[3] (mrem)	Residence	1.9E+00	15
Iodines and Particulates[4]			
Maximum Organ – Thyroid (mrem)	Residence/Garden/Meat	4.5E+00	15

1 Annual liquid effluent doses for the MEI determined by LADTAP II; the MEI is the adult receptor.
2 Annual gaseous effluent doses for the MEI determined by GASPAR II; dose for a receptor at the site boundary, near ground level.
3 Annual gaseous effluent external doses for the MEI determined by GASPAR II.
4 Annual gaseous effluent total thyroid doses from iodines and radioactive material in particulate form for the MEI determined by GASPAR II.
5 Dose limits in 10 CFR 50, Appendix I.

Notes:
mrem = millirem
mrad = millirad
MEI = maximum exposed individual

Table 5.4-16
Compliance of MEI Doses from All Units with 40 CFR 190.10 Criteria (mrem/yr)

Pathway	Liquid[1]	Gaseous[2]	Direct[3]	Total[4]	Limit[5]
Total Body	1.7E-01	1.0E+01	1.0E+00	1.1E+01	25
Thyroid	6.6E-01	2.4E+01	0.0E+00	2.5E+01	75
Other Organ - Bone	5.4E-01	2.3E+01	0.0E+00	2.4E+01	25

[1] Annual liquid effluent doses for the MEI determined by LADTAP II; the MEI is the adult receptor for total body dose and the child for thyroid and bone dose.
[2] Annual gaseous effluent doses for the MEI determined by GASPAR II; the MEI is the child receptor.
[3] Annual direct dose is assumed to be 1 mrem per year.
[4] Site totals are summed across receptors and locations to provide a conservative site total.
[5] Dose limits in 40 CFR 190.10.

Notes:
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-17
Doses from All Units to Population Within 50 Miles (person-rem/yr)[1]

Pathway	Total Body	Thyroid
Liquid	9.6E+00	7.2E+00
Gaseous		
Noble gases	3.2E+00	3.2E+00
Iodines	8.0E-02	4.0E+01
Particulates	2.9E+00	2.3E+00
C-14	4.0E+01	4.0E+01
H-3	1.3E+01	1.3E+01
Gaseous Total	6.0E+01	1.0E+02
Pathways Total	6.8E+01	1.0E+02
Background Radiation[2]	8.3E+05	

1 Doses per unit multiplied by 4 to approximate doses from all units
2 The background dose is obtained by multiplying the average natural background dose rate in the United States of 311 mrem/yr (0.311 rem/yr) by the 2067 population of2.66E6 persons.

Table 5.4-18
Liquid Effluent Doses from All Units to Biota

Biota	Dose for All Units (mrad/yr)
Fish	1.6E+00
Invertebrates	7.6E+00
Algae	2.5E+00
Muskrat	3.4E+00
Raccoon	1.3E+00
Heron	8.9E+00
Duck	3.2E+00

Notes:
mrad/yr = millirad per year

Table 5.4-19
Gaseous Effluent Doses from All Units to Biota

Pathway	Child TBD[1] (mrem/yr)	Teen TBD[1] (mrem/yr)	Adult TBD[1] (mrem/yr)	Biota Dose (mrad/yr)
Inhalation	3.2E+00	3.7E+00	3.6E+00	3.7E+00[2]
Vegetable consumption	4.6E+01	2.2E+01	1.6E+01	4.6E+01[2]
Plume immersion	3.0E+01	3.0E+01	3.0E+01	3.0E+01[2]
Ground deposition	2.2E+00	2.2E+00	2.2E+00	4.3E+00[3]
Total				8.4E+01[4]

1 Total body dose (TBD) determined from GASPAR II for human receptors located 0.25 mi from the reactor release point was used as biota dose.

2 Biota dose from gaseous effluent through inhalation, vegetable consumption, and plume immersion pathways is estimated as the maximum total body dose determined for human receptors located 0.25 mi of the SMR facility.

3 Because biota are closer to the ground, biota dose from the ground deposition pathway is determined as twice the ground deposition dose determined for humans to compensate for the height differential.

4 The total gaseous effluent dose to biota is estimated as the sum of inhalation, vegetable consumption, plume immersion, and ground deposition doses.

Notes:
mrad/yr = millirads per year
mrem/yr = millirems per year
TBD = total body dose

Table 5.4-20
Doses from All Units to Biota

Biota	Gaseous[1] (mrad/yr)	Liquid[2] (mrad/yr)	Total[3] (mrad/yr)	Total[4] (mrad/day)
Algae	0	2.5E+00	2.5E+00	6.7E-03
Invertebrate	0	7.6E+00	7.6E+00	2.1E-02
Fish	0	1.6E+00	1.6+00	4.5E-03
Muskrat	8.4E+01	3.4E+00	8.7E+01	2.4E-01
Raccoon	8.4E+01	1.3E+00	8.5E+01	2.3E-01
Heron	8.4E+01	8.9E+00	9.3E+01	2.5E-01
Duck	8.4E+01	3.2E+00	8.7E+01	2.4E-01

1 Total body dose determined from GASPAR II for human receptors located 0.25 mi from the reactor release point was used to model biota dose.
2 Biota dose from liquid effluent as modeled from LADTAP II.
3 Annual total body dose for biota from gaseous and liquid effluent.
4 Daily total body dose for biota from gaseous and liquid effluent as determined by dividing the annual dose by 365 days per year.

Notes:
mrad/yr = millirads per year
mrad/day = millirads per day

5.5 ENVIRONMENTAL IMPACTS OF WASTE

The following subsections discuss the environmental impacts of nonradioactive waste from the operation of two or more small modular reactor (SMR) units at the Clinch River Nuclear (CRN) Site. Regulations for generating, managing, handling, storing, treating, protecting, and disposing of these wastes are contained in federal regulations issued and overseen by the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA), and in Tennessee regulations overseen by the Tennessee Department of Environment and Conservation (TDEC). These regulations include the Clean Air Act, Clean Water Act, Atomic Energy Act, Resource Conservation and Recovery Act (RCRA), and others.

In NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, , Volume 1, NRC assembled several years of data from operating nuclear power stations and their effects on the environment. Station operations, and the regulatory requirements for protection of the environment, show that the impact of nonradioactive waste discharges from nuclear power operations is considered to be SMALL.

5.5.1 Nonradioactive-Waste-System Impacts

Descriptions of the SMR nonradioactive waste systems and chemical parameters are presented in Section 3.6. Nonradioactive wastes are managed in accordance with applicable federal, state, and local laws, regulations, and permit requirements, as well as Tennessee Valley Authority (TVA) Procedures. TVA expects to construct and operate a permanent onsite landfill for construction, site clearing, and grading debris. The construction/demolition landfill would be sized to accommodate the anticipated materials and would be located in the permanently cleared laydown area north of the main plant area. The landfill would be constructed in accordance with all relevant permit and licenses. No hazardous or municipal waste would be disposed of in this landfill. The landfill would be closed at the end of the construction period. The assessment of potential impacts resulting from the discharge of nonradioactive wastes is presented in the following subsections.

5.5.1.1 Impacts of Discharges to Water

Nonradioactive wastewater discharges to surface water from the facility are described in Subsection 3.6.3.2. Wastewater discharges include cooling tower blowdown; wastewater from the demineralized water system; wastewater from floor drains, sinks, and laboratories; and stormwater runoff. Additional aqueous waste streams may include raw cooling water, air conditioning condensate, steam generator blowdown, and high pressure fire protection water.

Chemicals such as biocides and corrosion inhibitors are used to treat intake or process waters. The quantities of chemicals to be used are determined during development of a Biocide/Corrosion Treatment Plan, which will be submitted as part of the application for a National Pollution Discharge Elimination System (NPDES) permit.

The preliminary site grading plan includes a holding pond on the western side of the CRN Site, which serves as the collection point for most process waste streams except for sanitary wastes and some stormwater discharges. The holding pond discharges to Watts Bar Reservoir through one or more diffusers located at approximately Clinch River Mile 15.5.

Wastewater discharges are regulated by the TDEC through a NPDES permit. The anticipated constituents and their concentrations in the facility's non-radioactive liquid waste discharges are provided in Table 3.6-1, and the average and maximum flow rates for the discharges are discussed in Section 3.4 and Subsection 3.6.3.2. A NPDES permit includes discharge limits established to protect receiving waters, and monitoring to ensure compliance with those limits. Temperatures and chemical concentrations for all discharges are also conditions of the NPDES permit. Biocides and chemicals used for water treatment are added to discharges in part per million concentrations and are largely consumed serving their purposes. TDEC takes the potential for these substances being in the discharge into consideration when establishing requirements for appropriate chemical parameter monitoring and acceptable limits in the NPDES permit. Therefore the impact from these discharges would be SMALL.

The CRN Site currently has a stormwater management system, designed for the Clinch River Breeder Reactor Project, consisting of stormwater runoff/collection ponds and piping. There are currently no known areas of significant erosion on the CRN Site that require controls. The existing stormwater management system would be modified, as needed, to support the CR SMR Project. Modifications may include one or more stormwater retention ponds for settling of solids, but no need has been identified for other treatment or oil/water separators. As part of the application for a NPDES permit, TVA is required to submit a Notice of Intent for Construction Activity Stormwater Discharges and an associated Stormwater Pollution Prevention Plan (SWPPP) to the TDEC. The NPDES permit will be obtained before any construction activities take place. Stormwater discharges are managed in accordance with a SWPPP during construction. Permanent stormwater management systems are designed and constructed to support operations and a NPDES permit requires monitoring of the discharges during operations. Therefore, impacts from stormwater discharge would be SMALL.

In conclusion, because engineering controls which prevent or minimize the release of harmful effluents would be used, and effluent concentrations would be maintained at levels below permitted limits established to be protective of water quality and aquatic life, potential impacts of discharges to water would be SMALL.

5.5.1.2 Impacts of Discharges to Land

Nonradioactive solid waste expected to be generated from the facility are described in Subsection 3.6.3.3. TVA maintains multiple procedures related to the management of non-radioactive solid waste, including used oil wastes, hazardous wastes, non-hazardous solid wastes, construction and demolition wastes (including spoils), and Universal Wastes (lamps, batteries, and pesticides). Nonradioactive solid wastes are disposed using a TVA-approved vendor. TVA complies with applicable federal, state, and local requirements and standards for handling, transporting, and disposing of solid waste. These include the 1976 RCRA, which amended the 1965 Solid Waste Disposal Act. TVA expects to construct and operate an onsite landfill for construction, site clearing, and grading debris. The construction/demolition landfill would be sized to accommodate the anticipated materials and would be located in the permanently cleared laydown area north of the main plant area. The landfill would be constructed in accordance with all relevant permits and licenses. Therefore, potential impacts from land disposal of nonradioactive wastes would be SMALL.

5.5.1.3 Impacts of Discharges to Air

As described in Subsection 2.7.2, Roane County is considered in attainment with the National Ambient Air Quality Standards, except that the county is a partial nonattainment area for particulate matter with a diameter less than 2.5 microns ($PM_{2.5}$) (part of the Knoxville-Sevierville- La Follette, Tennessee 2006 nonattainment area and part of Knoxville 1997 $PM_{2.5}$ nonattainment area). The CRN Site, however, does not lie within the partial nonattainment area for $PM_{2.5}$ in Roane County. Thus the CRN Site is considered in attainment with the air quality standards for all criteria pollutants. The CRN Site is located near the boundaries of Roane County with Knox and Loudon Counties. Knox and Loudon counties, in their entirety, are also within the Knoxville- Sevierville- La Follette, Tennessee $PM_{2.5}$ 2006 nonattainment area and within the Knoxville, Tennessee 1997 $PM_{2.5}$ nonattainment area. (Reference 5.5-1) TVA will consult with TDEC regarding the need for a TDEC Title V Operating Permit under the Clean Air Act following selection of the reactor design.

Nonradioactive gaseous effluents expected to be generated from the facility are described in Subsection 3.6.3.1. Operation of the nuclear power units increase gaseous and particulate emissions to the air by a small amount, primarily from equipment associated with the cooling towers and facility auxiliary systems. The primary sources of emissions from auxiliary systems are auxiliary boilers (Table 3.6-2), diesel generators (Table 3.6-3), and gas turbine generators (Table 3.6-4). The auxiliary boilers are used for heating the facility buildings, primarily during the winter months, and for process steam during reactor startups. The diesel generators/gas turbines and engine driven emergency equipment are used intermittently and for brief durations. Cooling tower impacts on terrestrial ecosystems are discussed in Subsection 5.3.3.2.

Air emission sources associated with the SMR units would be managed in accordance with federal, state, and local air quality control laws and regulations. Accordingly, air quality impacts from operation of the CR SMR Project would be SMALL for the surrounding communities and the nearest residents.

5.5.1.4 Sanitary Waste

During construction and operation, the facility will discharge sanitary wastewaters to the City of Oak Ridge Public Works Department. The projected effluent flow of an average of 50 gallons per minute (gpm) from the facility’s potable/sanitary water system to the City of Oak Ridge sanitary treatment system is included in Table 3.1-2, Item 5.1.1. This equates to an average daily flow of 72,000 gallons per day (gpd). The maximum flow rate, included in Table 3.1-2, Item 5.1.2, is estimated to be 100 gpm, or a maximum daily flow of 144,000 gpd. The maximum flow rate represents a small proportion (approximately 2.6 percent) of the 5.6 million gallon per day capacity of the City of Oak Ridge sanitary treatment system (Reference 5.5-2). Potential impacts associated with disposal of sanitary waste from operation of the SMR would be SMALL.

5.5.2 Hazardous and Mixed Waste Impacts

It is anticipated that the facility would be a Small Quantity Generator of Hazardous Wastes. These wastes are disposed using a TVA-approved vendor. TVA maintains procedures for management of hazardous and mixed waste at their facilities.

The term "mixed waste" refers specifically to waste that contains both hazardous waste and source, special nuclear, or byproduct material. Because radioactive materials at nuclear power facilities are regulated by NRC and hazardous wastes are regulated by EPA, nuclear power facilities managing mixed waste must meet the requirements of both regulatory agencies. The radioactive component of mixed waste must satisfy the definition of low-level waste in the Low-Level Radioactive Waste Policy Amendments Act of 1985. The hazardous component must exhibit at least one of the hazardous waste characteristics identified in Title 40 of the Code of Federal Regulation (40 CFR) 261, Subpart C, or be listed as a hazardous waste under 40 CFR 261, Subpart D.

Additionally, entities that generate, treat, store, or dispose of mixed wastes are subject to the requirements of the Atomic Energy Act, the Solid Waste Disposal Act of 1965, as amended by the RCRA in 1976, and the Hazardous and Solid Waste Amendments, which amended RCRA in 1984. In the State of Tennessee, the EPA has authorized the state to regulate those portions of the Federal act under RCRA.

5.5.2.1 Plant Systems Producing Hazardous and Mixed Waste

Nuclear power facilities typically do not generate large volumes of hazardous or mixed waste due to industry-wide, ongoing efforts to reduce mixed-waste generation. A 1990 survey conducted by NRC identified the types of hazardous and potentially mixed low-level waste listed below as common to reactor facilities (NUREG-1437, Rev. 0). The types of hazardous and potentially mixed waste that would be generated by the reactor selected for the CRN Site is expected to be consistent with the types identified by the survey. Types of hazardous or mixed waste may include:

- Waste oil from pumps and other equipment
- Chlorinated fluorocarbons resulting from cleaning, refrigeration, degreasing, and decontamination activities
- Organic solvents, reagents, compounds, and associated materials such as rags and wipes
- Metals such as lead from shielding applications and chromium from solutions and acids

- Metal-contaminated organic sludge and other chemicals
- Aqueous corrosives consisting of organic and inorganic acids

5.5.2.2 Hazardous and Mixed Waste Storage and Disposal

Specific hazardous and mixed waste management practices, treatment methods, and storage areas have not been established for the CRN Site. However, industry standard and regulatory compliant hazardous chemical control and radiological control measures would be applied during testing, handling, and storage (accumulation area) of hazardous and mixed wastes. In accordance with hazardous material management regulations in 40 CFR 261 and 265, onsite storage of hazardous and mixed wastes are limited. Therefore, hazardous and mixed wastes would be shipped offsite for treatment or disposal after a short accumulation period.

Examples of best management practices (BMPs) for hazardous and mixed waste storage and disposal include:

- Development of an emergency response plan
- Segregation of hazardous and mixed wastes from nonhazardous wastes
- Securing waste accumulations areas
- Posting accumulation areas with signs containing language similar to the following: “MIXED/ HAZARDOUS WASTE AREA” and “DANGER-UNAUTHORIZED PERSONNEL-KEEP OUT”
- Use of secondary containment and the presence of spill kits for liquid hazardous and mixed waste storage
- Compliant container labeling
- Routine inspections of waste accumulation areas

5.5.2.3 Waste Minimization Plan

Pursuant to the regulations cited in Subsection 5.5.2 regarding hazardous and mixed waste management, TVA develops and implements Waste Minimization Plans for nuclear power facilities. The following industry BMPs are elements of the Waste Minimization Plan:

- Inventory identification and control that utilizes a tracking system to manage waste generation data and waste minimization opportunities
- Work planning to reduce mixed waste generation (An example of work planning is pre-task planning to determine what materials and equipment are needed to perform the anticipated work.)
- Mixed waste reduction, recycling, and reuse methods that maximize opportunities for reclamation and reuse of waste materials are used whenever feasible

- Training and education of employees on the principles and benefits of the waste minimization

5.5.2.4 Environmental Impacts of Hazardous and Mixed Waste

The development and implementation of hazardous and mixed waste management BMPs and the Waste Minimization Plan as described above in Subsections 5.5.2.2 and 5.5.2.3 would ensure that generation of hazardous and mixed wastes is minimized by the SMR units at the CRN Site. Due to the project small volume of hazardous and mixed waste, no significant emissions or releases of hazardous materials are expected as a result of mixed waste management practices. Therefore, environmental impacts of hazardous and mixed waste would be SMALL.

5.5.3 References

Reference 5.5-1. U.S. Environmental Protection Agency, Nonattainment Status for Each County by Year for Tennessee, Website: http://www.epa.gov/oaqps001/greenbk/anay_tn.html, December 5, 2013.

Reference 5.5-2. City of Oak Ridge, Welcome to the City of Oak Ridge, Tennessee, Website: http://www.oakridgetn.gov/department/PublicWorks/Divisions/Wastewater-Treatment, 2015.

5.6 TRANSMISSION SYSTEM IMPACTS

This section describes the impacts of transmission system operation for the Clinch River (CR) Small Modular Reactor (SMR) Project. As discussed in Section 3.7, the final design of the transmission infrastructure to support operation of two or more SMRs at the Clinch River Nuclear (CRN) Site, including corridors and switchyards, has not yet been finalized. Section 3.7 describes a general concept of the interconnection components and activities necessary to complete the connection between the CRN Site and the existing power transmission systems. As described in Subsection 3.7.1, activities related to the transmission system on the CRN Site include the construction of proposed switchyards, looping in transmission lines, and relocation of an existing transmission line within the site boundary. Transmission line upgrades in conjunction with the CR SMR Project are expected to include reconductoring, uprating, and rebuilding of some segments within the existing lines on and off the CRN Site. These upgrades, which would increase the electrical capacity of the existing transmission system, include activities such as moving features that interfere with clearance, replacing and/or modifying existing structures, installing intermediate structures, and modifying or replacing some of the existing conductors in order to increase ground clearance.

Additionally, Tennessee Valley Authority (TVA) plans to install an underground transmission line within an existing overhead transmission line right-of-way (ROW) which spans the CRN Site and ties into the Bethel Valley substation. As described in Subsection 3.7.3.4, the proposed underground transmission line would be installed approximately 36 inches (in.) below the ground surface. Impacts associated with construction in transmission line ROWs are discussed in Sections 4.1 and 4.3.

Subsections 5.6.1 and 5.6.2 discuss potential environmental impacts to terrestrial and aquatic ecosystems, respectively. Subsection 5.6.3 addresses potential operational impacts of the existing and proposed transmission lines to members of the public.

As described in greater detail in Section 3.7, two TVA transmission lines currently traverse the CRN Site, the east-west 500-kilovolt (kV) Watts Bar NP – Bull Run FP line and the north-south 161-kV Kingston FP – Fort Loudoun HP #1 line. Additional interconnection components and activities would be necessary to complete the connection between the CRN Site and existing power transmission systems and ensure that National Electrical Safety Code (NESC) standards are met. These components, based on an SMR surrogate plant at a generating output of 800 MWe, include onsite switchyards, loops in the two existing lines, various uprating activities, and relocation of an onsite portion of the Kingston FP – Fort Loudoun HP #1 161-kV transmission line. TVA also plans to install a 69-kV underground transmission line (approximately 5 miles [mi] in length) within the existing ROW of the Watts Bar NP – Bull Run FP 500-kV line on U.S. Department of Energy (DOE) property. The 69-kV line would tie into the Bethel Valley substation, also on DOE property. Figure 3.7-2 shows the existing transmission system on and adjacent to the CRN Site and the approximate proposed 161-kV transmission line relocation route. Figure 3.7-2 shows the route of the proposed underground 69-kV transmission line from the CRN Site to the Bethel Valley substation. It is expected that transmission system construction activities would be completed within the CRN Site and/or existing transmission line ROWs.

5.6.1 Impacts to Terrestrial Ecosystems

TVA manages transmission corridors to prevent woody growth from encroaching on energized transmission lines and potentially causing disruption in service or becoming a general safety hazard. In addition to maintaining an adequate distance between transmission line conductors and vegetation, management of vegetation along the ROWs is necessary to ensure access to structures.

TVA has procedures in place for use during ongoing transmission line ROW maintenance activities. In addition, TVA transmission line maintenance activities are subject to periodic National Environmental Policy Act review where resources within the ROW are assessed and characterized. TVA procedural documents such as *Right-Of-Way Vegetation Management Guidelines* and *A Guide for Environmental Protection and Best Management Practices for Tennessee Valley Authority Transmission Construction and Maintenance Activities* provide guidance to TVA personnel conducting maintenance activities in transmission line ROWs (Reference 5.6-1; Reference 5.6-2). Activities addressed include such operations as re-clearing of vegetation, maintenance of access roads, and erosion control. Best management practices (BMPs) are provided for re-clearing methods such as cutting of trees and herbicide application, and for protection of sensitive resources. Structural controls, standards, and specifications are identified to maintain physical components within ROWs such as riprap and culverts.

Periodic inspections of TVA’s transmission lines would continue to be performed by aerial surveillance on a regular basis. These inspections are conducted to locate damaged equipment; in addition, any conditions that may interfere with normal operation of the line or adversely impact the surrounding area are reported. During these inspections, the condition of the vegetation within and adjacent to the ROW are noted. These observations are then used to plan corrective maintenance or routine vegetation maintenance.

Vegetation management along the ROW consists of two principal activities: felling of invasive trees adjacent to the cleared ROW, and vegetation control within the cleared ROW. Management of vegetation within the cleared ROW uses an integrated vegetation management approach based on BMPs designed to encourage low-growing plant species and discourage tall-growing plant species.

A vegetation re-clearing plan is developed for each transmission line segment based on the results of the periodic inspections described above. The two principal management techniques are mechanical mowing and herbicide application. Herbicides are applied in accordance with applicable state and federal laws and regulations. Only herbicides registered with the U.S. Environmental Protection Agency are used.

In NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, the U.S. Nuclear Regulatory Commission (NRC) evaluated transmission line ROW management (cutting and herbicide application) during the license renewal term at all nuclear power plants. NRC concluded that continued ROW management would not lower habitat quality or cause significant changes in wildlife populations in the surrounding habitat, and that the impact on terrestrial resources would be SMALL for all nuclear power plants.

As described in Subsection 3.7.3.4, the proposed location of the underground transmission line is 36 in. below ground surface within the existing 500-kV ROW. The heat from underground transmission lines dissipates through the surrounding soil. Thus, operation of the proposed line is expected to increase the soil temperature adjacent to the line. However, this thermal effect is very localized and limited. Modeling of temperature effects from an underground 380-kV line under full load conditions indicated that the temperature increase at the surface directly above the line would not exceed 1 to 2 degrees Celsius (33.8 to 35.6 degrees Fahrenheit [°F]), and at a distance of 5 meters from this point, a soil temperature increase would not be detectable. (Reference 5.6-3) Similarly, soil temperature increases from the operation of a 69-kV underground line and the area affected are expected to be localized and limited. Soil temperature increases potentially could slightly alter the composition of the terrestrial vegetation and associated wildlife habitat directly above the line, but any effects would quickly decline with distance, and the affected area would be limited to the transmission line ROW, where vegetation is controlled.

Transmission lines generate coupled electric and magnetic fields, referred to together as electromagnetic fields (EMF). The voltage on the conductors of the transmission line generates an electric field that occupies the space between the conductors and other conducting objects such as the ground, transmission line structures, or vegetation. A magnetic field is generated by the current (movement of electrons) in the conductors. Electric fields from underground transmission lines are limited by insulation, and no electric field would be detected outside the cable. The strength of the magnetic field that surrounds the conductor decreases rapidly with distance. (Reference 5.6-3) Studies have found that magnetic and electric fields from transmission lines do not cause adverse behavioral, health, or reproductive effects in wildlife or other animals (Reference 5.6-4). Thus, EMF effects on terrestrial wildlife from operation of the underground 69-kV line would be negligible.

In summary, TVA has methods in place to protect terrestrial habitats from potential adverse effects associated with ongoing transmission line ROW maintenance activities. Potential thermal and EMF effects of the proposed underground transmission line on terrestrial habitats are expected to be negligible. Therefore, impacts to terrestrial ecosystems resulting from the operation and maintenance of transmission lines would be SMALL.

5.6.2 Impacts to Aquatic Ecosystems

Transmission lines within the vicinity of the CRN Site span several aquatic habitats, including a reservoir, creeks, and streams. The proposed location of the underground transmission line is within an existing 500-kV transmission line ROW. As discussed in Subsection 4.3.2.5, construction of the 69-kV line includes installation under short segments of several streams within the 500-kV ROW. The potential effects of transmission lines on aquatic ecosystems arise mainly from water quality effects associated with maintaining ROWs. TVA is responsible for many miles of transmission lines that span several aquatic habitats and, therefore, has procedures for ROW maintenance to protect aquatic resources. As described in Subsection 5.6.1, TVA has developed procedures for ROW maintenance activities such as erosion control and herbicide application, which are designed to maintain water quality in surface water bodies and wetlands in and near transmission line ROWs.

Streamside management zones (SMZs) refer to TVA-specified buffer areas surrounding bodies of water, including ponds, streams, and rivers. The size of the SMZ is specified depending on the slope of the surrounding area, the type of stream, and the particular resource that may be present in the stream. TVA follows established BMPs specifically directed toward avoiding or minimizing adverse impacts to SMZs and the associated waterbodies during maintenance activities. Use of hand held equipment for clearing trees reduces soil and shoreline disturbance. Applications of herbicides (except those labeled for aquatic use) are conducted so that chemicals are not applied directly or allowed to drift into intermittent or perennial streams or other water bodies. (Reference 5.6-1) Due to the use of these technologies when working near aquatic environments, adverse effects on aquatic ecosystems would be minimal.

As discussed for terrestrial ecosystems in Subsection 5.6.1, thermal effects from the 69-kV underground line potentially could occur in sediment and water of the stream segments that cross over the buried line. Such effects on aquatic systems were evaluated by the DOE in an Environmental Impact Statement (EIS) for a proposed 300-kV direct current underground transmission line, which would extend from Canada to New York City and would be installed largely beneath bodies of water. This EIS estimated that sediment temperature increases associated with the operation of that underground line would be less than 2°F at the sediment surface, not accounting for further temperature reductions that would result from advective heat losses to flowing water. Temperature changes in the water itself were estimated to be less than 0.01°F. Such changes in sediment or water temperatures would be negligible in comparison to seasonal fluctuations. As discussed for terrestrial ecosystems, EMF may be higher directly above an underground transmission line than below an overhead line, but electric fields are limited by insulation, magnetic fields weaken rapidly with distance, and such fields have not been found to cause adverse effects in wildlife or other animals. EMF effects on aquatic wildlife from operation of the underground 69-kV line would be negligible. (Reference 5.6-4)

TVA routinely implements measures to minimize potential adverse effects on aquatic habitats from ongoing transmission line ROW maintenance activities. Potential thermal and EMF effects of the proposed underground transmission line on aquatic habitats are expected to be negligible. Therefore, impacts to aquatic ecosystems resulting from the operation and maintenance of the transmission lines would be SMALL.

5.6.3 Impacts to Members of the Public

The possible effects from electrical transmission systems on members of the general public include exposure to EMF, electrical shock, exposure to noise, radio and television interference, and visual effects. Existing transmission lines currently connected to the energy distribution system are available for use by the CR SMR Project. As described in Section 3.7, existing line characteristics indicate the highest voltage line associated with the CRN Site is 500 kV. Also, a new 69-kV underground transmission line is proposed for installation within the existing Watts Bar NP – Bull Run FP 500-kV ROW.

5.6.3.1 Electromagnetic Field Exposure

Transmission lines and other types of electrical wiring generate EMF. The strength of the field depends on the current, design of the line, and distance from the line. Most of this energy is dissipated in the ROW and the very low residual amount is reduced to background levels near the ROW or energized equipment. (Reference 5.6-5) Existing offsite transmission lines are available to connect the CR SMR Project to the energy distribution system. Construction of new offsite overhead transmission lines is not proposed. However, as discussed in Section 3.7, some existing lines would be reconductored, uprated, or rebuilt to upgrade the transmission system as needed for the operation of the CR SMR Project. The EMF generated by the existing transmission lines would not be affected by operation of the CR SMR Project.

Installation of one new underground transmission line is proposed. Exposure to EMF is different for underground transmission lines. Electric fields from underground transmission lines are limited by insulation, and no electric field would be detected outside the cable. The strength of the magnetic field that surrounds the conductor decreases rapidly with distance. EMF strength may be higher directly above an underground line than under an overhead transmission line, but the width of the underground line EMF corridor is much less because the underground line occupies a narrower area. Mitigation measures can decrease the EMF fields related to underground transmission lines to negligible levels. (Reference 5.6-3)

Because public exposure to EMF from existing offsite transmission lines would not change and EMF fields associated with the new underground transmission line would be localized and can be decreased to negligible levels, impacts to the public resulting from EMF exposure would be SMALL.

5.6.3.2 Electrical Shock

In NUREG-1437, Rev 1, NRC indicates that the greatest electrical shock hazard from a transmission line is direct contact with the conductors and that tower designs preclude direct public access to the conductors. However, electrical shocks can occur without physical contact. Secondary shock can happen when humans make contact with either capacitively charged bodies (such as a vehicle parked near a transmission line) or magnetically linked metallic structures (such as fences near transmission lines). The shock received by the person could be painful. The intensity of the shock would depend on the EMF strength, the size of the object, and the degree of insulation between the object, the person, and the ground.

The NESC is the basis for design criteria that are intended to limit the risk of shock and other hazards due to transmission lines. The NESC calls for transmission lines to be designed with minimum vertical clearances to the ground so that the short-circuit current to ground produced from the largest anticipated vehicle or object is limited to less than 5 milliamperes. In NUREG-1437, Rev. 1, NRC indicated that the electrical shock issue is of small significance for transmission lines that are operated in adherence with the NESC. As described in Subsection 3.7.1, TVA plans to upgrade transmission lines in conjunction with the CR SMR Project. These upgrades (e.g., moving features that interfere with clearance, replacing and/or modifying existing structures, and modifying or replacing some existing conductors so as to increase ground clearance) would be needed to increase the electrical capacity of the existing transmission system. Maintaining the required clearance to meet NESC design criteria reduces the risk of electrical shock.

For underground transmission lines, no electrical fields are detected outside the cable. The electric field extending from an underground transmission line is limited by insulation, and outside the cable no electrical field would be detected. (Reference 5.6-3) Therefore, the most likely potential for electric shock from an underground transmission line is associated with direct contact, such as digging.

Given that TVA maintains the transmission lines in compliance with NESC guidelines, impacts to members of the public due to electrical shock would be SMALL.

5.6.3.3 Noise

As discussed in NUREG-1437, Rev. 1, transmission lines can generate a small amount of sound energy during corona activity, which is a partial discharge of electrical energy. During corona events, the ionization of the air that surrounds conductors of the high-voltage transmission lines, which is caused by electrostatic fields in these lines, generates impulse corona currents. When the voltage on a particular phase is high enough, a corona burst occurs, and a noise is generated. This audible noise from the line can barely be heard in fair weather on higher-voltage lines. During wet weather, water drops collect on the conductor and increase corona activity so that a crackling or humming sound may be heard near the line. This noise is caused by small electrical discharges from the water drops.

For 500-kV transmission lines, this corona noise, when present, is usually approximately 40-55 A-weighted decibels (dBA). The maximum recorded corona noise has been 60-61 dBA. (Reference 5.6-5) As discussed in Subsection 4.4.1.1, noise levels below 65 dBA outside a residence are generally considered to be acceptable Therefore, the corona-related noise potentially generated by transmission lines would be acceptable.

As described in Subsection 3.7.3.4, the depth of the proposed underground transmission line would be 36 in. below the ground surface. Corona discharge is not an issue with underground lines except at aboveground components such as substations, since the energized conductors are fully enclosed in a semi-conducting layer within the insulated cables that serve to equalize the electrical gradient at the surface of the components (Reference 5.6-6). The underground line is not expected to generate noise that would be audible from above the ground surface.

The 500-kV and 161-kV lines that would serve the CR SMR Project are already operating and the noise levels they produce are expected to continue to remain acceptable. The underground transmission line planned for construction is not expected to generate audible noise. Therefore, there are no anticipated increases to the current ambient noise levels associated with the operation of the transmission system, and the effect on noise would be SMALL.

5.6.3.4 Radio and Television Interference

Corona activity from transmission lines can also generate EMF noise at frequencies used for radio and television signals. If interference were to occur with radio or television reception, it would be due to unusual failures of power line insulators or poor alignment of the radio or television antenna and the signal source. Both conditions are correctable and would be repaired if reported to TVA. (Reference 5.6-5) As described in Subsection 5.6.3.3, corona discharge and the associated interference is not an issue with underground transmission lines. Therefore, there are no anticipated increases in corona activity associated with operation of the transmission system and the impact of the transmission lines on radio and television signals would be temporary and SMALL.

5.6.3.5 Visual Impacts

Continued operation of the existing transmission lines associated with the CR SMR Project would not affect the visual character of the area. The transmission towers and cleared corridors are already in place. The location of the proposed new 69-kV transmission line is underground within the existing 500-kV transmission line ROW. However, a portion of the existing 161-kV line located on the CRN Site would be re-routed to the east, along the Clinch River arm of the Watts Bar Reservoir. The new towers and cleared corridor would be visible from the reservoir and several residences across from the CRN Site. Given the presence of the other transmission lines on the CRN Site and in the area, and the industrial nature of the proposed project, the effect of the re-located transmission line would not noticeably alter important attributes of the area’s visual character. Therefore, although the re-located transmission line would alter viewscapes in the immediate vicinity of the CRN Site, the overall impact of the transmission system on visual resources would be SMALL.

5.6.4 References

Reference 5.6-1. Muncy, J. A., "A Guide for Environmental Protection and Best Management Practices," 2012.

Reference 5.6-2. Tennessee Valley Authority, "Right-Of-Way Vegetation Management Guidelines; Energy Delivery Environmental Protection Procedures," Revision 3, September 23, 2013.

Reference 5.6-3. Golder Associates, "Study on the Comparative Merits of Overhead Electricity Transmission Lines Versus Underground Cables," PPSMDE081295, May, 2008.

Reference 5.6-4. U.S. Department of Energy, "Champlain Hudson Power Express Transmission Line Project Environmental Impact Statement," September, 2013.

Reference 5.6-5. Tennessee Valley Authority, "Power Supply Improvement Project," 2005-107, April, 2008.

Reference 5.6-6. Aspen Environmental Group, Final Mitigated Negative Declaration and Supporting Initial Study for PG&E's Embarcader-Potrero 230 kV Transmission Project (Section 5.18), Website: http://www.cpuc.ca.gov/Environment/info/aspen/embarc-potrero/toc-fmnd.htm, October, 2013.

5.7 URANIUM FUEL CYCLE AND TRANSPORTATION IMPACTS

This section describes the environmental impacts from the uranium fuel cycle (UFC) for operation of two or more small modular reactors (SMR) at the Clinch River Nuclear (CRN) Site. Subsection 5.7.1 describes the impacts of the UFC using Table S-3, "Table of Uranium Fuel Cycle Environmental Data," in Title 10 of the Code of Federal Regulations (10 CFR) 51.51. The subsections below 5.7.1 assess individual resources impact by the UFC. Subsection 5.7.2 describes the transportation of radioactive materials to and from the CRN Site.

The subsections under 5.7.2.1, Transportation Assessment, address the conditions for use of Table S-4, "Environmental Impact of Transportation of Fuel and Waste To and From One Light-Water-Cooled Nuclear Power Reactor," in 10 CFR 51.52 to characterize the impacts of radioactive materials transportation to and from the CRN Site. 10 CFR 51.52(a) provides a list of conditions that a planned reactor must meet to fully apply Table S-4 to assess the impacts from transportation of fuel and radioactive waste. However, the SMRs at the CRN Site do not meet the conditions for average fuel enrichment or average fuel burnup provided in 10 CFR 51.52(a)(2) and 10 CFR 51.52(a)(3), respectively. Therefore, detailed analyses of fuel transportation effects for normal conditions and for accidents are presented in Subsection 5.7.2.2 and Section 7.4, respectively.

5.7.1 Uranium Fuel Cycle Impacts

The environmental effects from the UFC to support operation of SMRs at the CRN Site using Table S-3 are described and assessed in this subsection. The UFC is defined as the total of those options and processes associated with the provision, utilization, and ultimate disposition of fuel for nuclear power reactors. The evaluation in this subsection addresses the following stages of the UFC:

- Uranium mining and milling
- Conversion to uranium hexafluoride
- Enrichment of uranium-235
- Fabrication of reactor fuel
- Reprocessing of irradiated fuel
- Transportation and management of radioactive wastes
- Disposal of the spent fuel

Natural uranium is extracted from the earth through either open-pit or underground mining or by an in-situ leaching (ISL) process. ISL involves injecting an acidic solution into the groundwater aquifer to partition uranium from a solid to aqueous phase and then pumping the uranium-rich solution to the surface for further processing. The ore or leaching solution is processed to produce uranium oxide (U_3O_8). The uranium oxide is then converted to uranium hexafluoride (UF_6) in preparation for the enrichment process.

The UF_6 is transported to a separate facility for uranium enrichment. Uranium enrichment involves increasing the percentage of the more fissile isotope uranium-235 (U-235) and decreasing the percentage of the isotope uranium-238 (U-238). The enrichment process exploits the slight differences in atomic weights of the two isotopes. A feature common to large-scale enrichment schemes is that they employ a number of identical stages which use a cascading process to produce successively higher concentrations of U-235. Each stage concentrates the product of the previous stage further before the product is sent to the next stage. Similarly, the tailings from each stage are returned to the previous stage for further processing.

At a fuel-fabrication facility, the enriched uranium is converted from UF_6 to uranium dioxide (UO_2). In Table 3.1-2, Item 18, the fuel for the SMRs at the CRN Site is assumed to be UO_2. The UO_2 is formed into pellets, inserted into hollow rods, and loaded into fuel assemblies. The fuel assemblies are placed in the reactor to produce power. After a significant amount of the U-235 contained within a fuel assembly has been depleted, the nuclear fission process becomes inefficient, and spent fuel assemblies are then replaced. Spent fuel assemblies are placed in an onsite, interim, wet storage to allow for short-lived fission product decay and to reduce the heat generation rate. Afterward, the fuel assemblies are transferred to dry storage casks and stored onsite while awaiting transportation to a spent fuel storage facility or a waste repository.

The Nuclear Non-proliferation Act of 1978 effectively banned any reprocessing or recycling of spent fuel from United States commercial nuclear power. The ban on reprocessing spent fuel was lifted in 1981, but the combination of economics, uranium ore stockpiles, and nuclear industry stagnation provided little incentive for the industry to pursue reprocessing. The Energy Policy Act of 2005 authorized the U.S. Department of Energy (DOE) to research and develop proliferation-resistant fuel recycling and transmutation technologies that minimize environmental or public health and safety effects. Therefore, federal policy does not prohibit reprocessing, but there are currently no mature projects pursuing commercial reprocessing or recycling of spent fuel in the United States.

Table S-3 of 10 CFR 51.51 provides estimates of the environmental effects of the UFC. The effects are calculated for a reference 1000-megawatt-electric (MWe) light water reactor (LWR) operating at an annual capacity factor of 80 percent for an effective electric output of 800 MWe. This LWR design is referred to as the reference plant throughout this section. Data are calculated and presented in tables for land use, water consumption, thermal effluents, radioactive releases, waste burial, and radiation doses. 10 CFR 51.51 requires that the data in Table S-3 be used as the basis for evaluation of a proposed project.

In developing the reference plant data, the U.S. Nuclear Regulatory Commission (NRC) staff considered two UFC options. The “no recycle” and “uranium-only recycle” options differ only in the resting place of spent fuel. The “no recycle” option assumes that all spent fuel would be stored at a federal waste repository. The “uranium-only recycle” option assumes that spent fuel would be reprocessed to recover unused uranium, which would be returned to the UFC. The reference plant values provided for reprocessing, waste management, and transportation are from the UFC option resulting in the larger environmental effect.

The reference plant values provided in Table S-3 were derived from industry averages for each type of facility or operation associated with the UFC. Recognizing that this approach results in a range of values for each estimate, the NRC staff defined the assumptions or factors to be applied so the calculated values are not underestimated. This approach was intended to ensure that the actual environmental effects are less than the quantities shown for the reference plant and envelop the widest range of operating conditions for LWRs.

The NRC regulation recommends evaluating UFC parameters, nuclear plant characteristics, and impacts to the environment based on a reference plant. To determine the annual fuel requirement, the NRC staff defined the “reference plant” as a 1000-MWe LWR. The characteristics of the reference plant include an 80 percent capacity factor, a 12-month fuel reloading cycle, and an average fuel burnup rate of 33,000 megawatt-days (MWd) per metric ton (MT) of uranium (MTU). The expected lifetime of a newly constructed nuclear plant is approximately 60 years (yr; the 40-yr initial licensing plus one 20-yr license renewal term). The sum of the initial fuel loading and all of the expected reloads for the lifetime of the reactor is divided by the 60-yr expected lifetime to obtain an average annual fuel requirement. This quantity of fuel was determined for both boiling water reactors (BWRs) and pressurized water reactors (PWR); the higher annual requirement, a BWR using 35 MTU, was chosen in Subsection 6.2.3, paragraph 3, of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 0 as the basis for the reference plant.

In NUREG-1437, Rev. 0, the NRC staff provided a detailed analysis of the environmental effects of the UFC. NUREG-1437, Rev. 1, provides a less detailed analysis and often references NUREG-1437, Rev. 0 for additional details. Although NUREG-1437, Rev. 0 and Rev. 1, are specific to license renewal, the information is relevant because the SMRs described by the plant parameter envelope (PPE) in Table 3.1-2 use the same fuel cycle process and the same type of fuel as the reference plant. Section 6.2 of NUREG-1437, Rev. 0 discusses the sensitivity to changes in the UFC on the environmental effects in detail.

In the past, uranium market conditions led to the closing of most domestic uranium mines and mills, and substantially reduced the environmental effects in the United States from these activities. According to the U.S. Energy Information Administration (EIA), Uranium Marketing Annual Report for 2013, the majority of uranium [as uranium oxide equivalent (U_3O_8e)] purchased by the United States reactors has historically been imported. In 2013, 83 percent of uranium purchased by owners and operators of United States commercial nuclear power reactors was of foreign origin. (Reference 5.7-1)

Domestic production of uranium has been showing an upward trend since 2003 to meet increasing demand and projected demand from new plants involved in licensing and construction (Reference 5.7-2). However, purchases decreased slightly from 58 million pounds of U_3O_8e in 2012 to 57 million pounds U_3O_8e in 2013 (Reference 5.7-1). EIA conducted an additional analysis in 2014 examining the potential impacts of excess uranium offered into the market from inventories at the DOE's Portsmouth and Paducah gaseous diffusion plants. During the period from 2014 to 2033, the EIA reports that 129 million pounds the U_3O_8e would enter the market from the DOE stockpiles (Reference 5.7-3).

The slight decrease in U_3O_8e purchases in 2013 and DOE uranium coming on to the market suggest that the environmental effects of mining and milling could temporarily drop to levels below those given for the reference plant. However, the effects are still bounded by the reference numbers in NUREG-1437, Rev. 0 and Rev. 1. Therefore, for the purposes of this analysis, the reference plant estimates have not been reduced.

As provided in Table 3.1-2, Item 16.6, the maximum net power output of the SMRs at the CRN Site is 800 MWe. Table 3.1-2, Item 16.4, provides a station capacity factor of 98 percent resulting in an effective net power output 784 MWe. The ratio of the effective net power output value for the SMRs described by the PPE (784 MWe) to the net electrical output for the 1000 MWe reference plant (800 MWe) provides a scaling factor of 0.98 to convert reference plant values to project-specific values at the CRN Site (Table 5.7-1).

The environmental effects of the UFC from operating SMRs at the CRN Site were evaluated to assess qualitative effects to the environment. This assessment is based on the values calculated in Tables 5.7-1 and 5.7-2[1]; an analysis of the radiological effects from radiological emissions from the UFC including radon-222 (Rn-222) and technetium-99 (Tc-99) provided in Tables 5.7-3 and 5.7-4; and average doses to the United States population from UFC and non-UFC sources of radiation provided in Table 5.7-5.

5.7.1.1 Land Use

The total annual land requirement for the UFC supporting SMRs at the CRN Site is presented in Table 5.7-2. The table lists values for both permanently and temporarily committed land. Permanent land commitments are those that may not be released for use after plant shutdown and/or decommissioning. This limitation on land use is because decommissioning activities on the pertinent land may not remove sufficient radioactive material to meet the limits in 10 CFR 20, Subpart E, for release of land for unrestricted use. Temporary land commitments are for the life of the specific UFC plant (e.g., a mill, enrichment plant, or succeeding plants). Following completion of decommissioning, such land can be released for unrestricted use.

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[1] As scaled off the UFC impacts for the 1000-MWe reference plant in 10 CFR 51.51, Table S-3 using the ratio provided in Table 5.7-1.

As provided in Table S-3 for the reference plant, Table 5.7-2 equates the UFC disturbed land area and overburden requirements for the SMRs at the CRN Site to an equivalently-sized (in electrical power production) coal-fired power plant using strip-mined coal as a fuel and requiring the same area of disturbed land and overburden movement. The comparison shows that UFC land requirements for SMRs at the CRN Site producing 800 MWe are equivalent to the coal mining land use requirements (disturbed land) for a coal-fired plant producing only approximately 88 MWe. Therefore, an equivalent area of disturbed land for coal production yields about 89 percent less electrical output than an equivalent amount of land disturbed for electrical production with uranium fuel or, for an equivalent amount of energy produced with coal, the land use requirements would be nine times greater.

Due to the recent increase in natural gas production in the United States, the net electrical output associated with natural gas production was compared to the net electrical output from SMRs at the CRN Site based on an equivalent area of disturbed land. It is estimated that natural gas production in Marcellus shale disturbs about 8.8 acres (ac) per well pad (cleared lands for pad and infrastructure). (Reference 5.7-4) Each well pad contains on average two natural gas wells and each well typically produces 10 million cubic feet (ft^3) of natural gas per day (Reference 5.7-4). Using conversion factors of 1021 British thermal units (Btu) per cubic foot of natural gas and an assumed power plant heat rate of 8152 Btu per kilowatt-hour, the resulting net electrical output from natural gas production in the Macellus shale is about 11.8 MWe per ac (Reference 5.7-5). For comparison, if the 21.6 ac of disturbed land required to support the fuel needs for SMRs at the CRN Site (Table 5.7-2) were dedicated to natural gas production, the land would only produce enough fuel for a gas-fired plant producing approximately 255 MWe. Therefore, an equivalent area of disturbed land for natural gas fuel production yields 68 percent less net electrical output that an equivalent amount of land disturbed for electrical production with uranium fuel.

If the quality and opportunity costs of the land are equivalent, then it is reasonable to state that land requirements for nuclear power are SMALL compared to coal-fired power plants and natural gas production. Therefore, it is concluded that the effect on land use to support the UFC for SMRs at the CRN Site is considered to be SMALL.

5.7.1.2 Water Use

Power stations supply electrical energy to the enrichment stage of the UFC. The primary water requirement of the UFC is waste heat removal from these power stations. Table S-3 of 10 CFR 51.51 provides a total water discharge (usage) within the UFC for the reference plant as 11,377 x 10^6 gallons per year, less than 4 percent of the actual water used to cool the 1000 MWe reference plant. Applying the 0.98 scaling factor, the water use within the UFC to support SMRs at the CRN Site is estimated to be approximately 11,149 million gallons per year. Therefore, like the water average and maximum net water demands for the reactors themselves described in Subsection 5.2.2.1.1, the impact from the water used to manage power needs to support the SMRs at the CRN Site are also SMALL assuming similar water sources.

According to Table S-3, the annual thermal discharge of power plants used within the UFC to support the 1000-MWe reference plant is approximately 4063 billion Btu; this usage is less than 5 percent of the actual thermal discharge of the 1000 MWe reference plant. The expected thermal effluent value for SMRs at the CRN Site is approximately 3982 billion Btu as presented in Table 5.7-2. Similarly, because the thermal effluent value for the proposed plants is less than the thermal effluent value for the reference plant, the thermal discharge from the UFC for the SMRs at the CRN Site would also be SMALL.

From 10 CFR 51.51, Table S-3 states that the consumptive water use of the UFC in support of the 1000-MWe reference plant, i.e., water discharged to air from cooling towers, is 2 percent of the water consumption of the plant itself. Therefore, considering the scaling factor of 0.98, the water consumption from the UFC supporting the SMRs at the CRN Site would have a SMALL effect with respect to water use.

5.7.1.3 Fossil Fuel Effects

Electrical energy and process heat are consumed during various phases of the UFC. The electrical energy is often produced by combustion of fossil fuels (coal and/or natural gas) at conventional power plants. From 10 CFR 51.51, Table S-3, the electrical energy needs associated with the UFC associated with the reference plant are 323,000 MW-hours (MWh) and represents less than 5 percent of the annual electrical power production of the reference plant. For SMRs at the CRN Site, the UFC electrical energy needs would be approximately 316,540 MWh, which is equivalent to 115,640 MT of coal or 132 million ft^3 of natural gas (Table 5.7-2).

In NUREG-1437, Rev. 0, the NRC concludes that the effects of direct and indirect consumption of electric power for fuel cycle operations produced using fossil fuels are small and appropriate for the electric power being produced from uranium fuel by the reference plant. NUREG-1437, Rev. 1, does not provide any additional information that would alter this conclusion. Since the power output and UFC demands for the SMRs at the CRN Site are less than those for the reference plant, it is concluded that environmental effects from the combustion of fossil fuels associated with UFC operations is also considered to be SMALL.

The NRC estimates that the carbon footprint of the UFC to support the 1000-MWe reference plant for the 40-yr plant life is about 17,000,000 MT of carbon dioxide (Reference 5.7-6). Scaling the 10 CFR 51.51 reference plant's UFC carbon footprint to obtain a UFC carbon footprint for the SMRs at the CRN Site, the carbon footprint for 40 yr of UFC emissions would be approximately 16,660,000 MT. The average annual emission rate would then be approximately 416,000 MT. This rate compares to a total annual emissions of 5,500,000,000 MT in 2011 for the entire United States (Reference 5.7-7). Therefore, it is concluded that the carbon footprint associated with UFC operations is also considered to be SMALL.

5.7.1.4 Chemical Effluents

The quantities of gaseous, liquid, and solid effluents needed to support the UFC for the 10 CFR 51.51 reference plant and for the SMRs at the CRN Site are presented in Table 5.7-2.

Gaseous effluents include the entrainment of the pollutants provided in Table 5.7-2. The effluent quantities from the UFC for the reference plant are from 10 CFR 51.51, Table S-3. The 0.98 scaling factor is applied to estimate the effluent quantities for the UFC supporting the SMRs at the CRN Site provided in Table 5.7-2. According to 10 CFR 51.51, Table S-3, the gaseous effluents from the UFC supporting the reference plant are equivalent to the gaseous effluents from a 45 MWe coal power plant. Applying the 0.98 scaling factor to each of the gaseous effluents and summing them, the gaseous effluents from the UFC supporting the SMRs at the CRN Site are equivalent to the gaseous effluents from a 44 MWe coal power plant.

Because of the gaseous effluents from the UFC needed to support the SMRs at the CRN Site are equivalent to the effluents from a small 44 MWe coal-fired power plant or, for an equivalent amount of energy produced with coal, the chemical effluents would be about 2.3 times greater. Therefore, it is concluded that the effects to the degradation of air quality from the power generation needed to support the UFC is SMALL.

Liquid chemical effluents produced during the UFC are associated with the fuel enrichment, fuel fabrication, and fuel reprocessing steps. While fuel reprocessing is not currently performed commercially in the United States, the effluent amounts provided in 10 CFR 51.51, Table S-3, and Table 5.7-2 include potential reprocessing activities. In Table 5.7-2 the 0.98 scaling factor is used to estimate the quantities of liquid chemical effluents from the UFC needs of the SMRs at the CRN Site. Because the effluents at these quantities require only small amounts of dilution by the receiving bodies of water to achieve concentrations that are below established standards, the effects to the degradation of water quality from the power generation needed to support the UFC is SMALL. Additionally, any liquid discharges into the navigable waters of the United States from power plants associated with UFC operations are subject to requirements and limitations set in National Pollutant Discharge Elimination System permits issued by an appropriate federal, state, regional, local, or affected Native American tribal regulatory agency.

Tailings solutions and solids are generated during the milling process; however, these materials are not released in quantities that would have a significant effect on the environment. Amounts of tailings and solids for the reference plant and the SMRs at the CRN Site are provided in Table 5.7-2. The effect of all effluent waste streams (gaseous, liquid, and solid) associated with the UFC needs for the SMRs at the CRN Site are considered to be SMALL.

5.7.1.5 Radioactive Effluents

The estimates of radioactive effluent releases from the UFC to the environment from one year of operation for the 10 CFR 51.51 reference plant and the SMRs at the CRN Site are presented in Table 5.7-2. Radioactive effluents from the UFC include gaseous and liquid effluents. However,

Table 5.7-2 does not address Rn-222 and its progeny (herein after referred to as Rn-222) from the UFC activity or Tc-99 released from waste management or reprocessing activities.

The 100-yr involuntary environmental dose commitment to the United States population from the reference plant's impact on the UFC is provided in Table 5.7-3. From NUREG-1437, Rev 1, Table 4.12.1.1-1, "Population Doses from Uranium Fuel Cycle Facilities Normalized to One Reference Reactor Year," the portion of dose commitment from radioactive gaseous effluents is 400 person-rem per year and the portion of dose commitment from radioactive liquid effluents per year due to all UFC operations is 200 person-rem. Applying the ratio of effective electric output values from Table 5.7-1 and the 0.98 scaling factor for the SMRs at the CRN Site, the dose commitment from radioactive gaseous and liquid effluents provided in Table 5.7-3 would be approximately 392 person-rem and 196 person-rem, respectively. Thus, the total 100-yr environmental dose commitment to the United States population from radioactive gaseous and liquid releases resulting from these portions of the UFC provided in Table 5.7-3 is 588 person-rem per year for the SMRs at the CRN Site.

Currently, the radiological effects associated with Rn-222 and Tc-99 releases are not addressed in the reference plant data in 10 CFR 51.51. Most Rn-222 releases are from mining and milling operations and emissions from mill tailings, and most Tc-99 releases are from gaseous diffusion enrichment facilities. Although the gaseous diffusion plants in the United States have been shut down, the following assessment is based on the assumption that gaseous diffusion plants are in operation.

In Table 6.2 of NUREG-1437, Rev. 0, the NRC staff estimated the Rn-222 releases from mining plus milling and emanating from mill tailings required to support each year of operations of the 1000-MWe reference plant to total 5200 curies (Ci). The major risks from Rn-222 are bone and lung cancer, and there is a small risk from whole body exposure. The organ-specific dose weighting factors from 10 CFR Part 20 are applied to the bone and lung doses to estimate the 100-yr dose commitment from Rn-222 to the whole body, which is estimated to be 140 person-rem for the reference plant. Using the 0.98 scaling factor, the Rn-222 releases from the UFC associated with SMRs at the CRN Site are estimated to be 5096 Ci and the estimated population dose commitment from mining, milling, and tailings before stabilization for each year of operation of SMRs at the CRN Site is estimated to be 136 person-rem (Table 5.7-4).

In NUREG-1437, Rev. 0, the NRC staff also considered the potential health effects associated with the release of Tc-99 as part of UFC operations. It was found that the releases of Tc-99 are from chemical reprocessing of recycled UF_6 before it enters the isotope enrichment cascade. The annual Tc-99 releases (in Ci) from the reference plant (0.012 Ci) and scaled releases from the SMRs at the CRN Site (0.012 Ci) are presented in Table 5.7-4.

The major risks from Tc-99 are from exposure of the gastrointestinal tract and kidney; additionally, there is a small risk from whole-body exposure. Using the organ-specific dose weighting factors from 10 CFR 20, these individual organ risks were converted to a whole-body

100-yr dose commitment per year of operation. These values are presented in Table 5.7-4 for the reference plant (100 person-rem) and for the SMRs at the CRN Site (98 person-rem).

Many radiation protection experts assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold dose response relationship is used to describe the relationship between radiation dose and detriments such as cancer induction. The Biological Effects of Ionizing Radiation (BEIR) VII report by the National Research Council, uses the linear, no-threshold dose response model as a basis for estimating the risks from low doses (Reference 5.7-8). This approach is accepted by the NRC as a conservative method for estimating health risks from radiation exposure, recognizing that the model may overestimate those risks. Based on this method, the risk to the public from radiation exposure using the nominal probability coefficient for total detriment can be estimated. This coefficient has the value of 570 fatal cancers, nonfatal cancers, and severe hereditary effects per 1,000,000 person-rem. From Table 5.7-3, the total whole body population doses (including Rn-222 and Tc-99) would be 840 person-rem/yr for the 1000-MWe reference plant and 822 person-rem/yr for the SMRs at the CRN Site. The estimated number of fatal cancers, nonfatal cancers, and severe hereditary effects would be less than one per year for both the 1000-MWe reference plant and the new plant.

In addition, at the request of the U.S. Congress, the National Cancer Institute conducted a study and published “Cancer in Populations Living near Nuclear Facilities: A Survey of Mortality Nationwide and Incidence in Two States” in 1991 (Reference 5.7-9). This report included an evaluation of health statistics around all nuclear power plants, as well as several other nuclear fuel-cycle facilities, in operation in the United States in 1981 and found “no evidence that an excess occurrence of cancer has resulted from living near nuclear facilities.” The contribution to the annual average dose received by an individual from the UFC-related radiation and other sources is presented in Table 5.7-5. (Reference 5.7-10)

Based on the information presented above, it is concluded that the environmental effect (population dose) from radioactive effluents from the UFC demands for the SMRs at the CRN Site is considered to be SMALL.

5.7.1.6 Radioactive Wastes

The quantities (in Ci) of radioactive waste material generated as part of the UFC (low-level waste [LLW], high-level waste [HLW], and transuranic [TRU] waste) are shown in 10 CFR 51.51(a), Table S-3, and Table 5.7-2. For LLW disposal, the NRC indicates in Table S-3 that no significant radioactive releases to the environment are expected.

Pursuant to 10 CFR 51.23(b) and 10 CFR 51.50(b)(2), this Environmental Report does not discuss the environmental impacts of spent nuclear fuel storage in a spent fuel pool or an interim spent fuel storage installation (ISFSI) for the period following the term of the reactor operating license, reactor combined license, or ISFSI license. Rather, the impact determination in NUREG-2157, *Generic Environmental Impact Statement for Contained Storage of Spent Nuclear Fuel,* regarding continued storage is deemed incorporated into the environmental impact statement.

5.7.1.7 Occupational Dose

As provided in Subsection 6.2.2.3 of NUREG-1437, Rev. 0, the annual occupational dose for the reference 1000 MWe reactor attributable to all phases of the fuel cycle is 600 person-rem. The fuel cycle for the SMRs would be similar to the fuel cycle for the reference plant. Individual occupational doses are maintained to meet the dose limits in 10 CFR Part 20, which is 5 rem/yr. Therefore, the environmental effects from this occupational dose is considered to be SMALL.

5.7.1.8 Transportation

As shown in Table 5.7-2, the annual transportation dose from exposure to workers and the general public for the 10 CFR 51.51 reference plant is approximately 2.5 person-rem. Applying the scaling ratio, the total annual occupational dose attributable to all phases of the UFC needs for the SMRs at the CRN Site is estimated to be approximately 2.4 person-rem. For comparative purposes, the estimated annual dose from natural background radiation to a person living within 50 miles (mi) of the CRN Site is 0.36 rem per person (Reference 5.7-11). Given the size of the total population (worker and general public) exposed during transportation, it is concluded that the dose from transportation is considered to be SMALL.

5.7.1.9 Summary

Using the federal evaluation process in NUREG-1437, Rev. 0 and Rev. 1, the evaluation subsection has examined the environmental effect of the UFC, including the dose from Rn-222 and Tc-99, as it relates to the operation of SMRs at the CRN Site. Based on this evaluation, it is concluded that the environmental effects of the contributions to the UFC from the operation of SMRs at the CRN Site is considered to be SMALL.

5.7.2 Transportation of Radioactive Materials

The public dose from the transportation of all radioactive waste (LLW, HLW, and TRU waste) is discussed in the preceding Subsection 5.7.1.8. The following information supports the assessment of spent nuclear fuel transportation:

- Reactor type and rated core thermal power (Section 3.2)
- Fuel assembly description (Subsection 3.8.1)
- Average irradiation level of irradiated fuel (Subsection 3.2.1)
- Capacity of onsite storage facilities and minimum fuel storage time (Subsection 3.8.2)
- Transportation distances (Section 7.4)

5.7.2.1 Transportation Assessment

As detailed in the following subsections, the SMRs at the CRN Site do not meet all of the conditions for the reactor and fuel provided in 10 CFR 51.52(a). Specifically, the SRM fuel enrichment can be greater than 4 percent by weight and SMR fuel burnup can be greater than 33,000 megawatt-days per metric ton. Therefore, the analyses of fuel transportation effects for normal conditions and for accidents are presented in Subsection 5.7.2.2 and Section 7.4, respectively.

Nonradiological effects from the transportation of fuel (new and spent) and other radiological wastes are traffic density, weight of the loaded truck or railcar, heat from the fuel cask, and transportation accidents. The NRC evaluated the environmental effects of transportation of fuel and waste for LWRs and found the impacts to be SMALL. The NRC analyses provided the basis for Table S-4 in 10 CFR 51.52, which summarizes the environmental effects of transportation of fuel and radioactive wastes to and from a reference plant (Table 5.7-6 and Table 5.7-7). Table S-4 addresses two categories of environmental consideration: (1) normal conditions of transport, and (2) accidents during transport.

Subparagraphs 10 CFR 51.52(a)(1) through (5) delineate specific conditions the reactor licensee must meet to use Table S-4 as part of its environmental report. For reactors not meeting all of the conditions in paragraph (a) of 10 CFR 51.52, paragraph (b) of 10 CFR 51.52 requires further analysis of the transportation effects.

The conditions in paragraph (a) of 10 CFR 51.52 establishing the applicability of Table S-4 are reactor core thermal power, fuel form, fuel enrichment, fuel encapsulation, average fuel irradiation, time after discharge of irradiated fuel before shipment, mode of transport for unirradiated fuel, mode of transport for irradiated fuel, radioactive waste form and packaging, and mode of transport for radioactive waste other than irradiated fuel. The following subsections describe the characteristics of the SMRs at the CRN Site relative to the conditions of 10 CFR 51.52 for use of Table S-4. If the conditions of Table S-4 are not met, detailed transportation accident analyses are required.

5.7.2.1.1 Reactor Core Thermal Power

Subparagraph 10 CFR 51.5(a)(1) requires that for comparison to the reference plant, the new reactor must have a core thermal power level not exceeding 3800 Megawatt thermal (MWt). In Table 3.1-2, Item 16.1, the SMRs on the CRN Site have a combined maximum thermal power level of 2420 MWt. Therefore the sum of the thermal power for all new SMRs at the CRN Site meets this condition.

The initial core loading of the reference plant is 100 MTU. In Table 3.1-2, Item 18.0.2, the surrogate SMR core contains 96 fuel assemblies. The mass of the uranium in the fuel assemblies is 0.304 MTU per fuel assembly, resulting in an initial core loading of about 30 percent of the 100 MTU assumed for the reference plant.

5.7.2.1.2 Fuel Form

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel be in the form of sintered uranium dioxide pellets. In Table 3.1-2, Item 18.0.1, fuel for the SMRs at the CRN site would be a sintered UO_2 fuel. Therefore, the requirement is met.

5.7.2.1.3 Fuel Enrichment

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel have a U-235 enrichment not exceeding 4 percent by weight. In Table 3.1-2, Item 18.1, the SMR fuel would have an enrichment of less than 5 percent which can exceed this condition. However, NUREG/CR-6703, *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU,* supported the conclusion that the environmental impacts of enrichments up to 5 percent were bounded by the impacts reported in Table S-4.

5.7.2.1.4 Fuel Encapsulation

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel pellets be encapsulated in Zircaloy rods. In Table 3.1-2, Item 18.7, the SMR fuel would use Zircaloy cladding and, therefore, meets the requirement.

5.7.2.1.5 Average Fuel Irradiation

Subparagraph 10 CFR 51.52(a)(2) requires that the average fuel burnup not exceed 33,000 MW-days per MTU. In Table 3.1-2, Item 18.2, average burnup for the SMR fuel assembly would be less than or equal to 51,000 MW-days per MTU which exceeds the limits of Table S-4. However, NUREG/CR-6703 supports the conclusion that the environmental impacts of higher fuel burnup rates were bounded by the impacts reported in Table S-4.

5.7.2.1.6 Time After Discharge of Irradiated Fuel Before Shipment

Subparagraph 10 CFR 51.52(a)(3) requires that no irradiated fuel assembly be shipped until at least 90 days after it is discharged from the reactor. The analysis provided by the NRC and referenced in Table S-4 assumes 150 days of decay time before shipment of any irradiated fuel assemblies (Reference 5.7-12). NUREG/CR-6703 assumes a minimum of 5 yr between removal from the reactor and shipment. NUREG-1437, Rev. 1, indicates that the NRC specifies 5 yr as the minimum cooling period when it issues certificates of compliance for casks used for shipment of power reactor fuel. Therefore, five years is considered the minimum decay time expected before shipment of irradiated fuel assemblies. In Table 3.1-2, 18.0.4, SMRs at the CRN Site would have a minimum 6-yr storage capacity, which exceeds that needed to accommodate 5-yr cooling of irradiated fuel before removal from the spent fuel pool and either transferred to onsite dry storage or transport offsite. Therefore, the requirement is met.

5.7.2.1.7 Mode of Transport for Unirradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) requires that unirradiated fuel be shipped to the reactor site by truck. Fuel is expected to be shipped to the CRN Site by truck from a fuel fabrication facility as far away as Washington State. Table S-4 includes a condition that truck shipment would not exceed 73,000 pounds. Fuel shipments to the CRN Site would comply with this and other state and federal requirements. Therefore, the criterion is met.

5.7.2.1.8 Mode of Transport for Irradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) allows irradiated fuel to be shipped by truck, rail or barge. Irradiated fuel is expected to be shipped from the CRN Site by truck. Currently, the DOE is responsible for spent fuel transportation from reactor sites.

Subparagraph 10 CFR 51.52(a)(6) Table S-4 includes a condition that the heat generated from irradiated fuel per shipping cask in transit would not exceed 250,000 Btu per hour (Btu/hr). Using the guidance provided in ANSI/ANS 5.1-2014, *American National Standard for Decay Heat Power in Light Water Reactors*, a conservative estimate of the heat load in a shipping cask is approximately 233,000 Btu/hr. This estimate is based on the following assumptions and PPE values: the NRC approved General Atomics GA-4 or similar cask will be used for shipping spent fuel (NUREG-2125, *Spent Fuel Transportation Risk Assessment*); SMR fuel assemblies are one-third the length of standard PWR fuel assemblies; 12 SMR fuel assemblies will be shipped in a GA-4 shipping cask; the power density of each fuel assembly is approximately 9 MWt; fuel assemblies are burned through three fuel cycles and loaded into casks five years after the core offload of the third fuel cycle; fuel burnup is 51 GWd/MTU (Table 3.1-2, Item 18.2); and 0.304 MTU per assembly (Table 3.1-2, Item 18.0.2). Therefore, while no cask has been designed for shipment of irradiated SMR fuel, it is expected that the Table S-4 criterion be met for fuel shipments from the CRN Site.

5.7.2.1.9 Radioactive Waste Form and Packaging

Subparagraph 10 CFR 51.52(a)(4) requires that radioactive waste be shipped from the reactor in packages and in a solid form (with the exception of irradiated fuel). As described in Subsection 3.8.3, the LLW generated by the SMRs at the CRN Site would be prepared, packaged, and shipped according to the U.S. Department of Transportation regulations. Therefore, the requirement is met.

5.7.2.1.10 Mode of Transport for Radioactive Waste

Subparagraph 10 CFR 51.52(a)(5) requires that the mode of transportation of LLW be either by truck or rail. LLW is expected to be shipped from the CRN Site by truck in accordance with state and federal requirements, including limiting shipments to 73,000 pounds. Therefore, the requirement is met.

5.7.2.1.11 Number of Truck Shipments

The NRC references the "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," also referred to as "WASH-1238," for transportation impacts from the 10 CFR 51.52 (Table S-4) reference reactor. Table S-4 specifies the following conditions for traffic density: less than one truck shipment per day or less than three rail cars per month. The number of truck shipments of unirradiated fuel, irradiated fuel, and solid radioactive waste to and from the CRN Site was calculated using the same truck loading rates as used in WASH-1238 or based on information provided in Table 3.1-2. The WASH-1238 truck shipments per year (traffic density) are compared to the CRN Site shipments in Table 5.7-7.

TVA estimates that 492 shipments of unirradiated fuel would be required for operating SMRs described by the PPE over 40 yr. In WASH-1238, the NRC assumed 18 shipments of new fuel would be made for the initial reactor loading of the 10 CFR 51.52 Table S-4 reference reactor and an additional 6 shipments per year for 39 yr resulting in a total of 252 shipments (Reference 5.7-12). The annual number of shipments of new fuel to the reference plant and the SMRs at the CRN Site are provided in Table 5.7-6. While the maximum number of fuel shipments for initial loading is 40, because the SMR design has not been selected and the initial loading scheme is not known, the average annual number assumes the same number of fuel shipments over the 40-yr lifetime of the SMRs.

TVA estimates that there would be 46 annual shipments of irradiated fuel from the SMRs at the CRN Site. As provided in Table 5.7-7, the normalized number of annual shipments is 137. The number of annual shipments of irradiated fuel from the reference reactor is 60 (Reference 5.7-12).

The number of solid radioactive waste shipments from the CRN Site is based on a volume of 5000 ft^3 per year as provided in Table 3.1-2, Item 11.2.3. As shown in Table 5.7-7, the number of solid radioactive waste shipments from the CRN Site would be about 61 truck shipments per year normalized to 75 shipments per year.

As shown in Table 5.7-8, the sum of the number of yearly truck shipments of fuel and radioactive waste to and from the CRN Site is estimated to be 227 trucks per year, or less than one truck shipment per day. Table S-4 from 10 CFR 50.52 also states that the reference reactor would have less than one truck shipment per day. Therefore the traffic density from the CRN Site would be comparable to the traffic density from the reference reactor.

5.7.2.1.12 Summary

Although the SMRs at the CRN Site meet most of the conditions in 10 CFR 51.51 and 51.52, the conditions for fuel burnup and fuel enrichment are not met. Therefore, TVA provided additional transportation analyses. These analyses are presented in Subsection 5.7.2.2 and Section 7.4, respectively.

5.7.2.2 Incident-Free Transportation Impact Analysis

The environmental impacts of radioactive materials transportation were estimated using the most recent version of the RADTRAN 6.5 computer code (Reference 5.7-13). RADTRAN is a nationally accepted standard program and code for calculating the risks of transporting radioactive materials. RADTRAN was used in estimating the radiological doses and dose risks to populations and transportation workers resulting from incident-free transportation and to the general population from accident scenarios. For the analysis of incident-free transportation risks, the code used scenarios for persons who would share transportation routes with shipments, persons who live along the route of travel, and persons exposed at stops. Environment impacts of incident-free transportation of fuel are discussed in this subsection. Transportation accidents are discussed in Section 7.4.

5.7.2.2.1 Transportation of Unirradiated Fuel

Table S-4 of 10 CFR 51.52 includes conditions related to radiological doses to transport workers and members of the public along transport routes. These doses, based on calculations in WASH-1238 (Reference 5.7-12), are a function of the radiation dose rate emitted from the unirradiated fuel shipments, the number of exposed individuals and their locations relative to the shipment, the time of transit (including travel and stop times), and the number of shipments to which the individuals are exposed.

Calculation of worker and public doses associated with annual shipments of unirradiated fuel were performed using the WebTRAGIS 6.0 and RADTRAN computer codes (Reference 5.7-14). One of the key assumptions in WASH-1238 for the reference LWR unirradiated fuel shipments is that the radiation dose rate at 3 feet from the transport vehicle is 0.1 millirem/hour (hr). This assumption is reasonable for the new plant technologies because the fuel materials would be low-dose rate enriched uranium and would be packaged similarly to the fuel analyzed in WASH-1238 (inside a metal container that provides sufficient radiation shielding).

For unirradiated fuel shipments, highway routes are analyzed using the routing computer code WebTRAGIS. It is assumed that all unirradiated fuel shipments come from Richland, Washington. The highway route controlled quantity (HRCQ) route setting was used to generate highway routes generally used by commercial trucks. The distance from the CRN Site to Richland, Washington is 2451 mi. The population summary module of the WebTRAGIS computer code is used to determine the exposed populations within a half-mile band on either side of the route.

The per trip dose values are combined with the average annual number of shipments of unirradiated fuel to calculate annual doses to the public and workers for comparison to Table S-4 dose values. The number of shipments per year is obtained from Table 5.7-6. The incident-free dose rates (in person-rem per shipment) were calculated by RADTRAN and are provided in Table 5.7-9. The dose rates ranged from 4.59E-03 person-rem per year for the transportation crew exposed at stops and 7.85E-03 person-rem per year for crew along the route to 5.81E-03 person-rem per year for the public in other vehicles along the transportation route.

5.7.2.2.2 Transportation of Irradiated Fuel

The environmental impacts of transporting spent fuel from the CRN Site to a spent fuel disposal facility assume Yucca Mountain, Nevada as a possible location for a geologic repository. The impacts of the transportation of spent fuel to a possible repository in Nevada provides a reasonable determination of the transportation impacts to a monitored retrievable storage facility because of the distances involved and the representative exposure of members of the public in urban, suburban, and rural areas.

Incident-free transportation refers to transportation activities in which the shipments reach their destination without releasing any radioactive cargo to the environment. Impacts from these shipments are from the low levels of radiation that penetrate the heavily shielded spent fuel shipping cask. Radiation doses occur to the following:

- Persons residing along the transportation corridors between the CRN Site and the potential repository
- Persons in vehicles passing a spent fuel shipment
- Persons at vehicle stops for refueling, rest, and vehicle inspections
- Transportation crew workers

This analysis is based on shipment of spent fuel by legal-weight trucks in casks with characteristics similar to casks currently available (i.e., massive, heavily shielded, cylindrical metal pressure vessels). Each shipment is assumed to consist of a single shipping cask loaded on a modified trailer. These assumptions are consistent with assumptions made in evaluating environmental impacts of spent fuel transportation in Addendum 1 to NUREG-1437, Rev. 0. As discussed in NUREG-1437, Rev. 0, these assumptions are conservative because the alternative assumptions involve rail transportation or heavy-haul trucks that reduce the overall number of spent fuel shipments.

The transportation route selected for a shipment determines the total potentially exposed population and the expected frequency of transportation-related accidents. For truck transportation, the route characteristics most important to the risk assessment include the total shipping distance between each origin-destination pair of sites and the population density along the route.

For irradiated fuel, it is assumed that all irradiated fuel is sent to the potential Yucca Mountain repository. The distance from the CRN Site to the repository was determined to be 2292 mi by the WebTRAGIS (Reference) computer code for a highway route-controlled quantity. Routing and population data used in RADTRAN for truck shipments were obtained from the

WebTRAGIS computer code. The population data in the WebTRAGIS computer code is based on the 2010 United States census.

The population doses are calculated by multiplying the number of spent fuel shipments per year by the per-shipment doses. The numbers of shipments per year are obtained from Table 5.7-7. The incident-free dose rates (in person-rem per shipment) were calculated by RADTRAN and are provided in Table 5.7-9. The dose rates ranged from 5.55 person-rem per year for the transportation crew exposed at stops and 9.32 person-rem for the crew along the route to 3.66 person-rem per year for the public in other vehicles along the transportation route.

5.7.2.2.3 Transportation of Radioactive Waste

Incident-free transportation refers to transportation activities in which shipments reach their destination without releasing any radioactive cargo to the environment. Impacts from these shipments are from the low levels of radiation that penetrate the radioactive waste shipping containers. Radiation doses occur to the following:

- Persons residing along the transportation corridors between the CRN Site and the potential repository
- Persons in vehicles passing a radioactive waste shipment
- Persons at vehicle stops for refueling, rest, and vehicle inspections
- Transportation crew workers

This analysis is based on shipment of radwaste by legal-weight trucks in either sea-land containers or high-integrity containers similar to those currently available. Each shipment is assumed to consist of a single shipping container from the CRN Site to Andrews, Texas.

The transportation route selected for a shipment determines the total potentially exposed population and the expected frequency of transportation-related accidents. For truck transportation, the route characteristics most important to the risk assessment include the total shipping distance between each origin-destination pair of sites and the population density along the route.

For radioactive waste, WebTRAGIS selected a HRCQ route of Interstate highways through Tennessee, Arkansas, and Texas. The route is 1214 mi.

Routing and population data used in RADTRAN for truck shipments was obtained from the WebTRAGIS computer code. The population data in the TRAGIS computer code is based on the 2010 United States census. All radioactive waste shipments are transported by legal-weight trucks to the Texas site over commercial truck routes.

The population doses are calculated by multiplying the number of radioactive waste shipments per year by the per-shipment doses. The numbers of shipments per year are identified in Table

5.7-7. The incident-free dose rates (in person-rem per shipment) were calculated by RADTRAN and are provided in Table 5.7-9. The dose rates ranged from 1.61 person-rem per year for the transportation crew exposed at stops and 2.55 person-rem along the route to 1.92 person-rem per year for the public in other vehicles along the transportation route.

5.7.2.2.4 Comparison to 10 CFR 51.52 Table S-4

For an equal comparison to the reference reactor in 10 CFR 51.52 Table S-4, the number of shipments in Table 5.7-8 for the SMR must be normalized. For each technology, the number of shipments is normalized based on net electric generation relative to the 1100 MWe and 80 percent capacity factor reference reactor analyzed in WASH-1238 (NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*). Additionally, the unirradiated fuel shipments are adjusted to account for the initial core loading in the annual number of shipments for each reactor technology. The spent fuel shipments are scaled to reflect the capacity of 0.5 MTU/container used for the reference reactor. The number of radioactive waste shipments is based on 3800 ft^3 and 46 shipments per year from the reference reactor (from WASH-1238) or 82.6 ft^3 per shipment (2.34 cubic meters (m^3) per shipment). The resulting annual truck shipments normalized to the reference reactor are summarized in Table 5.7-8. Annual doses provided in Table 5.7-9 are based on the normalized number of shipments.

Table 5.7-9 provides a total crew dose of 19.1 person rem per reactor year. This compares against the Table S-4 value of 4 person-rem per reactor year. While the estimate is more than four times the Table S-4 value, it is still considered small given the increased number of normalized shipments, and the greater assumed transportation distances (WASH-1238 uses 1000 mi for unirradiated fuel shipments, 1000 mi for irradiated fuel shipments, and 500 mi for radioactive waste shipments (Reference 5.7-12)). The doses provided in Table 5.7-9 also assume the maximum dose rate for all shipment types, and the use of 30 minutes as the average time for a truck stop in the calculations.

Table 5.7-9 also provides a total public dose of 10.1 person rem per reactor year. Onlookers are members of the public exposed to a shipping container for a short duration during periods when the transportation vehicle is stopped. This compares against the Table S-4 value of 3 person-rem per reactor year. While the estimate is more than three times the Table S-4 value, it is still considered small given the increased number of normalized shipments, the greater assumed transportation distances, and the increased populations along the transportation routes. Table S-4 does not provide a cumulative dose for the population exposed along the transportation routes for direct comparison.

5.7.2.3 Summary

A detailed analysis of the environmental impacts for the transportation of unirradiated fuel, irradiated fuel, and radioactive waste transported to and from the CRN Site was performed in accordance with 10 CFR 51.52(b). An evaluation of the environmental impact due to transportation of unirradiated fuel, irradiated fuel, and radioactive waste at alternative indicates that the alternative sites are not obviously superior to the CRN Site.

The new plant would have sufficient fuel pool storage capacity to enable a minimum cooling period of five years and sufficient storage capacity to permit irradiated fuel to cool sufficiently to meet the requirements of shipping casks available at the time the fuel is shipped.

In the analysis it was assumed that all shipments of unirradiated fuel, irradiated fuel, and radioactive waste are by truck. The shipping weights would comply with federal, state, local, and tribal government restrictions as appropriate. The total number of shipments for the CRN Site are outlined in Table 5.7-8, is 227 per year (normalized) which meets the Table S-4 requirement of less than one per day.

The radiological effects of incident-free conditions of transport are summarized in Table 5.7-9. The radiological effects of accidents in transport are provided in Section 7.4. The values obtained from these analyses represent the impacts from incident-free transportation of radioactive materials to and from the CRN Site. The population doses to the transport crew and onlookers resulting from the new plant normalized to the reference reactor exceed Table S-4 values. However, these increases are reasonable given the different exposure parameters between WASH-1238 and the CRN Site RADTRAN model. Therefore, based on the analyses and above discussion, the environmental impacts of transportation of unirradiated fuel, irradiated fuel, and radioactive waste would be SMALL.

5.7.3 References

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Reference 5.7-3. Meade, Thomas B. and Supko, Eileen M., Review of the Potential Impact of DOE Excess Uranium Inventory On the Commercial Markets, Website: http://www.energy.gov/sites/prod/files/2014/05/f15/ERI%20Market%20Analysis.pdf, April 25, 2014.

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Reference 5.7-11. U.S. Nuclear Regulatory Commission, Personal Annual Radiation Dose Calculator, Website: http://www.nrc.gov/about-nrc/radiation/around-us/calculator.html, June 28, 2013.

Reference 5.7-12. U.S. Atomic Energy Commission, "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants (WASH-1238)," December, 1972.

Reference 5.7-13. Sandia National Laboratories, "RADTRAN 6 Technical Manual," SAND2013-0780, January 2014.

Reference 5.7-14. UT-Battelle, LLC. Transportation Routing Analysis Geographic Information System (TRAGIS), Version 6.0. U.S. Department of Energy Contract No. DE-AC05-00OR22725. Website: https://webtragis.ornl.gov/tragis/app/map/view, 2017.

Table 5.7-1
Scaling Factor- Reference Plant and CRN SMRs

Parameter	10 CFR 51.51 Reference Plant (1000 MWe LWR)	CRN Site SMRs
Net Electric Output	1000 MWe	800 MWe
Capacity Factor	80 percent	98 percent
Effective Electric Output	1000 MWe x 80 percent = 800 MWe	800 MWe x 98 percent = 784 MWe
Ratio of Effective Electric Output Values	1	0.98[1]

[1] This scale factor is used to calculate the Standard Plants values in Tables 5.7-2 through 5.7-4.

Table 5.7-2 (Sheet 1 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	Maximum effect per annual fuel requirement or RRY	Reference Reactor Data multiplied by scale factor = 0.98	Maximum effect per annual fuel requirement or RRY multiplied by scale factor
Natural Resource Use				
Land (ac)				
Temporarily committed	100		98	
Undisturbed area	79		77.4	
Disturbed area	22	This is equivalent to a 110 MWe coal-fired power plant.	21.6	This is equivalent to an 88 MWe coal-fired power plant; 89% less energy per ac than the SMR option
Permanently committed	13		12.7	
Overburden moved, million MT	2.8	This is equivalent to a 95 MWe coal-fired power plant.	2.74	This is approximately equivalent to a 93 MWe coal-fired power plant; 88% less energy per ac than the SMR option
Water (millions of gal)				
Discharged to air	160	= 2 percent of model 1000 MWe LWR with cooling tower	157	< 2 percent of model 1000 MWe LWR with cooling tower
Discharged to water bodies	11,090		10,868	
Discharged to ground	127		124	
Total	11,377	< 4 percent of the water needs of the 1000 MWe LWR with once-through cooling.	11,149	< 4 percent of the water needs of the 1000 MWe LWR with once-through cooling.

Table 5.7-2 (Sheet 2 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	Maximum effect per annual fuel requirement or RRY	Reference Reactor Data multiplied by scale factor = 0.98	Maximum effect per annual fuel requirement or RRY multiplied by scale factor
Fossil fuel				
Electrical energy, MW hour (MWh)	323,000 MWh	< 5 percent of model 1000 MWe output	316,540 MWh	< 5 percent of model 1000 MWe output
Equivalent coal (MT)	118,000	This is equivalent to the consumption of a 45 MWe coal-fired power plant.	115,640	This is equivalent to the consumption of a 44 MWe coal-fired power plant.
Natural gas (standard cubic feet [scf])	135 million		132 million	
Chemical Effluents (MT)				
Gases, incl. entrainment				
SO_x	4400	These values are equivalent to the emissions from a 45 MWe coal-fired plant for a year.	4312	These values are equivalent to the emissions from a 44 MWe coal-fired plant for a year.
NO_x	1190		1166	
Hydrocarbons	14		13.7	
CO	29.6		29.0	
Particulates	1154		1131	
Other gases				
F	0.67		0.66	
HCl	0.014		0.014	
Liquids				
SO^-_4	9.9		9.7	
NO^-_3	25.8		25.3	

Table 5.7-2 (Sheet 3 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	Maximum effect per annual fuel requirement or RRY	Reference Reactor Data multiplied by scale factor = 0.98	Maximum effect per annual fuel requirement or RRY multiplied by scale factor
Fluoride	12.9		12.6	
Ca^{++}	5.4		5.3	
Cl^-	8.5		8.33	
Na^+	12.1		11.9	
NH_3	10.0		9.8	
Fe	0.4		0.4	
Tailings solutions	240,000		235,200	
Solids	91,000		89,180	
Radiological Effluents, Ci				
Gases, incl. entrainment				
Rn-222	-		-	
Ra-226	0.02		0.02	
Th-230	0.02		0.02	
U	0.034		0.033	
H-3 (thousands)	18.1		17.7	
C-14	24		23.52	
Kr-85 (thousands)	400		392	
Ru-106	0.14		0.13	
I-129	1.3		1.3	
I-131	0.83		0.81	

Table 5.7-2 (Sheet 4 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	**Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant**		**Annual Fuel Requirement Impacts CRN Site SMRs**	
	Reference plant Data	**Maximum effect per annual fuel requirement or RRY**	**Reference Reactor Data multiplied by scale factor = 0.98**	**Maximum effect per annual fuel requirement or RRY multiplied by scale factor**
Tc-99	-		-	
Fission products and transuranics (TRU)	0.203		0.199	
Liquids				
Uranium and daughters	2.1		2.06	
Ra-226	0.0034		0.0033	
Th-230	0.0015		0.0015	
Th-234	0.01		0.0098	
Fission and Activation	5.9×10^6		5.8×10^6	
Solids (buried onsite)				
Other than high level waste (HLW) (shallow)	11,300		11,074	
TRU and HLW (deep)	11,000,000		10,780,000	
Other Environmental Considerations				
Thermal Effluents, (Billions of British thermal units [Btu])	4063 billion Btu	< 5 percent of the model 1000 MWe LWR	3982 billion Btu	< 5 percent of the model 1000 MWe LWR
Transportation				
Exposure of workers and the general public	2.5 person-rem		2.4 person-rem	
Occupational exposure	22.6 person-rem	From reprocessing and waste management	22.1 person-rem	From reprocessing and waste management

Table 5.7-3
Whole Body 100-Year Dose Commitment Estimate

Uranium Fuel Sources	10 CFR 51.51 Reference Plant (person-rem)	CRN Site SMRs (person-rem)
From radioactive gaseous effluents (all fuel operations excluding reactor releases and the dose commitment due to Rn-222 & Tc-99)	400	392
From radioactive liquid effluents (all fuel-cycle operations excluding reactor operation)	200	196
Subtotal	600	588
Total Rn-222 (see Table 5.7-4)	140	136
Total Tc-99 (see Table 5.7-4)	100	98
Total with Rn-222 and Tc-99	840	822

Table 5.7-4
Estimated 100-Year Environmental Dose Commitment from Mining and Milling for Each Year of Operation

	1000 MWe Reference plant NUREG-1437, Rev. 0, Subsection 6.2.2.1		Facility CRN Site SMRs	
	Annual Release (Ci)	100-year Committed Dose (person-rem)	Annual Release (Ci)	100-year Committed Dose (person-rem)
Radon-222				
Mining	4100	110	4018	108
Milling and tailings (other than stabilized)	1100	29	1078	28
Total for Rn-222	5200	140	5096	136
Technetium-99				
Chemical reprocess	0.007	100	0.007	98
Groundwater	0.005		0.005	
Total for Tc-99	0.012	100	0.012	98

Table 5.7-5
Radiation Exposure to the United States Population

Exposure Source	Average Dose Equivalent to United States Population (mrem/yr)
Natural:	
Radon/Thoron	229
Cosmic	31
Other	50
Occupational	0.62
Consumer Products	12
Medical:	
Medical Procedures	223
Nuclear medicine	74
Approximate Total	620

Source: (Reference 5.7-10)

Table 5.7-6
Number of Truck Shipments of Unirradiated Fuel

Reactor Type	Number of Fuel Shipments		
	Initial Load[1]	**Annual Reload[2]**	**Total**
Reference LWR	18[2]	6	252
SMRs at the CRN Site	40 (maximum)	12 (assumed even loading over 40 years)	492
Normalized	NA	15	600

1 Shipments of the initial core have been rounded up to the next highest whole number.
2 The initial core load for the reference PWR in WASH-1238 was 100 MTU with 18 truck shipments (Reference 5.7-12).

Notes:
NA = Not Applicable

Table 5.7-7
Number of Radioactive Waste Shipments

Reactor Type	Waste Generation Rate	Number of Shipments per reactor-yr	Normalized Shipments per reactor-yr
Irradiated Fuel			
Reference LWR	30 MTU per year	60	NA
SMRs at the CRN Site	56.1 MTU per year	46	137[1]
Solid Radioactive Waste			
Reference LWR	3800 cubic feet per year	46	NA
SMRs at the CRN Site	5000 cubic feet per year	61	75

[1] Normalized based on 0.5 MTU per shipping container and the net power using a conservative 90 percent capacity for the 800 MWe CRN Site SMRs.

Note:
NA = Not Applicable

Table 5.7-8
CRN Site SMR Comparisons to 10 CFR 51.52 Reference Conditions

Characteristic	Reference Reactor 10 CFR 51.52/WASH-1238[1]	CRN Site SMRs
Thermal Power Rating (MWt)	3800 MWt	2420 MWt
Fuel Form	Sintered uranium dioxide pellets	Sintered uranium dioxide pellets
U-235 Enrichment (%)	< 4	< 5
Fuel Rod Cladding	Zircaloy rods	Zircaloy rods
Average Fuel Irradiation (MWd per MTU)	≤ 33,000	≤ 51,000
Unirradiated Fuel		
Transport Mode	Truck	Truck
Irradiated Fuel		
Transport Mode	Truck, rail, or barge	Truck, rail, or barge
Decay time before shipment	> 5 years per contract with DOE	> 5 years per contract with DOE
Radioactive Waste		
Transport Mode	Truck or rail	Truck or rail
Waste Form	Solid	Solid
Packaged	Yes	Yes
Traffic Density (shipments)		
Unirradiated Fuel – Initial Loading	12	40
Unirradiated Fuel - Reload	15/year	12.3/year 15/year normalized
Irradiated Fuel	60/year	46/year 137/year - normalized
Radioactive Waste	46/year	61/year (75/year normalized)
Total	121/year	119.3/year (227 – normalized)
Trucks per day	< 1/day	< 1/day

[1] (Reference 5.7-12)

Table 5.7-9
Total Shipment Cumulative Dose Summary

Exposed Population	Source			
	Unirradiated Fuel	**Irradiated Fuel**	**Radioactive Waste**	**Total**
Crew Dose (person-rem per year)				
At Stops	4.59E-03	5.55E+00	1.61E+00	7.16E+00
Along Route	7.85E-03	9.32E+00	2.55E+00	1.19E+01
Total Crew Dose				**1.91E+01**
Public Dose (person-rem per year)				
At Stops				
Sharing Stops	2.15E-03	2.74E+00	7.50E-01	3.49E+00
Residents	1.95E-04	1.70E-01	1.02E-01	2.72E-01
Along Route				
Other Vehicles	5.81E-03	3.66E+00	1.92E+00	5.59E+00
Residents	8.84E-04	3.75E-01	3.28E-01	7.04E-01
Total Public Dose				**1.01E+01**

5.8 SOCIOECONOMIC IMPACTS

The following subsections describe the potential socioeconomic impacts from operating the Clinch River (CR) Small Modular Reactor (SMR) Project. Subsection 5.8.1 describes physical impacts of CR SMR Project operation to the Clinch River Nuclear (CRN) Site and vicinity. Subsection 5.8.2 describes social and economic impacts on the region. Subsection 5.8.3 describes environmental justice impacts as a result of CR SMR Project operation.

5.8.1 Physical Impacts of Station Operation

This subsection assesses the potential physical impact due to operation of the CR SMR Project on the nearby communities or residents. Potential impacts include noise, odors, exhausts, thermal emissions, and visual intrusions. Tennessee Valley Authority (TVA) complies with federal, state and local environmental regulations applicable to these potential effects to reduce the potential for adverse impacts to the CRN Site and vicinity.

There are no residences located within the CRN Site. The majority of land located north and east in the vicinity of the CRN Site is federal land and is part of the ORR. The remaining area surrounding the CRN Site is predominantly rural and characterized by isolated residences, farmland, and wooded tracts. The locations of surrounding communities within the vicinity are described in Section 2.1. Population distribution is described in Subsection 2.5.1.

An estimated 500 operations workers are needed for operation of the CR SMR Project at full power at the CRN Site, as presented in Table 3.1-2, Item 16.3.1. The impacts from these workers on the local and regional area are discussed in Subsection 5.8.2.

5.8.1.1 Noise

The U.S. Department of Housing and Urban Development has established noise impact guidelines for residential areas based on day-night average sound levels (DNL) (Title 24 of the Code of Federal Regulations [51.103). Neither the State of Tennessee nor Roane County has developed noise regulations that specify acceptable community noise levels. When feasible, TVA uses the U.S. Environmental Protection Agency (EPA) guideline of 55 A-weighted decibel (dBA) DNL as a design goal if the nearest receptor is residential. For industrial and commercial areas, TVA uses a 60 dBA equivalent noise level as a design goal at the property line. (Reference 5.8-1) As described in Section 2.8, the DNL is the sound level average over a 24-hour (hr) period used to define the level of average noise exposure to a community during that 24-hr period. As part of the DNL sound level calculation, an additional 10 dB is added to nighttime (10:00 PM to 7:00 AM) sound levels to account for the increased sensitivity of the community to nighttime noise. When the background DNL is 60 dBA or less, TVA uses the Federal Interagency Committee on Noise recommendation that a 3 dB increase in DNL indicates a possible impact and necessitates further analysis (Reference 5.8-2).

As stated in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* Rev. 1, in general, noise levels below a DNL of 65 dBA outside a residence are considered to be acceptable. Therefore, DNLs up to 65 dBA are considered to be SMALL impacts in this Environmental Report.

Onsite Noise

Noise sources from the operation of the CR SMR Project include heating, ventilation, and air conditioning systems; vents; transformers; electrical equipment; switchyard equipment and transmission lines; water pumps; material-handling equipment; motors; public address systems; cooling towers; generators; and trucks and vehicular traffic. Tests of emergency warning sirens are conducted periodically, with advance notification to the public. Many noise sources are confined indoors, underground, or are used infrequently.

The main source of continuous noise is associated with the mechanical draft cooling towers. The cooling towers operate at less than 70 dBA at a distance of 1000 feet (ft), as presented in Table 3.1-2, Item 3.3.10.

As described in Section 2.2, the Site vicinity is largely rural residential and agricultural land in an area of alternating ridges and valleys. Ambient noise levels at the CRN Site are described in Section 2.8. Noise from the CR SMR Project is attenuated through distance and abated by natural features such as forests and ridges.

To assess the noise impacts on the surrounding environment, receptor sites were selected including the nearest residences, churches, schools, cemeteries, and the nearest public facilities. All of the identified sensitive receptors are located more than 1000 ft from the estimated position of the cooling towers at the CR SMR Project. The nearest offsite residence is located approximately 1900 ft southwest from the edge of the cooling tower block across the Clinch River arm of the Watts Bar Reservoir from the CRN Site. NUREG-1437, Rev. 1 indicates that noise levels below 65 dBA are considered acceptable outside a residence. It also notes that cooling towers emit noise of a broadband nature, which masks other noises such as transformers at most sites. Noise produced by the cooling towers is attenuated with distance and intervening vegetation. Because noise levels from the cooling towers are less than 70 dBA at 1000 ft from the towers (Table 3.1-2, Item 3.3.10) and the nearest residence is almost twice that distance, noise levels at the nearest residence are attenuated to 65 dBA or less. Therefore noise impact would be SMALL and mitigation would not be warranted.

Transmission Line Noise

High-voltage transmission lines can emit noise when the electric field strength surrounding the lines is greater than the breakdown threshold of the encapsulating air, creating an energy discharge. This discharge is known as corona discharge, and is affected by ambient weather conditions such as wind, precipitation, air density, and humidity and energized surface irregularities. Corona results in audible noise, radio, and television interference, energy losses, and the production of ozone and oxides of nitrogen. The noise created from corona discharge can result in a noise which can be heard near the base of the transmission lines. Noise from corona discharge along the transmission line is low (well below the 65 dBA threshold) and does not pose a noise-induced risk to the surrounding community (NUREG-1437, Rev. 1). Corona discharge is not an issue with underground lines except at aboveground components such as substations (Reference 5.8-3).

The 500-kilovolt (kV) and 161-kV lines that serve the CR SMR Project are already operating and it is expected that the noise levels they produce would continue to be acceptable. It is expected that the underground transmission line planned for construction would not generate audible noise. Therefore, there are no anticipated increases to the current ambient noise levels associated with the operation of the transmission system, and the effect of the CR SMR Project on noise would be SMALL.

5.8.1.2 Air Quality

The Clean Air Act of 1977, which was last amended in 1990, requires EPA to establish ambient concentration thresholds for certain compounds based upon the identifiable effects the compounds may have on the public health and welfare. Subsequently, EPA promulgated regulations in Title 40 of the Code of Federal Regulation (40 CFR) 50 (subsections 50.4 – 50.13 and 50.15 – 50.18) that set National Ambient Air Quality Standards (NAAQS) for criteria compounds: sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter with a diameter less than 10 microns (PM_{10}), particulate matter with a diameter less than 2.5 micros ($PM_{2.5}$), lead (Pb), and ozone. As described in Subsection 2.7.2, the CRN Site is in attainment for air permitting purposes. The portion on Roane County in which the CRN Site is located is in attainment for all air pollutants. However, neighboring counties (Anderson, Blount, Knox, and Loudon) and part of Roane County (not including the CRN Site) are designated nonattainment for $PM_{2.5}$. (Reference 5.8-4; Reference 5.8-5)

Generation of electricity associated with the operation of two or more SMRs would not be a source of criteria pollutants or air toxics emissions. Supporting equipment such as cooling towers, emergency diesel generators, auxiliary boilers, standby power gas turbines, and other combustion sources emit criteria pollutants and air toxics. Currently a specific SMR technology and supporting equipment have not been selected, so detailed emissions data from supporting equipment are not available. However, supporting equipment for the surrogate plant, as defined in the plant parameter envelope (PPE) presented in Tables 3.1-1 and 3.1-2, has been assumed for this evaluation. It is expected that supporting equipment would generate minor levels of emissions, because any equipment firing fossil fuels is used intermittently and the CR SMR Project includes required controls to minimize emissions. Preliminary annual estimates for criteria pollutant emissions from SMR-supporting fossil fuel fired equipment are presented in Table 5.8-1.

Table 5.8-1 shows that current expected maximum annual emissions, for any individual pollutant, would be under 38 tons per year (TPY) for the fossil fuel fired units. This level is well below the Prevention of Significant Deterioration (PSD) major source threshold of 250 TPY for any pollutant defined in 40 CFR 52.21. These emissions estimates, along with emissions from other pollutant sources, are evaluated in more detail once the CR SMR Project final SMR design has been selected. In addition, because the project is not located in a nonattainment area for any pollutant, the CR SMR project is not subject to review under Nonattainment New Source Review (NSR).

Once the SMR design is selected and emissions are defined, the Tennessee Department of Environmental Conservation (TDEC), Division of Air Pollution Control will be consulted regarding air permitting requirements. Air permitting, as necessary under both federal and state regulations, will be completed to demonstrate compliance with applicable air rules. The air permitting process involves ensuring that air emissions sources are operated consistent with manufacturer's specifications and emissions are mitigated by the application of air pollution control equipment and best emissions control practices as required under state and federal regulations. In addition, all air-related construction and operating permits will be obtained and potential impacts to sensitive areas addressed as necessary under state and federal air laws.

Once the project design has been selected, air quality modeling will be conducted as required to demonstrate project emissions will not result in exceedances of the NAAQS. Modeling, as required, will be conducted using current EPA models and modeling methodology. Power generation is also associated with emissions of greenhouse gases (GHGs). The primary GHGs include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). SMRs are not sources of GHGs, although supporting equipment emits some GHGs. The Nuclear Energy Institute (NEI) reports that "independent studies have assessed nuclear energy's life cycle emissions and found them to be comparable to wind, solar, geothermal and hydroelectric generation" (Reference 5.8-6). Supporting this conclusion:

- NEI cites that in 2012, the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory concluded: "Collectively, life cycle assessment literature shows that nuclear power is similar to other renewables and much lower than fossil fuel in total life-cycle GHG emissions." (Reference 5.8-6)
- NEI cites a World Nuclear Association 2011 study that noted: (1) "greenhouse gas emissions of nuclear power plants are among the lowest of any electricity generation method and on a lifecycle basis are comparable to wind, hydroelectric, and biomass," (2) "lifecycle emissions of natural gas are 15 times greater than nuclear," and (3) "lifecycle emissions of coal generation are 30 times greater than nuclear." (Reference 5.8-6)

NEI has compiled a comparison of Life-Cycle CO_2 equivalent (weighted CO_2, CH_4, and N_2O) emissions (in tons per gigawatt-hour) for different energy sources; these are presented in Table 5.8-2. Findings demonstrate that CO_2 equivalent emissions from nuclear power are significantly below those of the most common sources of energy. (Reference 5.8-7)

GHG emissions may also be subject to PSD review. For a new source to be major for GHG emissions under the PSD regulations, the source must first be major for another regulated pollutant (other than GHG) and have the potential to emit more than 75,000 TPY of CO_2 equivalent air emissions. Applicable GHG rules and regulations (40 CFR 52.21(b)(49)(iv)(a)) will be addressed during the CR SMR Project's air permitting as required.

The CR SMR Project would generate indirect source emissions from motor vehicles during facility operation. Typically the primary emissions of concern are GHG (CO_2 equivalent), CO, PM, nitrogen oxide (NO_x) and volatile organic compounds (VOCs). Emissions of NO_x and VOCs are precursor pollutants in the formation of ozone. As with other air related sources, motor vehicle emissions and required air quality modeling would be addressed during the air permitting process with the TDEC. Air quality modeling, if required for a comparison of project impacts to ambient air quality standards, would be based on air emissions factors developed using the EPA Motor Vehicle Emission Simulator emissions model. In the event the air permitting process indicated that measures were necessary to reduce ambient air concentrations, the project would employ the appropriate mitigation measures.

During SMR operation, motor vehicle activity would be associated with the facility's work force and truck deliveries to the CRN Site. Once the facility is operating, mitigation measures as necessary may include staggered shift times, requiring delivery vehicles to shut down engines during off-loading, restricting idling times of onsite vehicles, use of electric and hybrid vehicles, and supporting and promoting van/carpooling and other commuter programs. Motor vehicle emissions are not expected to create significant impacts but will be addressed, along with mitigation measures, as required under federal and state regulations during the air permitting process. Air impacts from motor vehicle activity during facility operations are expected to be SMALL because: (1) mitigation measures would be implemented to reduce vehicular emissions, (2) Section 5.8.2.3 indicates that with recommended transportation improvements, LOS at the local intersections would be adequate to mitigate vehicle queuing and improve flow through these intersections, (3) emissions from the work force are not continuous throughout the day and are primarily limited to the hours during which shift changes occur, and (4) the project is currently located in attainment areas for CO, PM, NO_x, and O_3 which are the primary pollutants of concern for motor vehicles.

Based on preliminary design information of the CR SMR project and attainment status of Roane and surrounding counties, the CR SMR project's air related geographic area of interest for criteria pollutants is expected to fall within Roane County and the surrounding counties of Loudon, Knox, Anderson, and Morgan. Once an SMR design is selected, air quality modeling under the Tennessee air permitting process would detail the project's air quality geographic area of interest in the context of other nearby sources. Because the project's supporting equipment, which emits criteria pollutants, would be operated infrequently and for limited periods of time, it is expected the project's modeling impact area would be within 10 miles (mi). The area out to 10 mi would include Roane County and portions of Loudon, Knox, Anderson and Morgan Counties. Also, even though the project area is in attainment of all criteria pollutants, the surrounding nonattainment areas may need to be considered during air permitting. The surrounding counties of Loudon, Knox and Anderson, along with Census Block Group 47-145-0307-2 in Roane County are nonattainment for $PM_{2.5}$. Once the project design is selected and vendor data are provided to support more detailed air quality analysis, the geographic area of interest would be refined if necessary.

Because climate change is global in nature and currently focuses on the policies established by national governing agencies, the project's geographic area of interest for GHG would need to be considered in the context of United States policy and national GHG emissions. Further, individual states are developing GHG regulations, thus consideration of GHG emissions under state regulations may in all likelihood also be necessary. Therefore for GHG emissions, the project's operations geographic area of interest is national (United States) in scale. Because GHG emissions and associated impacts require a global perspective, small incremental changes from individual projects must be evaluated collectively. This is beyond the scope of an individual project and is therefore addressed by the United States under the authority of the EPA at the national scale.

Supporting equipment used during operation, including cooling towers and various fossil fuel combustion sources, is expected to generate minor levels of criteria pollutants and air toxics emissions. However, the effects on air quality from these sources would be minor because they would be used intermittently and emissions would be minimized by using required controls. In addition, air permitting will be completed to demonstrate compliance with applicable air rules. CO_2 equivalent emissions are expected to be low in comparison to most other energy technologies, particularly the most common technologies used. Accordingly, air quality impacts from operation of the CR SMR Project would be SMALL for the surrounding communities and the nearest residents.

5.8.1.3 Thermal Emissions

The CR SMR Project's cooling towers use water from the Clinch River arm of the Watts Bar Reservoir to cool facility water. In the process, thermal plumes are released to both the ambient air and back to the Clinch River arm of the Watts Bar Reservoir.

As described in Section 3.4, the CRN SMR Project's cooling system includes mechanical draft cooling towers for the transfer and dissipation of heat from the facility's cooling water to the atmosphere. Releases to the atmosphere from cooling towers include a visible vapor plume released from the towers, which is formed as water vapor condenses in cooler ambient air. The visible vapor plume presents no threat to the environment. Small water droplets, referred to as drift, associated with the tower's circulating water and which contain dissolved solids, are also emitted and escape with the exhaust air. Drift deposition is generally greatest close to the towers. The principal concern associated with cooling tower drift is the downwind deposition of salts. Significant salt deposition can adversely affect sensitive plants and animal communities and change water and soil chemistry. Although final SMR design has not been selected, the CR SMR Project includes efficient drift eliminators to minimize drift emissions.

Computer modeling of the CR SMR Project's mechanical draft cooling towers used the Electric Power Research Institute's Seasonal and Annual Cooling Tower Impact (SACTI) model for evaluating potential impacts to the CRN Site and its immediate surroundings. Thermal discharges to the atmosphere from the facility's cooling towers are detailed in Subsection 5.3.3.1. Based on these results, there would be no fogging or icing at any distance from the cooling towers and additional water deposition would have a negligible effect on precipitation and humidity. The SACTI calculations indicate that the effects of salt deposition from cooling tower operation would be limited to the area within 600 meters (m) of the cooling towers, with the maximum deposition rate occurring 100 m to the west. Therefore, the effects of cooling tower operation on local residents and the public in the surrounding area from precipitation, humidity, fogging or icing, and salt deposition would be SMALL. The predicted frequencies of plume shadowing, or shading of the ground, beyond the CRN Site are low, and the impacts to the surrounding area would be SMALL. The visual effects of visible plumes generated by the cooling towers, as calculated by the SACTI model, are addressed in Subsection 5.8.1.4.

As shown in Figure 3.1-1, the CR SMR Project includes a holding pond to mix the cooling tower blowdown and discharge streams from miscellaneous demineralized water users and miscellaneous raw water users. Treated liquid radwaste is discharged downstream of the holding pond. The holding pond is used for discharge mixing so that the discharge from the facility into the Clinch River arm of the Watts Bar Reservoir is homogeneous in temperature and composition. Use of the holding pond is not intended for purposes of heat removal from the facility discharge, or for management of discharge flow rates, and cooling effects of the pond are not given credit in the hydrothermal analysis. The purpose of the pond is for discharge flow mixing only. However, this mixing acts to further reduce temperatures and moderate flow rates, making this is a conservative modeling assumption for purposes of the hydrothermal analysis. Assuming the holding pond was to function under a worst case scenario as a cooling pond, guidance provided in NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,* states that the:

- Plume will exist as ground level fog, but will evaporate within 300 m or lift to become stratus for wind speeds greater than 2.2 m per second
- Plume will exist as fog over the pond, lifting to become stratus for winds less than or equal to 2.2 m per second

An analysis of nearby areas of importance shows the closest area of importance is Interstate 40, which is located 0.6 mi (900 m) from the nearest border of the CRN Site. Because this area is greater than 300 m from the holding pond, potential worst case scenario impacts from the holding pond would be minor to non-existent.

Operational impacts of thermal discharges to surface water are discussed in Subsection 5.2.2.2. As described in Subsection 3.4.1, the Cooling Water System for the facility uses circulating makeup water from the Clinch River arm of the Watts Bar Reservoir as the mechanism for cooling the main condenser. The circulating makeup water is pumped into the mechanical draft cooling towers, and from there it is circulated in and out of the main condenser. A portion of the water evaporates or is lost as drift from the cooling towers. The remainder of the water becomes blowdown from the mechanical draft cooling towers. The blowdown passes through a holding pond on its way to a discharge on the reservoir. This discharge results in a thermal plume in the receiving waterbody.

Discharges from the SMRs are permitted under the TDEC National Pollutant Discharge Elimination System (NPDES) program, which regulates the discharge of pollutants into waters of the state. Under NPDES regulations, waste heat is regarded as thermal pollution and is regulated in the same way as chemical pollutants. As discussed in Subsection 5.3.2.1, modeling was performed to evaluate the thermal effects on surface water of the discharge from the SMRs at both a local and a regional scale. The results show that with a minimum steady flow of 400 cubic feet per second through the planned Melton Hill Dam bypass, thermal impacts in the Clinch River arm of the Watts Bar Reservoir are manageable within state NPDES regulatory limits at a distance of approximately 50 ft from the diffuser under steady state conditions. To allow for worst-case conditions with unsteady flows in the reservoir and operation of the CR SMR Project under PPE conditions, a circular mixing zone of 150 ft is sufficient.

Because the discharge is managed in accordance with requirements of the TDEC NPDES permit, and the modeling indicates compliance with the thermal water quality criteria, physical effects of the thermal discharge are considered to be negligible. Accordingly, impacts to the public and recreational users of the Clinch River arm of the Watts Bar Reservoir would be SMALL.

5.8.1.4 Visual Intrusions

The existing visual resources near the CRN Site are described in Subsection 2.5.2.5.1. Visual and aesthetic effects associated with a project occur as a result of the introduction of a structure or facility that is not consistent with the existing viewshed. Consequently, the character of an existing site is an important factor in evaluating potential effects of an introduced facility on the visual resource. The overall aesthetic character of the CRN Site is good, with natural and scenic views relatively uninterrupted by man-made objects. Because the areas immediately surrounding the CRN Site are bound by water features, forests, and ridge lines, direct visual access to the CR SMR Project is limited primarily to onsite workers, residents living along the Clinch River arm of the Watts Bar Reservoir across from the CRN Site, and recreators using the reservoir.

Most of the structures associated with the CR SMR Project are not expected to be visible to the general public. Section 3.1 describes the CR SMR Project layout and the external appearance of the proposed facility. The tallest power block structure is 160 ft above finished grade and the mechanical draft cooling towers are 65 ft above finished grade (Table 3.1-2, Items 1.1.1 and 3.3.8, respectively). Renderings were made, using baseline photographs and the CR SMR Project PPE, in order to estimate possible visual impacts once construction is complete. The renderings show the tallest facility structure visible from each location as well as the cooling tower plumes.

Figure 5.8-1 presents a map showing the Key Observation Points (KOPs) from which the CR SMR Project would be visible. Baseline photographs were collected at each KOP and renderings were developed to show the potential appearance of the CR SMR Project from these viewpoints. Figures 5.8-2 through 5.8-29 show the baseline photographs and the renderings with the tallest facility structures visible, the annual average plume, and the winter plume.

The SACTI model results predict that the visible plume, on an annual basis, would not go beyond 300 m from the towers more than 3 percent of the time for any wind direction. (The maximum annual frequency at 300 m is 2.97 percent of the time for the east direction from the cooling towers.) About 50 percent of the time, the plume centerline is at 150 to 160 m above the ground. The annual plume visualization was drawn so that the centerline of the plume transitions from the top of the cooling tower up to 150 m above the ground, out to a distance of 300 m downwind of the towers. The SACTI model generates a visible plume length for every hour modeled (day and night, and for conditions of good visibility and poor visibility). Longer plumes generally occur with colder temperatures and when the atmosphere is more saturated. Colder temperatures generally occur more frequently during nighttime hours when the plume would not be highly visible, while saturated atmospheric conditions can be accompanied by fog or rain where a visible plume would likely be obscured. Thus the SACTI model is likely to provide conservative results.

Using the 3 percent visible plume length criteria for any direction, the spring, summer, and fall are well reflected by the average annual numbers. As noted above, the SACTI model’s annual predicted visible plume length does not exceed 300 m more than 3 percent of the time for any direction. For spring and fall, the 3 percent visible plume lengths are also at 300 m and for summer, the 3 percent visible plume length is at 200 m. The 50-percent centerline plume height during spring, summer, and fall ranges from around 140 m to 170 m, while the annual 50-percent centerline plume height is 150 m. Thus, the annual SACTI plume data provide a good estimate for the spring, summer, and fall seasons.

For winter, using the same 3 percent plume length criteria, visible plumes extend to 1700 m for the east-northeast, east, east-southeast, and southeast directions (for these directions the visible plume frequency was greater than 3 percent to 1700 m). For all other directions in winter, the 3 percent visible plume length is predicted at 300 m, as for the annual case. The 50-percent centerline plume height for winter is 200 m, somewhat higher than the annual case. As plume visibility may be considerably more noticeable during winter, both average annual plumes and winter plumes are rendered.

In all instances, the plumes are presented perpendicular to the observer.

The photo at KOP 5 (Figure 5.8-2) was taken from the northeast, across the Clinch River from the CRN Site. The view is of a country road with an agricultural field, a small building and a power line. The CRN Site itself is not visible in the photo as the trees screen the view. Rendering 1 (Figure 5.8-3) shows the CRN facility in place. It is seen as two large square blocks extending above the tree line. It is not visually intrusive, however, because the height of the trees is similar and the facility is in the distance. Rendering 2 (Figure 5.8-4) shows the CRN facility during operations with the modeled average annual plume. The plume is not large, but it is hovering above the towers, which draws attention to them. The CRN facility looks larger because of the association with the plume. The visual intrusion is small, however, and if it were a cloudy day, the plume and the facility would not be as obvious from this location. Rendering 3 (Figure 5.8-5) shows the CRN facility during operations in the winter, when the plume would be most obvious. As with the average plume, the eye is drawn towards the CRN facility towers and they are more significant. However, because the plume appears to be dispersing and blowing in the wind, the larger size makes it look like natural clouds. Overall, depending on the atmospheric conditions, the CRN facility would present a SMALL visual intrusion from KOP 5.

The photo at KOP 7 (Figure 5.8-6) was taken from the northwest of the CRN Site, also across the Clinch River. The photo shows an open area with trees in the middle ground and hills in the background. The view is of a rural natural setting with appealing character. Rendering 1 (Figure 5.8-7) shows the CRN facility in the distance. It has essentially replaced the top of the hill in the background of the photo. The CRN facility is barely visible from this location and does not interfere with the general aesthetics of the scene. Rendering 2 (Figure 5.8-8) shows the CRN facility during operations with the average annual plume in place. Due to the partial tree screen in this location, the plume does not draw as much attention to the towers as in KOP 5, which is more open. This view is reminiscent of natural clouds as most of the sky is not exposed to the viewer. Rendering 3 (Figure 5.8-9) shows the CRN facility during operations in the winter season. This view is basically a more dramatic version of the previous rendering, with the scenery appearing to be a more cloudy day. It is a slight juxtaposition, however, and if the observer were to stop and contemplate this scene, they would register the industrial complex located in the distance behind the forest. This could become disturbing or annoying, depending on the length of the observer’s visit. There are only a few residences in this area, most of which would be screened by trees; most views would simply have a cloudy spot on the horizon where the plume is located. As there is an existing tree screen and few residences in this location, the visual intrusions created by the operation of the CRN facility would be SMALL.

The photo at KOP 8 (Figure 5.8-10) was taken from the southeast, approximately 1 mi from the center point of the CRN Site. It is similar to the photo at KOP 5 (Figure 5.8-2) with an agricultural field in the foreground with trees and hills in the background. The power lines overhead and the transmission line right-of-way (ROW) form the focal point of the photo. Rendering 1 (Figure 5.8-11) shows the CRN facility at the end of the transmission line ROW. It is so far distant that it is difficult to identify as a structure. Rendering 2 (Figure 5.8-12) shows the CRN facility with the average annual plume. The plume, as in the two previous photo locations (5 and 7), makes the CRN facility much more visually obvious, especially in an otherwise clear sky. Rendering 3 (Figure 5.8-13) shows the CRN facility with the winter plume. This view is actually less intrusive than the average plume view, because the winter plume appears as naturally occurring clouds would. In general, due to the distance of the CRN facility from the viewer, visual intrusions at this location would be SMALL.

The photo at KOP 16 (Figure 5.8-14) was taken from the southwest, directly across the Clinch River from the CRN Site. It is an open area with few trees along the river bank. Rendering 1 (Figure 5.8-15) shows the CRN facility clearly visible in the middle ground. It overtops the trees on the far river bank and injects an industrial aspect into the rural, natural landscape. From this viewpoint, the CRN facility is the most imposing. However, it is still screened partially by the trees and the surrounding hills in the distance are similarly visually sized. Rendering 2 (Figure 5.8-16) shows the CRN facility in this location with the average annual plume. The plume makes the facility more visible from this location, increasing the industrial aspect of the scene. Rendering 3 (Figure 5.8-17) shows the CRN facility with the winter plume. The view resembles a cloudy day, although there may only be clouds in this one area. The observer may be confused by the image, or would notice the CRN facility more, as the plume is only in the vicinity of the facility. Due to the size of the facility and plume from this location, visual intrusions would be considered MODERATE.

The photo at KOP 19 (Figure 5.8-18) was taken from the north-northwest, from the surface of the Clinch River, approximately 1 mi from the center of the CRN Site. The CRN facility is barely visible in Rendering 1 (Figure 5.8-19), located in the middle ground, just visible above the treetops. Rendering 2 (Figure 5.8-20) shows the CRN facility with the average annual plume and Rendering 3 (Figure 5.8-21) shows the facility with the winter plume. The plumes draw the eye to the CRN facility, making it more noticeable than without. The facility itself is still almost invisible, however, and on a cloudy day it would likely go unnoticed from this location. On a clear day though, the plume presents an industrial view in an otherwise calming and natural scene. Due to the plume, the visual intrusions from this location would be MODERATE on clear days and SMALL on cloudy days.

The photo at KOP 22 (Figure 5.8-22) was taken from the northeast, approximately 1.5 mi from the center of the CRN Site. Rendering 1 (Figure 5.8-23) shows the CRN facility in the distance. It is dwarfed by the large hill on the left, and is not visually dominant from this viewpoint. Renderings 2 and 3 (Figures 5.8-24 and -25) show the CRN facility with the average annual plume and winter plume, respectively. This view is similar to the previous photo (KOP 19) and associated renderings. Therefore, visual intrusions would be MODERATE on clear days and SMALL on cloudy days at this location as well.

The photo at KOP 40 (Figure 5.8-26) was taken from the northwest, approximately 1.5 mi away, on the Clinch River. Rendering 1 (Figure 5.8-27) shows the CRN facility on the far right, as a minor visual intrusion just above the trees in the distance. The two plume renderings (Figures 5.8-28 and -29) reveal a similar appearance as most of the other renderings. Both the average annual plume and the winter plume serve to draw attention to the CRN facility in the distance, increasing the level of visual intrusion at this location. The annual plume is more visible than the winter plume at this spot, however, due to the distance and the dispersion of the larger plume.

Due to the distance from the observer, the surrounding natural landscape, and the large expanse of sky visible from this location, the visual intrusion from the operation of the CRN facility would be SMALL.

Overall, the renderings show that the CRN facility would be well screened by the riparian trees from most locations. The surrounding hills also help to soften the industrial aspects of the view because they are larger than the facility and make it seem smaller and less imposing. From a distance of approximately 2 mi, the CRN facility would not be visible at all from most viewpoints. The average annual plume and the winter plume, however, draw the observer’s attention to the CRN facility, inserting an industrial aspect to a mostly natural landscape. The plume impacts would be larger on a clear, cloudless day than on an overcast day. Therefore, due to the plume, the visual intrusion due to operation of the CR facility would range from SMALL to MODERATE, depending on the location of the observer and the atmospheric conditions.

5.8.2 Social and Economic Impacts of Station Operation

This subsection evaluates the potential demographic, economic, infrastructure, and community impacts associated with operation of two or more SMRs at the CRN Site. The evaluation assesses potential impacts associated with operation of the CR SMR Project, including routine capital expenditures needed to support operations and the size of the operations workforce. The analysis is based on the PPE, which is discussed in Section 3.1 and provided in Tables 3.1-1 and 3.1-2.

5.8.2.1 Population and Housing

This analysis of population and housing is based on an operations workforce of 500 workers, which represents the total number of operational employees for operation of the CR SMR Project at full power, as presented in Table 3.1-2, Item 16.3.1. An additional 1000 workers would temporarily work at the CRN Site during periodic refueling and major maintenance activities, as presented in Table 3.1-2, Item 16.3.2.

As discussed in Subsection 3.10.3, it is anticipated that approximately 250 operations workers would already reside within the 50-mi region of the CRN Site. The remaining 250 workers would relocate into the region. It is conservatively assumed that 100 percent of this in-migrating workforce would relocate within the geographic area of interest. All of the 1000 temporary workers required for the scheduled refueling outages are assumed to be from outside the region. It is assumed they would temporarily reside in the geographic area of interest.

5.8.2.1.1 <u>Population</u>

In 2010, the population within the 50-mi radius of the CRN Site was 1,158,026 and is projected to grow to 1,305,189 by 2021 (Tables 2.5.1-2 and 2.5.1-5). The four-county geographic area of interest, including Anderson, Knox, Loudon, and Roane Counties, had a population of 610,092 in 2010 and a projected population of 682,278 in 2020 and 807,594 in 2040 (Table 2.5.1-6).

It is assumed that each operations worker that relocates into the geographic area of interest would bring a family. The average household size in Tennessee is 2.48 (Reference 5.8-8). Therefore, an in-migrating workforce of 250 would increase the population of the geographic area of interest by 620 people, or 0.1 percent of the geographic area of interest population in 2010. It is assumed that the residential distribution of the in-migrating operations workforce would resemble the residential distribution of the DOE Oak Ridge workforce. Of the 11,433 employees at the DOE Oak Ridge facilities that reside within the geographic area of interest, 27 percent reside in Anderson County, 50 percent in Knox County, 6 percent in Loudon County, and 17 percent in Roane County. Therefore, of the total population increase due to the operations workforce, it is assumed that 166 people (27 percent of 620) would settle in Anderson County, 310 people in Knox County, 37 people in Loudon County, and 107 people in Roane County. These numbers constitute 0.2 percent, 0.1 percent, 0.1 percent, and 0.2 percent of the 2010 populations of Anderson, Knox, Loudon, and Roane Counties, respectively.

Scheduled refueling is performed every 2 years for each SMR unit, as presented in Table 3.1-2, Item 18.0.4. It is conservatively assumed that the 1000 temporary workers required for each periodic refueling outage work at the CRN Site for 30 to 60 days. This is based on the mean duration of refueling outages for pressurized water reactors of 37 days and the maximum of 54 days (Reference 5.8-9). Based on the infrequent nature and limited length of time for refueling outages, it is assumed that the temporary refueling workers would not permanently relocate to the geographic area of interest and would not bring families.

As described in Subsection 4.4.2.1, the CR SMR Project includes construction of multiple SMRs that would be brought into operation sequentially; therefore, there would be a period of time when one or more SMRs is operating while other SMR(s) are being constructed. The duration of this overlap between preconstruction/construction and operation would be expected to take between three and five years. During that overlap period, the combined project workforce would include the construction workforce (3300 workers) plus the operation workforce (366 workers) for an estimated total onsite workforce of 3666 workers. As presented in Subsection 4.4.2.1, an in-migrating construction workforce of 1115 would increase the population in the geographic area of interest by 2765 people, or 0.5 percent of the geographic area of interest population in 2010. During the overlap period between preconstruction/construction and operation, the population in the geographic area of interest would increase by 3385 people (2765 associated with construction and 620 associated with operation). This combined population increase constitutes 0.6 percent of the 2010 population of the geographic area of interest.

The operations workers and their families would represent a small increase to the population of the four counties within the geographic area of interest (0.1 percent) and the combined population increase associated with in-migrating workers during the overlap period between preconstruction/construction and operation would also represent a small increase (0.6 percent). The temporary refueling workers would not be associated with a permanent increase in the geographic area of interest population. Therefore, based on a population increase of less than 1 percent in the geographic area of interest, the potential impacts on population for the CR SMR Project would be SMALL.

5.8.2.1.2 Housing

Subsection 2.5.2.6 and Table 2.5.2-10 summarize availability of housing in the year 2010 in the geographic area of interest. This information was used as a basis for estimating the number of housing units that may be available for CR SMR Project operations workers. Generally, the counties with larger populations (in particular Knox County) have more available vacant housing.

NUREG-1437, Revision 1 presents criteria for the assessment of housing impacts based on the discernible changes in the housing availability, prices, and changes in housing construction or conversions. These criteria are:

- SMALL: small and not easily discernible change in housing availability; increases in rental rates or housing values equal to or slightly exceeding the statewide inflation rate; and no extraordinary construction or conversion of housing
- MODERATE: discernible but short-lived reduction in housing availability; rental rates or housing values rise slightly faster than statewide inflation rate with prices realigning as new housing added or project-related demand diminished; and minor or temporary conversions of non-living space to living space
- LARGE: very limited housing availability; rental rates and housing values increase well above normal inflation rate for state; and substantial conversions of housing units as well as overbuilding of new housing units.

There is currently enough housing to accommodate all the expected in-migrating families in Knox County alone. Knox County, with the greatest number of housing units in the geographic area of interest, had 17,700 vacant units in 2010, with 6777 for rent and 3747 for sale. In the geographic area of interest as a whole, there were a total of 26,403 vacant housing units, with 8984 for rent and 5120 for sale in 2010. It is likely adequate housing would be available within the geographic area of interest at the time the in-migrating operations workforce would move into the area. If all of the new in-migrating workers move to the geographic area of interest, 620 operations workers and family members would seek permanent housing in the four counties. It is also probable that workers on short-term assignments, such as refueling operations, would utilize temporary housing in the form of hotels, seasonal homes, and recreational vehicle parks and campgrounds. As described in Subsection 2.5.2.6, there are over 8100 hotel rooms in the Knoxville area and another 1185 rooms in Anderson, Loudon, and Roane Counties. According to the 2010 Census, the geographic area of interest has 2329 seasonal housing units. Also, there are approximately 1302 temporary housing sites at recreational facilities in the geographic area of interest (Table 2.5.2-12). Also, refueling outage workers could utilize temporary housing in the surrounding region, beyond the four counties in the geographic area of interest. During the overlap between preconstruction/construction and operation, 3385 people would potentially seek permanent and temporary housing within the geographic area of interest.

The in-migrating operations workforce of 250 workers and overlap period workforce of 1365 (1115 construction + 250 operations) are small compared to the 26,403 vacant housing units within the geographic area of interest. Also the 1000 temporary workers required for the scheduled refueling outages, assumed to be from outside the region, could be accommodated in approximately 3600 seasonal and temporary housing units and 9200 hotel rooms within the geographic area of interest. Based on the large number of available vacant housing units in the geographic area of interest and the relatively small requirements for the in-migrating operations and overlap period workforces and the temporary refueling outage workforce, the potential impacts on housing would be SMALL.

5.8.2.2 Employment and Income

Subsection 2.5.2.1 and Tables 2.5.2-1 through 2.5.2-8 summarize current employment characteristics and income levels in the geographic area of interest. Employment of the operations workforce and routine capital expenditures needed to support CR SMR Project operations over the period of operation would have economic impacts on the surrounding region.

NUREG-1437, Revision 1 presents criteria for the assessment of economic impacts based on operation-related employment as a percentage of total employment for the relevant study area. These criteria are:

- SMALL: if operations employment accounts for less than 5 percent of total study area employment
- MODERATE: if operations employment accounts for 5 to 10 percent of total study area employment
- LARGE: if operations employment accounts for more than 10 percent of total study area employment.

The 500 operations workers assumed for the SMR Project account for 0.1 percent of the total workforce (based on 2011 employment levels) within the four counties in the geographic area of interest, and the 1000 temporary refueling outage workers represent 0.2 percent of the total workforce. During the overlap period between preconstruction/construction and operation, the total workforce of 3666 represents 1 percent of the total workforce.

The U.S. Department of Commerce Bureau of Economic Analysis, Economics and Statistics Division, calculates multipliers for industry jobs and earnings within a specific region. The economic model they use is called the Regional Input-Output Modeling System (RIMS II).

RIMS II multipliers were obtained for the geographic area of interest consisting of Anderson, Knox, Loudon, and Roane Counties. The RIMS II direct effect employment multiplier for jobs in the utilities industry is 2.2149. Thus, for every newly created operations job at the CR SMR Project, an estimated additional 1.2149 jobs would be created in the region. (Reference 5.8-10) Based on the Bureau of Economic Analysis multiplier and an operations workforce of 500, the CR SMR Project would create approximately 607 indirect jobs within the geographic area of interest during the period of operation. The combined total of 1107 direct operations jobs plus indirect jobs represents approximately 0.3 percent of the geographic area of interest workforce.

It is assumed that most indirect jobs would be service related and it is expected that those jobs would be filled by the existing workforce within the geographic area of interest. As of 2011, there were approximately 24,000 unemployed persons in the geographic area of interest (Table 2.5.2-2). The 607 indirect jobs created by the CR SMR Project during the operations phase represent approximately 2.5 percent of the existing unemployed workforce.

For every dollar earned by an operations worker, an additional 0.5423 dollars is added to the regional economy based on the Bureau of Economic Analysis Utilities industry direct-effect earnings multiplier for the geographic area of interest (Reference 5.8-10).

It is assumed that the additional 1000 temporary workers required for each periodic refueling outage reside temporarily in the geographic area of interest during the 30- to 60-day outage period. Therefore, they would affect the local economy to a lesser extent than the permanent operations workforce.

As described in Subsection 4.4.2.2, the combined total of 3300 direct construction jobs plus 2450 indirect jobs would result in an increase of 5750 jobs, representing approximately 1.5 percent of the geographic area of interest workforce. During the overlap period between preconstruction/construction and operation, the combined direct plus indirect total of 6857 jobs (5750 construction-related + 1107 operation-related) represents approximately 1.7 percent of the geographic area of interest workforce.

The employment of the operations workforce and temporary refueling outage workers over the CR SMR Project period of operation, as well as employment during the overlap period between preconstruction/construction and operations, would have positive economic effects on the geographic area of interest and surrounding region. The CR SMR Project would introduce millions of dollars into the regional economy, creating indirect jobs that can help reduce unemployment and add business opportunities for housing and service-related industries. Operational activities at the facility would result in additional positive economic effects in the region related to expenditures for goods and services. Considering that operations-related employment (direct operations jobs plus indirect jobs) and overlap period-related employment each represents less than 5 percent of the workforce in the geographic area of interest, there would be a SMALL beneficial impact of CR SMR Project operations on the economy.

5.8.2.3 Transportation

Figure 2.5.2-1 identifies federal highways and state roads that provide access to the geographic area of interest. Operations workers would typically access the CRN Site via Tennessee State Highway (TN) 58 and Bear Creek Road. As shown in Figure 3.1-2, driveway access to and from the CRN Site is from Bear Creek Road.

As discussed in Subsection 2.5.2.2.3, capacity analyses of the four intersections most likely to be affected by the construction and operation of the CR SMR Project were performed in 2013 as part of the traffic assessment for the CRN Site (Reference 5.8-11). The intersections analyzed are TN 58 at Bear Creek Road ramp, TN 58 at TN 327, TN 95 at Bear Creek Road, and Bear Creek Road at Bear Creek Road ramp.

NUREG-1437, Revision 1 presents criteria for the assessment of transportation impacts based on the effect of operations traffic on the level of service (LOS) for roadways within the relevant study area. These criteria are:

- SMALL: LOS A and B are associated with small impacts because the operation of individual users is not substantially affected by the presence of other users; no delays occur and no improvements are needed

- MODERATE: LOS C and D are associated with moderate impacts because the operation of individual users begins to be severely restricted by other users; upgrading of roads or additional control systems may be required

- LARGE: LOS E and F are associated with large impacts because the use of the roadway is at or above capacity level, causing traffic delays and a potential increase in accident rates; major renovations of existing roads or additional roads may be needed.

Traffic generation estimates were determined for several scenarios, including for the peak year 2024 during the overlap period between preconstruction/construction and operation, which was assumed to have a construction workforce of 3300 (maximum number onsite during a 24-hr period) and an operations workforce of 366. Capacity analyses were performed for the AM and PM peak hours for all the study intersections. Under existing roadway conditions, Bear Creek Road as a two-lane section (between Bear Creek Road ramp and Proposed Site Entrance) was projected to operate at level of service (LOS) F (i.e., low variable speeds, heavily congested) in AM peak and the PM peak hours. Based on this traffic analysis, roadway improvements were recommended to mitigate adverse impacts to LOS as a result of increased traffic volume; these recommended improvements are summarized in Subsection 4.4.2.3. It is assumed that those improvements would provide an acceptable operation for the peak year 2024, which would have the largest combination of construction and operations traffic volumes.

It is assumed that approximately 75 percent of the operations workers work the 1st shift (7:00 AM to 3:00 PM), 5 percent the 2nd shift (3:00 PM to 11:00 PM), and 5 percent the 3rd shift (11:00

PM to 7:00 AM). The remaining 15 percent, including 5 percent in training and 10 percent on annual sick leave, were not included in the daily traffic generation estimates. Based on this breakdown of shift workers, during the long-term operations phase approximately 375 employees arrive at the CRN Site around 7:00 AM. Assuming one person per vehicle, this represents 375 vehicles. If the local roadways were in their current configuration, this influx of traffic could create an adverse impact to transportation in the immediate CR SMR Project area. (Reference 5.8-11) However, the peak operations workforce at the completion of the CR SMR Project would be well below the peak overlap workforce evaluated in the traffic assessment for the CRN Site. Therefore, although operations traffic could slightly increase the commute time along Bear Creek Road for persons working at the Clinch River Industrial Park, the roadway improvements recommended to accommodate the peak overlap period would also accommodate the operations staff traffic once the CR SMR Project is complete.

Similarly, traffic accidents and related injuries and fatalities associated with operations at the CRN Site are anticipated to increase slightly over current conditions, but not as much as during construction. The analysis for traffic accidents during the peak overlap period is discussed in Subsection 4.4.2.3. The roadway improvements recommended to accommodate the peak overlap traffic are anticipated to be sufficient mitigation to minimize traffic accidents associated with CRN Site operations.

During refueling operations, an increased number of vehicles would be travelling on the local roads. Using the same shift breakdown as described for the operations workers, an estimated 750 additional outage worker vehicles arrive at the CRN Site around 7:00 AM. The total of operations and outage worker vehicles (1125) is less than the year 2024 total of construction and operations workers used in the traffic analysis (3666). Therefore, it is anticipated that the LOS at each of the intersections studied in the traffic assessment would be adequate, because the intersections would have been upgraded to handle the higher construction traffic volumes.

The mitigation measures used to offset the construction impacts on local roads, as described in Subsection 4.4.2.3, are sufficient to offset operational impacts to LOS for these roads. Considering that the road improvements are designed to accommodate the much larger construction workforce, the improved LOS resulting from the mitigation measures would have a beneficial impact on operations of those intersections and roads. Therefore, impacts to local roads would be beneficial and SMALL.

The volume of equipment delivered by rail and barge during operation of the CR SMR Project and during the overlap period is expected be similar to the volume of large components transported during construction. Therefore, the impact on local railroads and on barge traffic on the Clinch River arm of the Watts Bar Reservoir would be SMALL.

The estimated geographic area of interest population increase associated with operation of two or more SMRs at the CRN Site is approximately 620 workers and family, and 3385 people (2765 associated with construction and 620 associated with operation) for the overlap period between construction/preconstruction and operation. This could slightly increase public transportation usage, which would have a SMALL impact on public transportation facilities in the geographic area of interest.

5.8.2.4 Tax Revenues to Local Jurisdictions

NUREG-1437, Revision 1 presents criteria for the assessment of impacts on local tax receipts based on the magnitude of potential new tax payments, or payments in lieu of taxes, in relation to total revenues in the host community. These criteria are:

- SMALL: if the new tax payments constitute less than 10 percent of total revenues for local taxing jurisdictions
- MODERATE: if the new tax payments constitute 10 to 20 percent of total revenues for local taxing jurisdictions
- LARGE: if the new tax payments constitute more than 20 percent of total revenues for local taxing jurisdictions.

Several types of taxes are generated by operational activities and by workforce expenditures. These include sales and use taxes on employee purchases and personal property tax associated with employees. In addition, TVA makes tax equivalent payments. As described in Subsection 4.4.2.4, Anderson, Knox, Loudon, and Roane Counties are the tax districts that are assumed to be most directly affected by the CR SMR Project.

Sales and use taxes would be generated in the geographic area of interest and region through retail expenditures of the operations and refueling outage workforce and the preconstruction/construction and operations overlap period workforce. Property tax revenues would be generated by the increased economic activity involving the operations and overlap period workforce. Revenues such as residential property taxes, real estate transfer fees, and motor vehicle taxes are collected by or on behalf of the state government. These funds are then distributed to the jurisdictions, including schools and public services.

As discussed in Subsection 2.5.2.3, TVA makes tax equivalent payments to eight states under Section 13 of the TVA Act of 1933, including the State of Tennessee. TVA pays 5 percent of its gross proceeds from the sale of power (with certain exclusions) to states and counties where its power operations are carried out (the State of Tennessee and Roane County for the CR SMR Project). Payments to each state are determined based upon the proportion of TVA power property and power sales, in each state, compared to TVA's total power property and power sales, respectively. TVA’s tax equivalent payments to the four counties in the geographic area of interest are presented in Table 2.5.2-11 and total revenues in those counties are provided in Table 2.5.2-7. Fiscal Year (FY) 2013-2014 is the most recent year for which data on TVA tax equivalent payments and total county revenues are both available. The percentage of total county revenues represented by the TVA tax equivalent payment (i.e., TVA payment divided by total county revenues) for FY 2013-2014 are:

- Anderson County, 1.0 percent ($1.1 million/$109.6 million)
- Knox County, 0.4 percent ($3.4 million/$846.9 million)
- Loudon County, 1.6 percent ($1.1 million/$67.3 million)
- Roane County, 1.8 percent ($1.6 million/$91.3 million)

Although the amount of sales and property taxes as well as TVA tax equivalent payments would be large in absolute terms, they would be small when compared to the total amount of taxes collected within the geographic area of interest.

Given the structure by which the TVA makes tax equivalent payments, the general distribution structure of funding by the State of Tennessee, as well as the increase in sales and property taxes, the new tax payments are expected to represent less than 10 percent of total revenues and potential impact of taxes within the geographic area of interest and region would be SMALL and beneficial.

5.8.2.5 Land Use

In NUREG-1437, Revision 1, the NRC defines levels of significance for identifying impacts to offsite land use related to refurbishment of an existing nuclear facility. The analysis is based on population changes caused by refurbishment activities. These significance levels are applicable to the analysis of the impacts associated with operating a new nuclear power plant. NRC concluded that the impacts to offsite land use during refurbishment at nuclear plants are considered:

- SMALL: if population growth results in very little new residential or commercial development compared with existing conditions and if the limited development results only in minimal changes in an area’s basic land-use pattern
- MODERATE: if plant-related population growth results in considerable new residential or commercial development and the development results in some changes in an area’s basic land-use pattern
- LARGE: if population growth results in large-scale new residential or commercial development and the development results in major changes in an area’s basic land-use pattern

NRC identified key predictors of population-induced land use changes as:

- SMALL: if plant-related population growth is less than 5 percent of the study area’s total population, especially if the study area has established patterns of residential and commercial development, a population density of at least 60 persons per square mile, and at least one urban area with a population of 100,000 or more within 50 mi

- MODERATE: if plant-related population growth is between 5 and 20 percent of the study area's total population, especially if the study area has established patterns of residential and commercial development, a population density of 30 to 60 persons per square mile, and one urban area within 50 mi

- LARGE: if plant-related population growth is greater than 20 percent of the study area's total population and population density is less than 30 persons per square mile

Subsection 4.4.2.5 describes impacts to offsite land use due to the influx of 2765 construction workers and family members. As stated in Subsection 4.4.2.5, according to U.S. Nuclear Regulatory Commission (NRC) guidelines, population-induced land use changes would be SMALL because the construction-related population increase would be 0.5 percent of the geographic area of interest population, the area has an established pattern of residential and commercial development, a population density of greater than 60 people per square mile, and at least one urban area with a population of 100,000 or more within 50 mi (178,874 in Knoxville, Tennessee). As discussed in Subsection 5.8.2.1, an in-migrating operations workforce of 250 workers and their family members would increase the population of the geographic area of interest by 620 people, or 0.1 percent of the geographic area of interest population in 2010. Population increases during the overlap period between preconstruction/construction and operations would represent an increase of 0.6 percent of the geographic area of interest population. Accordingly, the population-induced land use changes associated with the smaller operations-related population and the population during the overlap period would be minor, and the impacts on land use would be SMALL.

As discussed in Subsection 5.8.2.1, population increases due to the operations workforce constitute 0.2 percent, 0.07 percent, 0.08 percent, and 0.2 percent of the 2010 populations of Anderson, Knox, Loudon, and Roane counties, respectively. The population density is greater than 60 people per square mile in each county: 222.8 in Anderson County, 850.5 in Knox County, 211.8 in Loudon County, and 150.2 in Roane County. Accordingly, population-induced land use changes would also be SMALL if the counties within the geographic area of interest are considered individually.

A temporary influx of approximately 1000 workers during refueling operations are not expected to cause impacts to offsite land use because these temporary employees are assumed to utilize temporary housing in the form of hotels, seasonal homes, and recreational vehicle parks and campgrounds.

Overall, because CR SMR Project-related population growth would be less than 5 percent, according to NRC guidelines the population-induced impacts to offsite land use patterns would be SMALL.

5.8.2.6 Recreation

NUREG-1437, Revision 1 presents criteria for assessing the impacts of nuclear power plants on recreation and tourism based on level of demand for recreational facilities. The criteria are:

- SMALL: if current facilities are adequate to handle local levels of demand
- MODERATE: if facilities are overcrowded during peak demand times
- LARGE: if additional recreation areas are needed to meet ongoing demands.

The existing visual resources and recreational opportunities near the CRN Site are described in Subsection 2.5.2.5.1. A number of public and private recreational facilities and a range of outdoor activities are located in the vicinity of the CRN Site, as described in Subsection 2.5.2.5.2, and in the region, as discussed in Subsection 2.5.1.3. Recreational opportunities in the immediate vicinity of the CRN Site include outdoor activities such as fishing and boating (including on the Clinch River arm of the Watts Bar Reservoir), hunting, hiking, and camping. Recreational areas within the CRN Site vicinity and region could potentially be impacted by the increased population of operations workers and their families and the increased competition for transient housing during refueling outages. Workers who relocate to the geographic area of interest are expected to utilize recreational areas and facilities to a similar degree as the permanent population of the geographic area of interest. Because many of the recreational opportunities of the region are outdoor activities without associated maximum capacities, it is difficult to accurately estimate utilization by the permanent population. As discussed on Subsection 5.8.2.1, an in-migrating workforce of 250 would increase the population in the geographic area of interest by 620 people, or 0.1 percent based on the 2010 population of 610,092 and an in-migrating workforce of 1365 would increase the population by 3385 people or 0.6 percent. Sufficient recreational facilities are available to accommodate the associated increase in usage. Therefore, impacts to recreation resources during CR SMR Project operation would be SMALL. Based on the regional supply of transient housing, including 2329 seasonal units and 1302 temporary housing sites at recreational facilities in the geographic area of interest, the impact on recreational facilities due to increased competition for transient housing during refueling outages also would be SMALL.

5.8.2.7 Community Infrastructure and Services

NUREG-1437, Revision 1 has consolidated the evaluation of public utilities, public safety, and education within the community services and education issue area. (Education is addressed in Subsection 5.8.2.8.) The criteria identified for community services are:

- SMALL: if little or no change occurs in the community’s ability to respond to the level of demand and there is no need to add capital facilities or additional personnel

- MODERATE: if overtaxing of facilities during peak demand periods occurs or some permanent additions to public safety forces or new capital equipment purchases are needed
- LARGE: if existing service levels are substantially degraded and additional capacity, personnel, or equipment is needed.

Demands from operational activities as well as from associated population increases were considered when evaluating the effects of operation of the CR SMR Project on infrastructure and services. During the period of operation, an estimated 250 workers would migrate into the geographic area of interest accompanied by 370 family members, for a population increase of 620, and the total permanent onsite operations workforce would be an estimated 500 workers. An additional 1000 temporary workers would be on site during the periodic refueling operations. During the overlap period, an estimated 1365 workers would in-migrate accompanied by 2020 family members, for a total population increase of 3385.

Water Supply Facilities

Potential impacts to potable water supplies would result from additional demands on water supply facilities associated with operation-related water needs and the increase in the local population (in-migrating operations workers). The source of water for the potable and sanitary water systems at the CRN Site is municipal water from the City of Oak Ridge Public Works Department, which obtains its raw water from the surface water in the Melton Hill Reservoir. As discussed in Subsection 4.4.2.7, the U.S. Geological Survey (USGS) estimates that the average person uses 80 to 100 gallons per day (gpd) of water at home, including bathing, laundry, and outdoor watering. Using the presumption that the operations workers are present on site for 8 hr per day, it is assumed that a conservative estimate of 50 gpd of potable water per worker would be required. The peak operations workforce of 500 operations workers and 1000 outage workers would require a maximum of 75,000 gpd, or 0.08 million gallons per day (mgd), of potable water. During the overlap period, the peak overlap workforce of 3666 (3300 construction workers and 366 operations workers) would require a maximum of 183,300 gpd, or 0.18 mgd. As shown in Table 2.5.2-15, the utility has a maximum potable water capacity of 9.9 mgd and an average daily consumption of 7.7 mgd, for an excess capacity of 2.2 mgd. The onsite maximum potable water usage during operations of 0.08 mgd represents less than 4 percent of excess capacity and the maximum of 0.18 mgd during the peak overlap workforce represents less than 9 percent of excess capacity. Therefore, operational impacts to water supply facilities and the temporary overlap period impacts would be SMALL.

The impacts to the water supply systems within the geographic area of interest from the operations-related population increase can be estimated by calculating the amount of potable water that is required by these individuals. Table 2.5.2-15 contains details regarding the more than 20 public water suppliers in the four counties of the geographic area of interest, including their maximum daily capacity and current demand. Most of these water supply systems are operating well below capacity. As stated earlier, the USGS estimates that the average person uses 80 to 100 gpd of water at home. This represents an increased demand of approximately 62,000 gpd (during operations) and 338,500 gpd (overlap period). Because all of the local utilities are operating below capacity and the in-migrating workforce would be spread out among four counties, an increase of 620 persons (operations) or 3385 persons (overlap period) in the geographic area of interest would not adversely affect the local utilities' capacity to supply potable water to their customers. Therefore, impacts to public water supply systems in the geographic area of interest would be SMALL.

The 1000 refueling outage workers are conservatively assumed to reside within the geographic area of interest during periodic refueling activities. The associated increase in potable water demand would be temporary and spread over several water supply systems. Most of these water supply systems are operating well below capacity. Therefore, impacts to public water supply systems in the geographic area of interest would be SMALL during refueling activities.

<u>Wastewater Treatment Facilities</u>

Similar to potable water supplies, potential impacts to wastewater treatment facilities would result from onsite operation-related needs and the increase in the local population associated with in-migrating operations workers. Wastewater generated during operation of the CR SMR Project is discharged to the City of Oak Ridge Rarity Ridge sanitary treatment facility. As previously described, the average person in the United States uses 80 to 100 gpd of water at home, including such activities as dishwashing, laundry, and outdoor watering. During operations, a peak operations workforce of 500 operations workers and 1000 temporary outage workers are on site on any particular day. Assuming that half of their water consumption occurs at the CRN Site results in 40 to 50 gpd of wastewater per worker, and a maximum of 75,000 gpd or 0.08 mgd of wastewater produced on site during peak operations. During the overlap period, a maximum of 183,300 gpd or 0.18 mgd of wastewater would be produced on site. As shown on Table 2.5.2-16, the City of Oak Ridge Rarity Ridge facility has a maximum treatment capacity of 0.6 mgd and an average daily utilization of 0.1 mgd, for an excess capacity of 0.5 mgd. The onsite wastewater production of 0.08 mgd represents approximately 15 percent of excess capacity and the wastewater production of 0.18 mgd represents approximately 36 percent of excess capacity. Although the temporary demand during the overlap period would be noticeable, it would not overtax existing facilities and there would be no capital purchases required to increase treatment capacity. Accordingly, the operations-related impact to wastewater treatment facilities would be SMALL.

Table 2.5.2-16 lists the wastewater treatment facilities in the geographic area of interest, their maximum daily capacity, and wastewater flows processed daily. The increase to the geographic area of interest population of an estimated 620 operation-related residents and 3385 overlap period-related residents would increase demand for wastewater treatment. Because the in-migrating population is not expected to settle in one area exclusively, this increased demand would be distributed among several facilities in the four counties. All of the wastewater treatment facilities in the geographic area of interest are operating below capacity, and would be able to absorb the increased demand without adversely affecting the current customers. Therefore, based on the current excess capacities of the existing wastewater treatment facilities in the geographic area of interest, impacts to wastewater treatment facilities would be SMALL.

The 1000 refueling outage workers are conservatively assumed to reside within the geographic area of interest during periodic refueling activities. The associated increase in wastewater treatment demand would be temporary and distributed over several water supply systems. Most of these water supply systems are operating well below capacity. Therefore, impacts to public water supply systems in the geographic area of interest would be SMALL during refueling activities.

Police Services

The number of sworn law enforcement officers and the resident-to-officer ratio for the four counties and the larger cities in the geographic area of interest are given in Table 2.5.2-17. The recommended ratio of officers to residents is between 1 and 4 officers to 1000 residents, or a police officer-to-resident ratio between 1:250 and 1:1000 (Reference 5.8-12). Table 2.5.2-17 shows that the cities within the geographic area of interest are within this ratio range and the counties are at or slightly above 1:1000. As previously stated, during the period of operation an estimated 620 workers and family members and during the overlap period an estimated 3385 workers and family members would migrate into the geographic area of interest. It is expected that most of these workers would reside in the larger cities in the area, including Knoxville, Oak Ridge, Clinton, Harriman, Kingston, and Lenoir City, Tennessee. These cities would be able to absorb the additional residents without the necessity of hiring more police officers because their police forces are already larger than the size required to achieve the recommended ratio of officers to residents. Table 5.8-3 shows distribution of the operations workforce among the four counties within the geographic area of interest and the resulting increased total populations by county. These population increases would increase the police-to-resident ratios slightly. The percent increase in ratio attributed to operation would be 0.2 percent in Anderson, Loudon, and Roane counties and no change in Knox County. During the overlap period, an increase in ratio attributed to construction would also occur, including 1.0, 0.9, 0.4, and 1.0 percent in Anderson, Knox, Loudon, and Roane Counties, respectively (as described in Subsection 4.4.2.7). Based on the percentage increase in police-to-resident ratios, the impact of in-migrating operation-related population to police services would be SMALL.

The 1000 refueling outage workers are conservatively assumed to reside within the geographic area of interest during periodic refueling activities. The associated population increase would be temporary and spread over the geographic area of interest. Therefore, impacts to police services in the geographic area of interest would be SMALL during refueling activities.

Fire Protection Services

The existing levels of fire protection services in the geographic area of interest are close to the national average, as described in Subsection 2.5.2.7.3. Firefighter-to-resident ratios range from 1:205 in Roane County to 1:715 in Knox County. During operations, the City of Oak Ridge Fire Department provides primary fire and emergency medical services to the CRN Site. The first responder is the station located at the East Tennessee Technology Park, approximately 3.2 mi north of the CRN Site. Table 5.8-4 shows distribution of the operations workforce among the four counties within the geographic area of interest and the effect of the larger populations. These population increases would increase the firefighter-to-resident ratios slightly. The percent increase in ratio attributed to operations would be 0.3 and 0.5 percent in Anderson and Roane counties, respectively, and no change in Knox and Loudon counties. During the overlap period, the additional percent increase in ratio attributed to construction would be 1.0, 0.9, 0.4, and 1.0 percent in Anderson, Knox, Loudon, and Roane Counties, respectively (as described in Subsection 4.4.2.7). Therefore, the potential impacts of the in-migrating residents to fire protection services during operation would be SMALL.

The 1000 refueling outage workers are conservatively assumed to reside within the geographic area of interest during periodic refueling activities. The associated population increase would be temporary and spread over the geographic area of interest. Therefore, impacts to fire protection services in the geographic area of interest would be SMALL during refueling activities.

Medical Services

The available medical services in the geographic area of interest, including health care facilities and nursing homes, are described in Subsection 2.5.2.7.3 and Tables 2.5.2-18 and 2.5.2-19. During operation of the CR SMR Project, onsite medical personnel would be expected to treat minor injuries to workers. More extensive injuries would be treated at one of the medical centers in the vicinity of the CRN Site. The influx of operations workers, temporary refueling outage workers, and overlap period construction and operation workers to the geographic area of interest would not disrupt the existing medical services available in the area. An addition of approximately 620 operation-related residents would increase the geographic area of interest population by 0.1 percent and an addition of 3385 overlap period construction and operations workers would increase the population by 0.6 percent, which would not adversely affect existing medical services. Therefore, impacts to medical services would be SMALL.

5.8.2.8 Education

NUREG-1437, Revision 1 presents criteria for the assessment of education impacts based on the baseline conditions of the potentially affected school system (e.g., whether it is below, at, or exceeding maximum allowed student/teacher ratio). These criteria are:

- SMALL: project-related enrollment increases of 3 percent or less; no change in the school systems' abilities to provide educational services and no additional teaching staff or classroom space is needed
- MODERATE: project-related enrollment increases of 4 to 8 percent; school system must increase its teaching staff or classroom space
- LARGE: project-related enrollment increases above 8 percent; current institutions not adequate to accommodate the influx of students or project-related demand can be met only if additional resources are acquired.

Schools and student populations are discussed in Subsection 2.5.2.8. In the 2010 US Census Bureau estimates, 17.1 percent of the population of Tennessee was 5 to 17 years old (i.e., school age) and students accounted for 15.1 to 16.3 percent of total county populations in the four-counties within the geographic area of interest. It is assumed that an estimated 250 operations workers would come from outside the 50-mi region. This would result in a population increase of 620 based on an average household size in Tennessee of 2.48 persons. Using the highest county figure of 16.3 percent for student population, an estimated 101 school-aged children would relocate within the geographic area of interest.

As described in Subsection 5.8.2.1, it is assumed that 27 percent of the in-migrating operations workforce resides in Anderson County, 50 percent in Knox County, 6 percent in Loudon County, and 17 percent in Roane County. Table 5.8-5 applies the population distribution percentage assumptions to the number of school-aged children in the in-migrating operations workforce population to estimate the number of operations-related school-aged children in each of the four counties. Knox County would experience the largest increase in school-age population of 51 students. This represents less than 0.1 percent of the current public school population of 58,800. Roane County, with an additional 17 students, would experience the largest relative increase at 0.2 percent. Public school teacher-to-student ratios in the geographic area of interest are 1:14 in Anderson County and 1:16 in Knox, Loudon, and Roane counties (Reference 5.8-13). The increase in number of students would not change the teacher-to-student ratios (Table 5.8-5). During the overlap period between construction and operation, the population in the four-county geographic area of interest would increase by 3385 persons, including an estimated 552 school-aged children. This represents an increase of 0.6 percent in current public school enrollment. Project-related school enrollment increases would be less than 3 percent and increased revenues from property taxes and sales taxes on purchases as a result of workforce expenditures would help offset the additional education-related costs. Therefore, impacts to education within the geographic area of interest would be SMALL.

5.8.3 Environmental Justice Impacts

Executive Order 12898 (59 FR 7629) directs federal executive agencies to consider environmental justice under the National Environmental Policy Act. This Executive Order ensures that minority and/or low-income populations do not bear a disproportionate share of adverse health or environmental consequences of a proposed project, which in this instance is operation of two or more SMRs at the CRN Site. (Reference 5.8-14)

Subsection 2.5.4 describes the evaluation process used to identify minority and low-income populations living within the region that meet the conditions associated with the NRC guidance. Census blocks, block groups, and relative distances of minorities and low-income populations around the CRN Site are identified in Table 2.5.4-1 and Figures 2.5.4-1 and 2.5.4-2.

As shown in Figure 2.5.4-1, the spatial distribution of block groups with minority populations in the region is clustered in the City of Knoxville in Knox County, Tennessee and the City of Alcoa in Blount County, Tennessee. No block groups in Roane County (in which the CRN Site is located) or in Anderson County contain minority populations as defined in Subsection 2.5.4.2. As discussed in Subsection 2.5.4.2, the identified aggregate minority population closest to the CRN Site is located approximately 20 mi to the east in Blount County, Tennessee. The closest Hispanic minority population is located in Loudon County, Tennessee, approximately 9 mi southeast of the CRN Site.

As shown in Figure 2.5.4-2, the majority of the low-income population in the geographic area of interest is in the City of Knoxville, in Knox County, Tennessee. There is one low-income population block group within Roane County, Tennessee and one within Anderson County, Tennessee. As discussed in Subsection 2.5.4.3, the closest low-income population block group is located in Loudon County, Tennessee, approximately 7 mi southeast of the CRN Site. As shown on Figures 2.5.4-1 and 2.5.4-2, there is some overlap between the locations of minority and low-income population groups.

As discussed in Subsection 2.5.4.4, no other populations or groups (e.g., subsistence populations) were identified that represent environmental justice populations in the region. Two locations of potential significance to minority communities were identified, however. The Wheat Community Burial Ground is a mid-19th century African American cemetery located approximately 1 mi northwest of the northern boundary of the CRN Site on the east side of TN 58. The community of Scarboro, a small predominantly African American community established in 1950, is located in Anderson County approximately 0.5 mi from the Oak Ridge Reservation Y-12 plant.

5.8.3.1 Potential Physical Impacts

For the purpose of this environmental justice assessment, physical impacts under consideration due to CR SMR Project operation include potential effects on land use, water, and ecology. Ecological resources are a concern in the event that any minority or low-income populations in the area are dependent on fishing or farming for subsistence. Potential impacts on land use are described in detail in Section 5.1. Impacts on water are described in Section 5.2. Ecological and public health impacts in regard to the cooling system, radiation exposure pathways, and the transmission system are described within Sections 5.3, 5.4, and 5.6, respectively.

The CR SMR Project includes structures and facilities located within the CRN Site boundaries as well as on nearby and adjacent offsite areas. Offsite facilities include the 69-kV underground transmission line, railroad siding, and barge landing area, all located within property owned by the federal government and managed by the DOE or TVA and not in proximity to any residences. In addition, the Clinch River arm of the Watts Bar Reservoir is used to supply source water for the circulating water system for the SMR units.

As described in Section 5.1, the impacts on the surrounding public from any land use impacts as a result of CR SMR Project operation would be SMALL to MODERATE, including effects on land use in the vicinity of the CRN Site, transmission corridors and roadways, and historic properties. Because the effects are SMALL and because of the spatial distribution of minorities and low-income population in the region, the potential for disproportionate land use impacts on minority and low-income populations would be SMALL to MODERATE.

As described in Section 5.2, the impacts on the surrounding public from any water related impacts as a result of CR SMR Project operation would be SMALL, including hydrology, water use, and water quality. Because the effects would be SMALL and because of the spatial distribution of minorities and low-income population in the region, the potential for disproportionate water related impacts on minority and low-income populations would be SMALL

As described in Section 5.3, 5.4, and 5.6, the impacts on the surrounding public from any ecological and public health impacts as a result of CR SMR Project operation would be SMALL. Ecological and public health impacts were evaluated for cooling system effects on surface water and the atmosphere, radiological effects on humans and non-human biota, and transmission line effects on members of the public and terrestrial and aquatic ecosystems.. Because the effects would be SMALL and because of the spatial distribution of minorities and low-income population in the region, the potential for disproportionate ecological impacts on minority and low-income populations would be SMALL.

Based on the evaluations of land use impacts, water-related impacts, and ecological and public health impacts presented in Sections 5.1, 5.2, and 5.3, 5.4, and 5.6, physical impacts on the surrounding public from CR SMR Project operations would be SMALL. Based on the SMALL impacts overall, combined with the distribution patterns of minority and low-income populations, the potential for disproportionate impacts to minority and low-income populations would be SMALL.

5.8.3.2 Potential Socioeconomic Impacts

The socioeconomic resource categories with the greatest potential to affect minorities and low-income populations are transportation and housing. The impacts associated with the remaining socioeconomic resource categories (i.e., noise and air quality, land use, social and public services, economy, tax revenues, and recreation) would be SMALL, regardless of their spatial distribution relative to the CRN Site, and some have beneficial effects.

As described in Subsection 5.8.2.3, the mitigation measures used to offset the effects of construction traffic would also accommodate operations traffic; therefore, impacts to local roads during operation would be SMALL. Operations workers typically access the CRN Site via TN 58 and Bear Creek Road. Few houses are located along these access roads in the areas likely to be impacted by operation traffic. None of the minority or low-income census blocks are located along either TN 58 or Bear Creek Road. Although the Wheat Community Burial Ground is located off of TN 58, construction traffic would not impede access to the cemetery. No relocations of traffic to local offsite roads as a result of operation of the CR SMR Project are anticipated. Therefore, minority and low-income populations and locations of potential significance to minority populations would not be adversely impacted by operation traffic or disproportionately affected.

The impact of CR SMR Project operation, including periodic refueling activities, on the housing market in the CRN Site vicinity is expected to be small due to the large number of available vacant housing units and the relatively small requirements for the in-migrating operations workforce. However, due to the increased demand for housing in the region, rental housing costs could increase and potentially displace low-income renters. Considering the available number of housing units and assuming operations workers are not likely to need low-income housing, minority and low-income populations, including the Scarboro community, would not be adversely impacted or disproportionately affected by the operation-related demand for housing.

Positive socioeconomic impacts associated with operation are described in Subsection 5.8.2. These include increased employment opportunities, possible income increases, and generation of additional tax revenues, which are directly and indirectly related to CR SMR Project operations. These beneficial impacts also would be realized by minority and low-income populations.

The possibility that uniquely vulnerable minority or low-income communities, such as subsistence populations, might be located near the CRN Site was also evaluated. As discussed in Subsection 2.5.4.4, inquiries were made to local agencies, such as planning departments and social services agencies, academic institutions, and local businesses. None of the persons contacted identified any unique economic, social, or human health circumstances and lifestyle practices through which the minority and low-income populations could be disproportionately adversely affected by the CR SMR Project.

Based on the evaluation of potential socioeconomic effects of operation, impacts would be SMALL. Given the small impacts overall, combined with the distribution patterns of minority and low-income populations, the potential for adverse socioeconomic impacts that could disproportionately affect minority or low-income populations in the region would be SMALL.

5.8.4 References

Reference 5.8-1. AECOM, "Final Clinch River Site Ambient Noise Assessment Technical Report - Revision 1," Tennessee Valley Authority, April, 2014.

Reference 5.8-2. Federal Interagency Committee on Noise, "Federal Agency Review of Selected Airport Noise Analysis Issues," August, 1992.

Reference 5.8-3. Golder Associates, "Study on the Comparative Merits of Overhead Electricity Transmission Lines Versus Underground Cables," PPSMDE081295, May, 2008.

Reference 5.8-4. U.S. Environmental Protection Agency, Tennessee Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants, Website: http://www.epa.gov/oaqps001/greenbk/anayo_tn.html, January 30, 2015.

Reference 5.8-5. U.S. Environmental Protection Agency, EPA Approves Redesignation of Knoxville Area to Attainment for the 2008 8-Hour Ozone Standard, Website: http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/c0535b494c0ee0be85257e81004f5475!opendocument, July 13, 2015.

Reference 5.8-6. Nuclear Energy Institute, Life-Cycle Emissions Analysis, Website: http://www.nei.org/Issues-Policy/Protecting-the-Environment/Life-Cycle-Emissions-Analyses, 2015.

Reference 5.8-7. Nuclear Energy Institute, Comparison of Lifecycle Emissions of Energy Technologies, Website: http://www.nei.org/Issues-Policy/Protecting-the-Environment/Life-Cycle-Emissions-Analyses/Comparison-of-Lifecycle-Emissions-of-Selected-Ener, 2015.

Reference 5.8-8. U.S. Census Bureau, DP-1 Profile of General Population and Housing Characteristics: 2010 Demographic Profile Data, Website: http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_DP_DPDP1, 2010.

Reference 5.8-9. U.S. Nuclear Regulatory Commission, "Information Notice 2000-13: Review of Refueling Outage Risk," ADAMS Accession Number ML003752328, September 27, 2000.

Reference 5.8-10. U.S. Bureau of Economic Analysis, RIMS II Multipliers (2010/2010), Table 2.5 Total Multipliers for Output, Earnings, Employment, and Value Added by Industry Aggregation, Website: https://www.bea.gov/regional/rims/rimsii/, 2015.

Reference 5.8-11. AECOM, "Clinch River Site Traffic Assessment, Final Technical Report, Revision 0," Tennessee Valley Authority, March, 2015.

Reference 5.8-12. Broemmel, Jarett, Clark, Terry L., and Nielsen, Shannon, "The Surge Can Succeed," Military Review 87(4): 110-112, 2007.

Reference 5.8-13. U.S Department of Education and National Center for Education Statistics, Local Education Agency (School District) Universe Survey, Website: http://nces.ed.gov/ccd/elsi/, 2014.

Reference 5.8-14. Executive Order 12898 Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, February 11, 1994).

Reference 5.8-15. Federal Bureau of Investigation, Crime in the United States 2013, Table 80, Tennessee, Website: http://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2013/crime-in-the-u.s.-2013/tables/table-80/table-80-state-cuts/table_80_full_time_law_enforcement_employees_tennessee_by_metropolitan_nonmetropolitan_counties_2013.xls, 2015.

Reference 5.8-16. Federal Bureau of Investigation, Crime in the United States 2013, Table 78, Tennessee, Website: http://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/2013/crime-in-the-u.s.-2013/tables/table-78/table-78-cuts/table_78_full_time_law_enforcement_employees_tennessee_by_city_2013.xls, 2013.

Reference 5.8-17. U.S. Census Bureau, American Fact Finder, 2014 Population Estimates, Website: http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml, 2015.

Table 5.8-1
Preliminary Annual Estimates for Criteria Pollutant Emissions from SMR-Supporting Fossil Fuel Fired Equipment

Pollutant	Annual Emissions (Tons Per Year)
Nitrogen Oxides (NO_x)	37.6
Sulfur Dioxide (SO_2)	20.8
Carbon Monoxide (CO)	4.8
Particulates (PM)	4.0
Volatile Organic Compounds (VOC)	0.6

Table 5.8-2
Comparison of Life-Cycle CO_2 Equivalent Emissions for Different Energy Sources

Source	CO_2 Equivalent Emissions (Tons Per Gigawatt-Hour)
Coal	979
Gas	462
Biomass	253
Solar	53
Geothermal	42
Hydro	26
Nuclear	13
Onshore Wind	12

Source: (Reference 5.8-7)

Table 5.8-3
Law Enforcement Officers and Officer-to-Resident Ratios in Geographic Area of Interest

Counties in Geographic Area of Interest	Total Population in 2010	Additional Population Due to Facility Operation	Total with Additional Population	Number of Sworn Law Enforcement Officers[1]	Current Officer-to-Resident Ratio	Officer-to-Resident Ratio with Additional Population	Percent Increase from Current Officer-to-Resident Ratio
Anderson	75,129	166	75,295	148	1 : 508	1 : 509	0.2
Knox	432,226	310	432,536	851	1 : 508	1 : 508	--
Loudon	48,556	37	48,593	73	1 : 665	1 : 666	0.2
Roane	54,181	107	54,288	63	1 : 860	1 : 862	0.2

[1] Including city police force(s) within each county.

Note:
-- = no change

Sources: (Reference 5.8-15; Reference 5.8-16; Reference 5.8-17)

Table 5.8-4
Fire Fighters and Firefighter-to-Resident Ratios in Geographic Area of Interest

Counties in Geographic Area of Interest	Total Population in 2010	Additional Population Due to Facility Operation	Total with Additional Population	Number of Firefighters (Full time and Volunteer)	Current Firefighter-to-Resident Ratio	Firefighter-to-Resident Ratio with Additional Population	Percent Increase from Current Firefighter-to-Resident Ratio
Anderson	75,129	166	75,295	216	1 : 348	1 : 349	0.3
Knox	432,226	310	432,536	604	1 : 716	1 : 716	--
Loudon	48,556	37	48,593	201	1 : 242	1 : 242	--
Roane	54,181	107	54,288	264	1 : 205	1 : 206	0.5

Note:
-- = no change

Sources: (Reference 5.8-17)

Table 5.8-5
School Enrollments and Teacher/Student Ratios in Geographic Area of Interest

Counties in Geographic Area of Interest	Students Enrolled in Public School System	Full-Time Equivalent Teachers	Pupil/Teacher Ratio	Operations-Related Population Increase - Percent by County	School-Age Population Increase[1]	Percentage of Additional Public School Children per County	Teacher to Student Ratio with Additional Children
Anderson	12,598	925.1	13.62	27	27	0.22	1 : 13.6
Knox	58,815	3705.4	15.98	50	51	0.09	1 : 15.9
Loudon	7369	464.6	15.86	6	6	0.08	1 : 15.9
Roane	7413	475.2	15.60	17	17	0.23	1 : 15.6
Total	86,195	NA	NA	NA	101	0.12	NA

1 Based on addition of 101 school-aged children within geographic area of interest..

Note:
NA = Not Applicable

Source: (Reference 5.8-13)

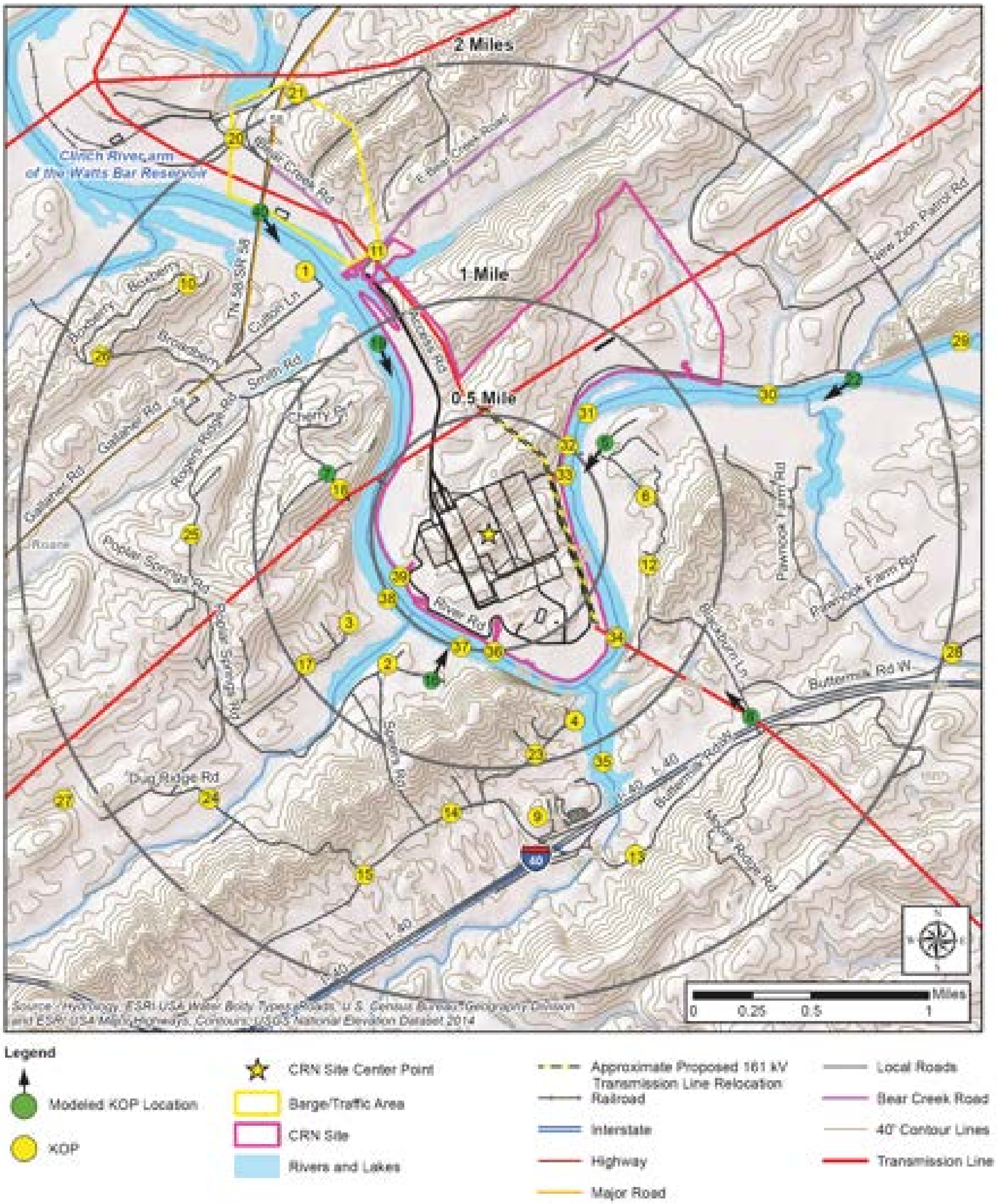


Figure 5.8-1. CRN Site Key Observation Points

Figure 5.8-2. Baseline View from KOP 5

Figure 5.8-3. View from KOP 5 with the CR SMR Project

Figure 5.8-4. View from KOP 5 with the CR SMR Project and the Average Annual Plume

Figure 5.8-5. View from KOP 5 with the CR SMR Project and the Winter Plume

Figure 5.8-6. Baseline View from KOP 7

Figure 5.8-7. View from KOP 7 with the CR SMR Project

Figure 5.8-8. View from KOP 7 with the CR SMR Project and the Average Annual Plume

Figure 5.8-9. View from KOP 7 with the CR SMR Project and the Winter Plume

Figure 5.8-10. Baseline View from KOP 8

Figure 5.8-11. View from KOP 8 with the CR SMR Project

Figure 5.8-12. View from KOP 8 with the CR SMR Project and the Average Annual Plume

Figure 5.8-13. View from KOP 8 with the CR SMR Project and the Winter Plume

Figure 5.8-14. Baseline View from KOP 16

Figure 5.8-15. View from KOP 16 with the CR SMR Project

Figure 5.8-16. View from KOP 16 with the CR SMR Project and the Average Annual Plume

Figure 5.8-17. View from KOP 16 with the CR SMR Project and the Winter Plume

Figure 5.8-18. Baseline View from KOP 19

Figure 5.8-19. View from KOP 19 with the CR SMR Project

Figure 5.8-20. View from KOP 19 with the CR SMR Project and the Average Annual Plume

Figure 5.8-21. View from KOP 19 with the CR SMR Project and the Winter Plume

Figure 5.8-22. Baseline View from KOP 22

Figure 5.8-23. View from KOP 22 with the CR SMR Project

Figure 5.8-24. View from KOP 22 with the CR SMR Project and the Average Annual Plume

Figure 5.8-25. View from KOP 22 with the CR SMR Project and the Winter Plume

Figure 5.8-26. Baseline View from KOP 40

Figure 5.8-27. View from KOP 40 with the CR SMR Project

Figure 5.8-28. View from KOP 40 with the CR SMR Project and the Average Annual Plume

Figure 5.8-29. View from KOP 40 with the CR SMR Project and the Winter Plume

5.9 DECOMMISSIONING IMPACTS

The U.S. Nuclear Regulatory Commission (NRC) requires that a nuclear facility be decommissioned per NRC regulations after cessation of operations by safely removing it from service and reducing residual radioactivity to a level that permits release of the property and termination of the operating license. NRC regulation Title 10 of the Code of Federal Regulations (10 CFR) 50.82 specifies the actions that NRC and a licensee must take to decommission a nuclear power facility. The radiological criteria to be met for license termination are specified in 10 CFR 20, Subpart E.

The NRC prohibits licensees from performing decommissioning activities that result in significant environmental impacts not previously reviewed under 10 CFR 50.82. The NRC has indicated that licensees for existing reactors can rely on the information in NUREG-0586, *Generic Environmental Impact Statement (GEIS) on Decommissioning of Nuclear Facilities*, Supplement 1, to determine the environmental impacts of decommissioning existing nuclear power reactors. Supplement 1 was published in 2002 with the original NUREG-0586 published in 1988. Because decommissioning plans are required by the NRC after a decision has been made to cease operation of a licensed nuclear unit, detailed analyses of decommissioning alternatives are not prepared until cessation of operations. As such, this section addresses only general environmental impacts of decommissioning.

NRC regulation 10 CFR 50.75, which establishes the financial requirements for providing reasonable assurance that adequate funds for performing decommissioning are available at the end of facility operations, does not apply to early site permit applications.

5.9.1 NRC GEIS on Decommissioning of Nuclear Facilities

The Decommissioning GEIS (NUREG-0586, Supplement 1) describes decommissioning regulatory requirements, the decommissioning process, and environmental impacts of decommissioning of nuclear facilities. Before presenting impacts, the Decommissioning GEIS describes the NRC process for evaluating impacts. Activities and impacts that NRC considered to be within the scope of the Decommissioning GEIS include:

- Activities performed to remove the facility from service once the licensee certifies that the facility has permanently ceased operations
- Activities performed in support of radiological decommissioning, including decontamination and dismantlement of radioactive structures, systems, and components (SSCs) and any activities required to support the decontamination and dismantlement process
- Activities performed in support of dismantlement of nonradiological SSCs, such as diesel generator buildings and cooling towers
- Activities performed up to license termination and their resulting impacts as provided by the definition of decommissioning

- Human health impacts from radiological and nonradiological decommissioning activities.

The Decommissioning GEIS evaluates the environmental impact of the following three decommissioning methods:

- DECON: The equipment, structures, and portions of the facility and site that contain radioactive contaminants are removed or decontaminated to a level that permits termination of the license shortly after cessation of operations. DECON comprises four distinct periods of effort: (1) pre-shutdown planning/engineering, (2) facility deactivation and transition (no activities are conducted during this period that will affect the safe operation of the spent fuel pool), (3) decontamination and dismantlement with concurrent operations in the spent-fuel pool until the pool inventory is zero, and (4) license termination.
- SAFSTOR: The facility is placed in a safe stable condition and maintained in that state (safe storage) until it is subsequently decontaminated and dismantled to levels that permit license termination. During SAFSTOR, a facility is left intact, but the fuel is removed from the reactor vessel and radioactive liquids are drained from systems and components and then processed. Radioactive decay occurs during the SAFSTOR period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during the decontamination and dismantlement of the facility at the end of the storage period.
- ENTOMB: This alternative involves encasing radioactive SSCs in a structurally long-lived substance, such as concrete. The entombed structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.

As stated in the Decommissioning GEIS, decommissioning a nuclear facility that has reached the end of its useful life generally has a positive environmental impact. The air quality, water quality, and ecological impacts of decommissioning are expected to be substantially smaller than those of nuclear facility construction or operation because the level of activity and the releases to the environment are expected to be smaller during decommissioning than during construction and operation. The major environmental impact, regardless of the specific decommissioning option selected, is the commitment of small amounts of land for waste burial where the offsite disposal facility is located (onsite disposal is not considered for the DECON option). Socioeconomic impacts of decommissioning would result from the demands on, and contributions to, the community by the workers employed to decommission a nuclear facility.

The Decommissioning GEIS assesses the impacts from decommissioning reactor facilities of various types and sizes including pressurized water reactors (PWR) in the 1130 megawatt electric (MWe) to 1825 MWe range. The description of decommissioning a PWR in the original Decommissioning GEIS (NUREG-0586) states that, while SMALL, the major environmental consequence of decommissioning is the commitment of land area to the disposal of radioactive waste. Because the waste volume from decommissioning can be correlated to the size of the reactor facility as provided in Table 4-7 of Decommissioning GEIS (NUREG-0586, Supplement 1), it can be concluded that the impacts of decommissioning small PWRs at the CRN Site with a combined electrical power of 800 MWe (Table 3.1-2, Item 16.6) are bound by the impacts of the larger reference reactor described in Decommissioning GEIS.

According to Section 5.9 of NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*, studies of social and environmental effects of decommissioning large commercial power generating units have not identified any significant impacts beyond those considered in the Decommissioning GEIS. NUREG 1555 also describes that decommissioning experience with commercial scale nuclear power facilities has shown that the occupational exposures during the decommissioning period are comparable to those associated with refueling and facility maintenance when a facility is operational. Each potential decommissioning alternative would have radiological impacts from the transport of materials from the facility to their disposal sites. The expected impact from this transportation activity would not be significantly different from normal operations.

The NRC identified some of the differences between SMR designs and previously licensed reactors in SECY-11-0181, such as the following:

- Reduced size and quantity of components and equipment to be disposed
- Reduced area to be decontaminated (depending on the number of modules)
- Possible difficulty with accessibility for decontamination because of the small size of the components
- Possible difficulties related to the decommissioning of modules while other modules are in operation (Reference 5.9-1)

SECY-11-0181 also acknowledges the expected differences between the SMRs and large LWRs would lead to differences in the cost of decommissioning a nuclear facility.

5.9.2 Conclusions

Projected physical facility inventories associated with SMR designs are expected to be less than those for currently operating nuclear reactors due to advances in technology, the smaller size of SMR reactor facility footprints, and simplified maintenance regimes for SMRs. Based on this comparison, Tennessee Valley Authority (TVA) has concluded that the environmental impacts identified in the Decommissioning GEIS are bounding for an SMR facility constructed and operated at the CRN Site. TVA has not identified any significant new information during this environmental review that would indicate the potential for decommissioning impacts not previously reviewed. Therefore, TVA does not anticipate adverse effects from the decommissioning process for the SMRs at the CRN Site and the impact would be SMALL.

5.9.3 References

Reference 5.9-1. Johnson, Michael R., "Policy Issue Information," SECY-11-0181, December 22, 2011.

5.10 MEASURES AND CONTROLS TO LIMIT ADVERSE IMPACTS DURING OPERATION

This section summarizes the principal adverse environmental impacts of operations and controls to limit these impacts. The cause-and-effect relationships between operational environmental disturbances and the corresponding affected environmental receptors/resources are presented in Table 5.10-1. The horizontal axis on the matrix represents the principal environmental disturbances and the vertical axis depicts the environmental receptors or resources that could be affected by those disturbances. Table 5.10-1 also summarizes feasible measures and controls that have been identified for mitigating operational impacts.

The significance indicators provided in Table 5.10-1 are designated using the following descriptors: SMALL (S), MODERATE (M), or LARGE (L). The significance indicators are defined in Section 5.0. The assignment of significance levels (S, M, and L) is based on the assumption that for each impact, corresponding feasible and adequate measures and controls (or equivalents) are implemented. If a SMALL (S) significance determination is made without the implementation of measures and controls, then no additional measures and controls are identified in Table 5.10-1. A blank cell in the elements column, “Potential Environmental Disturbances and Impact Levels," denotes “no impact” of that type on the environmental resource. Each “Impact Description or Activity” attribute is assigned a number and each “Feasible and Adequate Measures and Controls” attribute is assigned a number in parenthesis that corresponds to the respective “Impact Description or Activity.”

The feasible and adequate measures and controls described in Table 5.10-1 are considered reasonable from a practical, engineering, and economic view; many are based on statutes and regulatory requirements or are generally accepted practices within the utility industry. Therefore, these measures and controls are not expected to present an undue hardship on the applicant. Based on a review of the operational impacts described in this chapter, some general feasible and adequate measures and controls for reducing adverse impacts at the Clinch River Nuclear (CRN) Site include:

- An environmental safety and health plan has been prepared and is followed.
- Operational employees receive appropriate training on environmental compliance and safety procedures.
- Safety data sheets are required for applicable hazardous materials at the CRN Site. Operational employees are trained on the appropriate use of hazardous materials.
- Hazardous materials are used in accordance with applicable federal, state, and local laws and regulations and Tennessee Valley Authority (TVA) procedures.
- Hazardous wastes are treated, stored, and disposed of in accordance with the Resource Conservation and Recovery Act (RCRA), and other applicable federal, state, and local laws and regulations and TVA procedures. Operational employees are trained on the appropriate handling and disposal of hazardous wastes.

- As appropriate, a safety/environmental officer oversees and inspects operational activities.
- Operational activities are performed in accordance with applicable local, state, and federal ordinances, laws, and regulations and TVA procedures intended to prevent or minimize adverse environmental effects of operational activities on air, water, and land, and on plants, animals, workers and the public.
- Operational activities comply with applicable environmental laws, regulations, permits, and licenses, which place controls on how activities are performed.
- Operational activities are performed in compliance with applicable corporate environmental, safety, and operational procedures, which place controls on how activities are performed.
- Operational activities are performed in accordance with the Best Management Practices (BMPs), permits, and reporting and records retention procedures described in TVA's Environmental Protection (EPP) (Appendix B).

More specific mitigation measures are detailed in Table 5.10-1.

Table 5.10-1 (Sheet 1 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels: Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor	Impact Description or Activity	Feasible and Adequate Measures and Controls
5.1 Land Use Impacts															
5.1.1 The Site and Vicinity							S		S					1. Restriction of use of the land for most purposes other than those involving siting of utility projects. 2. Offsite disposal of waste.	(1) Land already designated for plant operations. (1) Limit disturbance of vegetation to the area within the site designated for CRN Site construction. (1-2) Minimize potential impacts through best management practices (BMPs) and TVA procedures. (2) Disposal of waste in accordance with applicable regulations and TVA procedures.
5.1.2 Transmission Corridors and Offsite Areas							S		S					1. Project implementation restricts use of land for most purposes other than those involving utility right-of-way (ROW) activities. 2. Continued impact to land from maintenance of the existing transmission line ROWs.	(1) To the extent feasible, avoid any additional disturbances of land in ROWs. (1-2) Inspect vegetation within and adjacent to ROW on a regular basis to assist in planning corrective and routine maintenance in accordance with TVA’s "A Guide for Environmental Protection and Best Management Practices for TVA Transmission Construction and Maintenance Activities." (2) Limit continued vegetation removal to the minimal amount needed to support the transmission line ROW.
5.1.3 Historic Properties							S							1. Potential to adversely affect historic and archaeological properties in areas of ground disturbance and maintenance.	(1) Conduct operations in compliance with the Programmatic Agreement.

Table 5.10-1 (Sheet 2 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.2 Water Related Impacts															
5.2.1 Hydrological Alterations and Plant Water Supply		S				S								1. Minor localized influence from cooling water system. 2. Small adverse impact on hydrological characteristics of CRN Site. 3. Stormwater discharge into nearby water bodies.	(1) Design diffuser to meet the objectives of maximizing thermal and chemical mixing while minimizing scour and hydrologic modifications. (2) Incorporate the hydrologic function of Stream S01 (displaced by cooling system intake) in conveying stormwater from the CRN Site into the stormwater management system for the CRN Site. (3) Manage stormwater in accordance with a site-specific Integrated Pollution Prevention Plan.
5.2.2 Water Use Impacts						S		S		S	S	S		1. Water loss primarily as a result of evaporative loses and drift from cooling towers 2. Effects to water users, including biota, from discharge of blowdown with small quantities of water treatment chemicals and other liquid effluents into reservoir.	(1) Design cooling towers to limit drift and evaporative water loss. (1) Control water availability through TVA's reservoir operating policy and construction of the Melton Hill dam by-pass. (2) Limit wastewater discharges and comply with Tennessee Department of Environment and Conservation (TDEC) National Pollutant Discharge Elimination System (NPDES) permit. (2) Minimize potential of hazardous materials/waste spills or releases through training and rigorous compliance with RCRA and applicable regulations and TVA procedures.

Table 5.10-1 (Sheet 3 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.3 Cooling System Impacts															
5.3.1 Intake System		S				S		S		S				1. Hydrodynamic force induced by intake system near the intake structure. 2. Some fish killed by impingement and entrainment. 3. Minor aquatic impact resulting from consumption of water from the Clinch River arm of the Watts Bar Reservoir.	(1) To the extent practical, design pumps, machinery, and screens to reduce hydrodynamic impacts. (2) Minimize withdrawals with closed-loop cooling cycle and reduce impingement and entrainment with low through-screen velocity at intake. (2) Minimize impingement and entrainment of organisms through compliance with Section 316(b) of the Clean Water Act (CWA) (implemented by the NPDES permit), per EPP Section 2.1 (Appendix B). (3) Design cooling water system to minimize water losses and reduce intake flows.
5.3.2 Discharge System		S			S	S				S		S		1. Small localized increase in surface water temperature from thermal plume resulting from water discharged to the reservoir. 2 Small impact on aquatic organisms from potential minor erosion or sedimentation near the discharge point. 3. Minor impact on aquatic organisms from thermal plume. 4. Small impact on aquatic organisms from small turbidity effect near the discharge structure.	(1) Compliance with state water quality standards and TVA procedures associated with thermal discharges. (1,3) Minimize the thermal discharge to the Clinch River arm of the Watts Bar Reservoir with closed loop cooling system. (2) To the extent practical, employ and position discharge structure so as to reduce erosion/sedimentation effects on aquatic organisms. (4) To the extent practical, design and position discharge structure so as to reduce turbidity effects on aquatic organisms.

Table 5.10-1 (Sheet 4 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.3.2 Discharge System (continued)														5. Small impact on benthic organisms from small amount of bottom scouring near the discharge structure. 6. Discharges of chemicals in blowdown water.	(5) To the extent practical, design and position discharge structure so as to reduce scouring effects on benthic organisms. (6) Monitor chemical concentrations to comply with the Biocide/Corrosion Treatment Plan submitted as part of the application for a TDEC NPDES permit, per EPP Section 2.1 (Appendix B).
5.3.3 Heat-Discharge System	S		S	S			S	S					S	1. Water vapor plume in the atmosphere from cooling towers release. 2. Contamination of soil from small amounts of waste salts and other chemicals from cooling towers in the atmosphere (drift deposition). 3. Minor increase in humidity in the CRN Site vicinity from cooling towers. 4. Minor impact on humans and terrestrial organisms from cloud shadowing. 5. Consumption of water from the reservoir due to cooling towers drift and evaporative losses. 6. Obscuring of view by water vapor plume. 7. Minor effect on wildlife near the cooling towers from operating noise.	(1) To the extent practical, design cooling towers using Best Available Technology to reduce evaporative losses and noise.

Table 5.10-1 (Sheet 5 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels: Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor	Impact Description or Activity	Feasible and Adequate Measures and Controls
5.3.4 Impacts to Members of the Public	S		S	S							S		S	1. Small increase in the background noise level from heat dissipation system. 2. Small impact to humans from increased humidity, vapor, and mineral emissions from the cooling towers. 3. Small cumulative socioeconomic impact on the surrounding region from evaporative and drift water loss. 4. Obscuring of view by water vapor plume. 5. Growth of etiologic agents (including organisms formerly referred to as thermophilic microorganisms) in the water cooling system.	(1) To the extent practical, use pumps and machinery that reduce noise levels. (2) Treat cooling water to reduce salt and mineral impurities. (3 and 4) Design cooling towers to reduce evaporative and drift water loses. (3) If necessary, initiate a water conservation program. (5) Periodically monitor and test water for etiologic agents (thermophilic microorganisms) according to programs such as the Centers for Disease Control’s Surveillance for Waterborne-Disease Outbreaks—United States.
5.4 Radiological Impacts of Normal Operations															
5.4.1 Exposure Pathways			S		S	S						S		1. Releases of radionuclides in gaseous effluents. 2. Releases of radionuclides in liquid effluents. 3. Exposure of humans to direct radiation and radioactive effluents.	(1-5) Doses from planned releases of radiation less than the limits prescribed under Title 10 of the Code of Federal Regulations (10 CFR) 20.1301and Title 40 of the Code of Federal Regulations (40 CFR) 190. (1-5) Implement a Radiological Environmental Monitoring Program to monitor specified exposure pathways. (1-5) Minimize effluent discharges in accordance with applicable regulations.

Table 5.10-1 (Sheet 6 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.4 Radiological Impacts of Normal Operations															
5.4.1 Exposure Pathways (continued)														4. Exposure of terrestrial species and habitats to direct radiation and radioactive effluents. 5. Exposure of aquatic species and habitats to direct radiation and radioactive effluents.	
5.4.2 Radiation Dose Modeling														NA	NA
5.4.3 Impacts to Members of the Public			S		S	S	S					S		1. Small incremental radiation dose to members of the public from the small modular reactors. 2. Radiation doses to members of the public from breathing, swimming, eating, drinking water, and contact with contaminated soil.	(1-2) Measure radiation doses to the public from liquid effluent releases to the reservoir and gaseous releases to the atmosphere. Calculated doses to the public are within the design objectives of 10 CFR 50 Appendix I and within regulatory limits of 40 CFR 190. (1-2) Implement a Radiological Environmental Monitoring Program to monitor specified exposure pathways. (1-2) Releases of radiation within regulatory limits. Calculated doses to the public are within the design objectives of 10 CFR 50 Appendix I and within regulatory limits of 40 CFR 190.

Table 5.10-1 (Sheet 7 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.4.4 Impacts to Biota other than Members of the Public			S		S	S			S	S		S		1. Radiation doses to biota via breathing, direct contact with contaminated water or soil, and ingestion.	(1) Although there are no acceptance criteria specifically for biota, there is no scientific evidence that chronic doses below 100 mrad/day are harmful to plants or animals. Calculated biota doses are less than 0.1 mrad/day. (1) As appropriate, erect barriers to restrict access to contaminated soil or water. (1) Monitor organisms to determine exposure to radiation.
5.5 Environmental Impacts of Waste															
5.5.1 Nonradioactive-Waste-System Impacts			S		S	S	S		S	S				1. Discharge of relatively low concentrations of hazardous nonradioactive emissions and effluents to the air, reservoir, and soil column as part of routine operations. 2. Generation and disposal of hazardous nonradioactive waste (e.g., waste paints, solvents, etc.) in licensed hazardous waste landfills. 3. Generation and disposal of nonhazardous waste (e.g., concrete, scrap metal, etc.) in licensed landfills.	(1) Release hazardous air emissions according to limits imposed by the Clean Air Act (CAA) Amendments of 1977, as amended, 41 USC 7401 et seq, the CAA regulations (40 CFR 50-99), and TVA procedures. (1) Release hazardous water effluents according to limits imposed by the CWA/Federal Water Pollution Control Act (FWPCA) and NPDES program and permit requirements, and TVA procedures. (2) Manage, treat, and dispose of hazardous waste according to RCRA regulations and TVA procedures. (1 and 2) Carefully monitor hazardous waste.

Table 5.10-1 (Sheet 8 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.5.1 Nonradioactive-Waste-System Impacts (continued)														4. Effluent and stormwater discharge. 5. Air emissions from equipment.	(3) Generate and dispose of nonhazardous nonradioactive waste according to applicable local, state, and federal regulations, including the Solid Waste Disposal Act, as amended, 42 U.S. Code (USC) 6901 et seq., and 40 CFR 261, *Identification and Listing of Hazardous Waste*, and TVA procedures. (1-3) Perform inspections for compliance with applicable waste management laws and regulations and TVA procedures. (1-3) As appropriate, train employees to follow applicable procedures and waste regulations.
5.5.2 Mixed Waste Impacts			S		S	S	S					S		1. Discharge of mixed waste emissions and effluents to the air, reservoir, or soil column as part of routine operations. 2. Disposal of mixed waste in licensed mixed waste landfills. 3. Potential chemical hazard and occupational exposure to radiological materials during handling and storage.	(1) Manage and release hazardous air constituents in accordance with the CAA regulations (40 CFR 50-99) and TVA procedures. (1) Manage and release hazardous water constituents in accordance with the CWA and TVA procedures. (1-3) Manage, treat, and dispose of hazardous waste constituents according to RCRA regulations, and TVA procedures. (1-3) Manage and dispose of radioactive constituents according to applicable regulations and TVA procedures. (1-3) As appropriate, train employees to follow applicable waste management procedures and regulations and TVA procedures.

Table 5.10-1 (Sheet 9 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.5.2 Mixed Waste Impacts (continued)															(1-3) Carefully monitor mixed waste. (1-3) Perform inspections for compliance with applicable waste management laws and regulations and TVA procedures. (1-3) Limit mixed waste generation through source reduction, recycling, and treatment options. (1-3) Develop and follow a waste management plan. (1-3) Develop and follow a waste minimization plan to reduces the amount of waste that is generated. (1-3) Adopt as low as reasonably achievable program and train employees on implementation of this program, as appropriate.
5.6 Transmission System Impacts															
5.6.1 Terrestrial Ecosystems									S					1. Impact on terrestrial ecology from continued maintenance involving clearing of vegetation along the existing ROWs. 2. Potential for some erosion following vegetative clearing and/or excavation operations. 3. Application of herbicides. 4. Operation of noisy equipment that produce air emissions.	(1-4) Minimize potential impacts through compliance with permitting requirements, BMPs, and TVA procedures, per EPP Section 2.2 (Appendix B). (1-4) Follow reporting and record keeping requirements of EPP Sections 2.3, 4.1, and 4.3 (Appendix B). (1-2) As appropriate, train employees on how to perform work in a manner that reduces adverse environmental impacts; to the extent feasible, avoid any additional disturbances to sensitive terrestrial or wetland habitats/species. (1, 3) Identify sensitive areas requiring restrictions on types of vegetation maintenance.

Table 5.10-1 (Sheet 10 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.6.1 Terrestrial Ecosystems (continued)															(2) As practical, reseed cleared areas to limit erosion using non-invasive species/native plants, per TVA procedures. (3) Use licensed operators to apply herbicides. (3) Comply with the TDEC General Permit for Pesticide Discharges (includes herbicides) (4) As practical, use noise suppression/mufflers on vehicles/machinery and maintain vehicles to reduce emissions.
5.6.2 Aquatic Ecosystems		S			S	S	S			S				1. Impact on aquatic biota from continued maintenance involving clearing of vegetation along ROWs near water bodies. 2. Potential for some erosion and subsequent runoff of sediment into water bodies. 3. Migration of herbicides into water bodies. 4. Potential discharge or spills of herbicides that pollute the aquatic ecosystem.	(1-4) Minimize potential impacts through compliance with permitting requirements, BMPs, and TVA procedures, per EPP Section 2.1 (Appendix B). (1-4) Follow reporting and record keeping requirements of EPP Sections 2.3, 4.1, and 4.3 (Appendix B). (1-4) Identify Streamside Management Zones requiring restrictions on the type of vegetation management activities performed. (1) To the extent feasible, avoid any additional disturbances to sensitive aquatic habitats/species. (2) As practical, reseed cleared areas to limit erosion using non-invasive species/native plants, per TVA procedures. (3) Use licensed operators to apply herbicides. (3) Comply with the TDEC General Permit for Pesticide Discharges (includes herbicides). (4) As appropriate, train employees on herbicides procedures to minimize the risk of spills or discharges.

Table 5.10-1 (Sheet 11 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.6.3 Impacts to Members of the Public	S			S			S			S			S	1. Effects on humans from noise from vehicles and equipment operated near inhabited or residential areas. 2. Potential electromagnetic fields effects of underground transmission line. 3. Potential for electric shock. 4. Continued aesthetics effects from maintenance of the transmission line ROW.	(1-4) Minimize potential impacts through compliance with permitting requirements, BMPs, and TVA procedures. (1) Minimize night and weekend maintenance operations to reduce noise impacts. (2) Use mitigation measures to decrease the electromagnetic fields related to the underground transmission line. (3) Maintain vertical clearance from the ground for overhead transmission lines and safety procedures to prevent direct contact with underground transmission line.
5.7 Uranium Fuel Cycle Impacts															
5.7.1 Uranium Fuel Cycle Impacts			S	S	S	S	S	S				S		1. Commitment of land for uranium processing facilities. 2. Consumption of cooling water during uranium oxide (UO_2) fuel fabrication. 3. Electrical energy used to power uranium processing facilities. 4. Management of hazardous and radioactive air emissions and effluents from the gaseous diffusion plant. 5. Management of hazardous, mixed, and radioactive waste.	(1) Construct plant according the BMPs. (3) As feasible, use energy efficient equipment/processes and introduce energy conservation program. (4) Discharge air emissions per CAA regulations (40 CFR 50-99). (4) Discharge water effluents per CWA/FWPCA and NPDES permit specifications. (4) Incorporate best available pollution control technology. (4) Treat and monitor emissions and effluents. (5) Manage hazardous constituents according to RCRA regulations.

Table 5.10-1 (Sheet 12 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
Environmental Resources (Section Reference)	**Noise**	**Erosion/Sedimentation**	**Air Disturbance/ Emissions**	**Traffic**	**Hazardous Materials/ Wastes**	**Surface and Ground Water**	**Land-Use/Disturbances**	**Water Use Consumption**	**Terrestrial Disturbances**	**Aquatic Disturbances**	**Socioeconomic Changes**	**Rad Exposure**	**Aesthetics/Dust/Odor**		
5.7.1 Uranium Fuel Cycle Impacts (continued)														6. Occupational radioactive dose to workers. 7. Transportation dose to workers and public. 8. Management of waste from operations, decontamination and decommissioning. Note: The Activities in this column and the Measures and Controls in the next column apply to operations and facilities that are not under the control of TVA.	(5) Manage radioactive constituents according to applicable regulations. (5) Implement waste minimization plan. (2, 5) Consider use of a more efficient enrichment technology. (3, 4, and 5) Consider centrifuge process over gaseous diffusion process that could significantly reduce energy requirements and environmental impacts. (3, 4, and 5) Consider use of new technologies with less fuel loading to reduce emissions, energy, and water usage. (6-7) As appropriate, monitor and train employees in radiation procedures/regulations pursuant to 10 CFR 20, 40 CFR 190, and 10 CFR 20.1301. (8) Prepare a detailed decontamination and decommissioning plan.
5.7.2 Transportation of Radioactive Materials												S		1. Occupational and public exposures to radioactive materials from incident-free transportation.	(1) Minimize shipments of unirradiated fuel, irradiated fuel, and radioactive waste (maximize packaging/shipping efficiency). (1) Maximize plant efficiency (reduce fuel needs). (1) Implement waste minimization procedures.

Table 5.10-1 (Sheet 13 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.8 Socioeconomic Impacts															
5.8.1 Physical Impacts of Station Operation	S		S				S						S	1. Potential episodic and limited noise impacts to workers and nearby residents. 2. Effects on humans from air pollutant and thermal emissions.	(1) As appropriate, train and appropriately protect workers to reduce the risk of potential exposure to noise. (1) Tests of emergency warning sirens with advance notification to the public. (2) Operate air emissions sources, and monitor release of air emissions, in accordance with state and federal regulations, air permit requirements and TVA procedures. (2) Include efficient drift eliminators to minimize drift emissions from cooling towers. (2) Manage thermal discharge from cooling water system in accordance with requirements of TDEC NPDES permit and TVA procedures.
5.8.2 Social and Economic Impacts of Station Operation				S							S		S	1. Traffic congestion impacts in the vicinity of the CRN Site due to operations traffic. 2. Potential ability of infrastructure and schools to accommodate influx of residents and students without additional facilities, services, or teachers. 3. Beneficial impact on economy and tax revenue.	(1) Offset operational and refueling event impacts to level of service for these roads by constructing the roadway improvements designed to accommodate the larger traffic volumes associated with construction traffic. (2) Offset demand associated with increased population with increased revenue from property taxes and sales taxes on workforce expenditures. (3) Maintain public access to boat ramps. (3) Maintain water quality so as not to impact fishing.

Table 5.10-1 (Sheet 14 of 14)
Summary of Measures and Controls to Limit Adverse Operational Impacts

Environmental Resources (Section Reference)	Potential Environmental Disturbances and Impact Levels													Impact Description or Activity	Feasible and Adequate Measures and Controls
	Noise	Erosion/Sedimentation	Air Disturbance/ Emissions	Traffic	Hazardous Materials/ Wastes	Surface and Ground Water	Land-Use/Disturbances	Water Use Consumption	Terrestrial Disturbances	Aquatic Disturbances	Socioeconomic Changes	Rad Exposure	Aesthetics/Dust/Odor		
5.8.2 Social and Economic Impacts of Station Operation (continued)														4. Limitation of recreational activities (i.e., fishing, boating, hunting, etc.) along the CRN Site shoreline.	
5.8.3 Environmental Justice Impacts	S		S	S			S	S			S			1. No disproportionately high adverse impacts to minority populations.	NA

Note:
NA = Not Applicable

5.11 CUMULATIVE IMPACTS RELATED TO STATION OPERATION

Impacts associated with facility operations are discussed in Chapter 5. Section 5.11 contains a summary of potential cumulative environmental impacts associated with operation of the Clinch River (CR) Small Modular Reactor (SMR) Project. The term cumulative impact is defined in the regulations of the Council on Environmental Quality (CEQ) implementing the National Environmental Policy Act (NEPA) (Title 40 of the Code of Federal Regulations [40 CFR] 1508.7) as follows:

> "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

The purpose of this section is to identify federal, state, local or other activities within the CR SMR Project region that could have cumulative impacts in conjunction with the proposed action. Potential impacts would include measurable changes to the analyzed resources which would not occur if the CR SMR Project were not constructed.

The geographic areas considered for the cumulative impacts of the CR SMR Project operations phase are the same as the resource based geographic areas of interest provided in Section 4.7. As indicated in Section 3.9, operation of the first SMR is scheduled to commence in early 2026. At that time, additional SMRs would still be under construction. Full operation of all SMR units of the facility is scheduled to begin in mid-2027.

For the purposes of this cumulative impacts assessment, the operational phase is considered separately from the construction phase, essentially assuming construction is complete and the CR SMR Project is fully operational. Cumulative impacts of CR SMR Project operations when added to other past, present, or reasonably foreseeable future actions are discussed below.

5.11.1 Past, Present, and Reasonably Foreseeable Future Projects

A summary of past, present, and reasonably foreseeable projects that could have a cumulative effect upon the geographic area of interest are provided in Section 4.7, Table 4.7-1. The table includes activities on the Oak Ridge Reservation (ORR), local industrial development, highway improvements, aviation projects, Tennessee Valley Authority's (TVA) generation projects (nuclear, fossil, and hydro), and local infrastructure improvements. The geographic areas of interest for each analyzed resource, as defined in Section 4.7 and Section 5.11, are provided in Table 5.11-1.

5.11.2 Cumulative Land Use Impacts

Subsection 4.7.2 summarizes the geographic and temporal scope of the cumulative analysis; the cumulative impacts associated with the past, present, and reasonably foreseeable future projects on land use; and the incremental contribution of preconstruction and construction activities to those cumulative impacts. This subsection addresses the incremental contribution of SMR operation to those cumulative impacts.

As discussed in Subsection 4.7.2, much of the Clinch River Nuclear (CRN) Site peninsula was under preparatory activities for the Clinch River Nuclear Breeder Reactor Project (CRBRP) in 1982 and 1983. CRBRP preparations ceased in 1983. The site was stabilized, major excavations backfilled, and vegetation planted. Planned use of this previously changed area by the proposed CRN SMR Project is consistent with the broader land use of the CRBRP; thus minimizing land use changes and the impact from the proposed CRN SMR Project.

As discussed in Section 5.1, impacts of the operation of the SMRs on land use and prime farmlands at the CRN Site and in the vicinity would be SMALL. Although project construction would permanently impact land use and soils on the CRN Site and in the Barge/Traffic Area, there would be no further impacts as a result of CR SMR Project operations.

Subsections 5.5.1.2 and 5.5.2 discuss the potential impacts from land disposal of nonradioactive wastes along with management and disposal of hazardous and mixed wastes. While sanitary wastewaters are to be discharged to the City of Oak Ridge Public Works Department, nonradioactive wastes are to be disposed offsite in state-approved sanitary landfills such as the Chestnut Ridge Sanitary Landfill, a Class I Municipal Solid Waste Facility located on the Anderson Knox county line adjacent to I-75. As discussed in Subsection 4.7.2, the Chestnut Ridge Landfill has a 50 year (yr) capacity to accept 1000 tons per day. Hazardous wastes would be managed by a TVA-approved vendor and disposed in accordance with TVA management procedures. The amount of waste would be minimized through TVA waste management programs and the impact would be SMALL.

Cumulative impacts from land-based disposal of nonradiological wastes are primarily a function of land availability. Because TVA would follow hazardous waste management and minimization practices, the facility is anticipated to be rated a Small Quantity Generator of Hazardous Wastes as defined by 40 CFR Part 262 and the operational volume of hazardous waste generated and disposed would be less than 1000 kilograms, or less than one metric ton (MT), per month. As discussed in Subsection 4.7.2, the volume of hazardous and mixed waste generated and disposed in the immediate vicinity of the CRN Site in 2014 included contributions from the Oak Ridge Reservation and exceeded 81 MT; therefore, the incremental increase of hazardous waste disposal associated with the CRN Site would be SMALL.

Past and present projects listed in Table 4.7-1 have cumulatively impacted land use throughout the region. As discussed in Subsection 4.7.2, spurred by the Manhattan Project, land use in the region of interest changed rapidly in the mid-20th century with the designation of large federal land holdings and the development of various hydroelectric dams, transportation routes, and manufacturing facilities. The cumulative impact of these projects has been MODERATE. In addition, continuing development and anticipated projects within the region, as listed in Table 4.7-1, continue to be influenced by the presence of the large federal land holdings in the area;

thus providing a persistent, MODERATE impact on land use. Foreseeable future impacts to land use include continued development of the Roane Regional Business and Technology Park, continued property transfer on the East Tennessee Technology Park (ETTP), planned construction and operation of the Sludge Build-Out Project, the construction and operation of the new Uranium Processing Facility at Y-12, continued operation of the High Flux Isotope Reactor at the Oak Ridge National Laboratory (ORNL), continued operation of the Spallation Neutron Source at ORNL, and planned Tennessee Department of Transportation (TDOT) roadway improvements in the area. Although the land use cumulative impact of foreseeable future products is MODERATE, impacts of the CR SMR Project operations on land use would be SMALL and their cumulative contribution to the overall impact would also be SMALL.

5.11.3 Cumulative Water Impacts

This subsection addresses the cumulative water use and water quality impacts from the proposed CR SMR Project on the CRN Site along with past, present, and reasonably foreseeable future projects. Section 2.3 describes the surface water and groundwater affected by the proposed CR SMR Project at the CRN Site. Section 5.2 describes impacts to hydrology, water use, and water quality during operational activities at the CRN Site. Cumulative impacts are presented separately for hydrology, water use, and water quality.

5.11.3.1 Surface Water Hydrology Impacts

Subsection 4.7.3.1 summarizes the cumulative impacts associated with the past, present, and reasonably foreseeable future projects, including global climate change, on surface water hydrology; and the incremental contribution of preconstruction and construction activities to those cumulative impacts. The geographic area of interest for cumulative surface water hydrology impacts is the watershed for the Watts Bar Reservoir. This subsection addresses the incremental contribution of SMR operation to those cumulative impacts.

Subsection 5.2.1.2.1 describes impacts to surface water hydrology during operation of the SMRs. As discussed in that subsection, impacts from the operation of the SMRs on water flow and pool levels in Watts Bar Reservoir would be SMALL. Although project construction would permanently impact one perennial stream and six ephemeral streams/wet-weather conveyances (WWCs), there would be no further impacts to these features as a result of operations. The hydrologic function of these features in conveying stormwater from the CRN Site would be incorporated into the stormwater management system used during operations. Given the small size of these features, permanent removal would not result in substantial hydrological impacts.

As discussed in Subsection 4.7.3.1, past and present projects listed in Table 4.7-1 have cumulatively impacted perennial streams and WWCs throughout the region. These impacts have occurred through the disturbance of the land area associated with each project, occupation of the original land area by a new facility or feature, and changes in the intensity and duration of precipitation as a result of global climate change. The largest cumulative impacts to perennial streams and WWCs likely resulted from the development of land area associated with agriculture, urban development, industrial development of the ORR, and development of the reservoirs operated by TVA. As a result, the total number and area of perennial streams and WWCs in the region has been reduced, and the impact of these cumulative projects has been MODERATE. During construction of the SMRs, the number and area of perennial streams and WWCs would be further reduced, adding incrementally to the cumulative impact.

As discussed in Subsection 5.2.1.2.1, project operation would not result in further impacts to surface water hydrology. Therefore, the incremental contribution from operations activities on surface water hydrology within the geographic area of interest would be SMALL.

5.11.3.2 Water Use Impacts

Cumulative water-use impacts are presented separately for surface water and groundwater.

5.11.3.2.1 Surface Water Use Impacts

Subsection 4.7.3.2.1 summarizes the cumulative impacts associated with the past, present, and reasonably foreseeable future projects, including global climate change, on surface water flows and availability; and the incremental contribution of preconstruction and construction activities to those cumulative impacts. The geographic area of interest for surface water use impacts is the seven-county area (Anderson, Knox, Loudon, Meigs, Morgan, Rhea, and Roane counties) surrounding the CRN Site. Although water use within the drainage basin of the Tennessee River both upstream and downstream of the CRN Site can affect the availability of surface water throughout the entire basin, the potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site, and to decrease substantially with distance from the Site. Generally, when impacts from a project within a local area are SMALL to none, it is expected that there would be no cumulative impacts greater than SMALL in the remainder of the geographic area of interest. This subsection addresses the incremental contribution of SMR operation to those cumulative impacts.

Subsection 5.2.1.2.1 describes impacts to surface water hydrology during operation of the SMRs, and Subsection 5.2.2.1.1 describes impacts to surface water availability during operation of the SMRs. As discussed in those subsections, the SMRs would withdraw surface water for cooling and other purposes, and some of the water withdrawn would be consumed through evaporation and drift. The analysis conducted demonstrated that, in the most conservative scenario, with a maximum water withdrawal rate of 30,708 gallons per minute (gpm) and a minimum daily average release of 400 cubic feet per second (cfs; 179,520 gpm) from Melton Hill Dam, the facility would withdraw approximately 17 percent of the daily average flow in the portion of the reservoir adjacent to the CRN Site, and approximately 7 percent of the daily average flow would be consumed. These estimates are expected to be conservative, as they are based only on the surface water that enters the reservoir through Melton Hill Dam, and does not include the much larger volume of water that enters the reservoir through Fort Loudoun Dam. As a result, the expected maximum consumptive use of water at the CRN site is considered to be inconsequential compared to the combined average conveyances from Melton

Hill Dam and Fort Loudoun Dam, and the hydrologic impacts of SMR operations on the overall flow and surface water availability in Watts Bar Reservoir would be SMALL

As discussed in Subsection 4.7.3.2.1, past, present, and reasonably foreseeable future projects, combined with the additional potential for a decrease in surface water availability due to global climate change, have resulted in SMALL cumulative impacts on surface water availability. Surface water uses for municipal, agricultural, and industrial purposes, including many of the projects listed in Table 4.7-1, remove surface water from the geographic area of interest, resulting in adverse impacts to surface water availability. The baseline data presented for surface water use in Subsection 2.3.2.1 represents the cumulative effect of all past and present projects within the geographic area of interest on surface water use. In addition, because the analysis included projections of water use to the year 2035, it incorporates reasonably foreseeable water uses. The estimates used to develop the reservoir operating policy included a total withdrawal of 13,990 million gallons per day (mgd) with a return of 13,010 mgd resulting in a net water demand of 980 mgd. As discussed in Subsection 2.3.2.1.1, the net water demand in the geographic area of interest in 2010 was 471 mgd, or 3.9 percent of the total withdrawals. The current watershed projection of water demand to 2035 indicates a total withdrawal of 9449 mgd with a return of 8737 mgd resulting in a net water demand of 712 mgd. (Reference 5.11-1) Therefore, both the current and projected future water demands are within the limits established for the reservoir operating policy, and cumulative impacts to surface water uses from past, present, and reasonably foreseeable future projects are SMALL.

TVA’s management of the dam and reservoir system stores excess surface water for use during periods of low precipitation. While this action does not increase the amount of surface water in the system, it does provide a beneficial impact on surface water availability by making water available during periods of low precipitation, except for periods of extreme drought.

As discussed in Subsection 5.2.2.1.1, the proposed SMR withdraws an average of 26 mgd (44 mgd maximum), which would increase the current projected total withdrawal within the Tennessee River Watershed to 9475 mgd (9493 mgd maximum). The proposed SMR withdrawal represents approximately 0.27 percent (0.46 percent maximum) of the current projected total withdrawal within the Tennessee River Watershed. The average and maximum net water use is 18 mgd, increasing the estimated projected net water demand to 730 mgd within the watershed and to 44 mgd for the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site. With the addition of the water use from SMR operation to the cumulative water use from other past, present, and reasonably foreseeable future projects, the cumulative water use is still well within the estimates that were used in the development of TVA’s reservoir operation system policy. Although operation of the SMRs would remove surface water from the system, the small amount that would be removed, as compared to the total amount available and the total amount projected to be needed for future use, show that the additional incremental cumulative impact would be SMALL.

5.11.3.2.2 Groundwater Use Impacts

Section 2.3 describes the groundwater affected by the proposed SMR Project at the CRN Site. In general, groundwater at the CRN Site recharges through precipitation and discharges to the Clinch River.

Subsections 5.2.1.2.2 and 5.2.2.1.2 describe impacts to groundwater use during normal operation of the proposed project at the CRN Site. There are no planned uses for groundwater during operational activities. Potable water is to be supplied to the CRN Site by the City of Oak Ridge. No new areas would be disturbed during anticipated operation and maintenance activities of the proposed CR SMR Project. Additional dewatering activities during operations and maintenance are anticipated to be smaller than preconstruction and construction dewatering activities. Therefore, it was concluded that impacts to groundwater use during normal operation of the proposed project at the CRN Site would be SMALL.

This cumulative analysis considers impacts from operation and maintenance activities along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to groundwater use within the geographic area of interest, the area most likely to be affected by the proposed CR SMR Project. For the purposes of this cumulative impact analysis, the geographic area of interest for groundwater use impacts is the Lower Clinch River Watershed from Melton Hill Reservoir down to the confluence of the Clinch, Emory, and Tennessee Rivers.

Groundwater use and availability are linked to water quality. As discussed in Subsection 2.3.3.2.2.2, groundwater contaminants from previous operations in the Lower Clinch River Watershed include radionuclides, volatile organic compounds (VOCs), and metals (arsenic, barium, and cadmium). Also discussed in Subsection 2.3.3.2.2.2, legacy contaminants from operations at the ORR include groundwater contaminant plumes with VOCs, metals, and radionuclides. As a result of these contaminant plumes, groundwater availability is curtailed both now and in the foreseeable future. Although current and future activities within the region would follow federal, state, and local regulations and guidelines, thus minimizing impacts to the groundwater system, the cumulative impact to groundwater use from past activities in the region is MODERATE, and the incremental impact from the CRN SMR Project would be SMALL.

In addition, the increasing probability of intense drought periods followed by intense precipitation events predicted by many of the climate change models may result in less permeable soils and thus less infiltration and recharge of the groundwater system. Further, these resultant changes to the groundwater system may favor different flow patterns; thus possibly changing contaminant transport through the groundwater system and thereby changing water availability for use. Although readily abundant surface water is expected to remain the chosen water source for the foreseeable future, changes in the utility of the groundwater may stress the water cycle system. However, because there are no planned uses for groundwater during CR SMR Project operations, the incremental additional cumulative impact associated with groundwater use would be SMALL.

5.11.3.3 Water Quality Impacts

Cumulative water-quality impacts are presented separately for surface water and groundwater.

5.11.3.3.1 Surface Water Quality Impacts

Subsection 4.7.3.3.1 summarizes the cumulative impacts associated with the past, present, and reasonably foreseeable future projects, including global climate change, on surface water quality; and the incremental contribution of preconstruction and construction activities to those cumulative impacts. The geographic area of interest for cumulative surface water quality impacts is the watershed for the Watts Bar Reservoir. Although projects within the drainage basin of the Tennessee River both upstream and downstream of the CRN Site can affect surface water quality throughout the entire basin, the potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site, and to decrease substantially with distance from the Site. Generally, when impacts from a project within a local area are SMALL to none, it is expected that there would be no cumulative impacts greater than SMALL in the remainder of the geographic area of interest. This subsection addresses the incremental contribution of SMR operation to those cumulative impacts.

Subsection 5.2.2.2 describes impacts to surface water quality during operation of the SMRs. As discussed in that subsection, the facility's wastewater discharges would be regulated by the Tennessee Department of Environment and Conservation (TDEC) through a National Pollution Discharge Elimination System (NPDES) permit, and temperatures and chemical concentrations for discharges would be in compliance with the terms and conditions of the Site's NPDES permit. In the most conservative scenario, the maximum facility discharge represents about 10 percent of the reservoir flow past the facility when the maximum discharge occurs coincidentally with the minimum daily average release from Melton Hill Dam. Because the characteristics and constituents of the facility discharge are proposed to be managed within the water quality criteria specified in the facility NPDES permit, and the volume of the discharge is small relative to the overall flow in the reservoir, the impact of facility operation on surface water quality would be SMALL.

Subsection 2.3.3.1 presents surface water quality results from a variety of sources, including studies of the U.S. Geological Survey in the Upper Tennessee River Basin, the TDEC 303(d) list, TVA's Reservoir Ecological Health Program, TVA's Site Preparation Monitoring Program, and TVA's Biological Monitoring Program. These studies provide a baseline for surface water and sediment quality based on analyses which occurred from 1994 to 2015, and therefore effectively represent the cumulative impact of all past and present projects. Impacts to surface water and sediment quality as a result of industry, mining, agriculture, urbanization, and toxic spills and releases have been identified. Surface water quality impacts include elevated bacteria, nutrients, and herbicides as a result of agriculture; elevated concentrations of polychlorinated biphenyls (PCBs), dioxin, and mercury in water, and semivolatile organic compounds in sediment, due to industrial sources and coal mining; and the presence of mercury, PCBs, and cesium-137 in sediment, as a result of past operations at the ORR. Global climate change also may adversely affect surface water quality in the future as increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts can result in increases in sediment, nitrogen, and other pollutant loads (Reference 5.11-2). In addition, TVA's operation of the dam and reservoir system has had a beneficial impact on water quality, by managing water flows to increase aeration and dilute industrial discharges.

Although water quality impacts from past and present projects have been documented, surface water quality in the Upper Tennessee River Basin usually meets existing guidelines for drinking water, recreation, and the protection of aquatic life (Reference 5.11-3). Sample results from the Site Preparation Monitoring Program for the Clinch River arm of the Watts Bar Reservoir upstream and downstream of the CRN Site indicate that TDEC's most stringent numeric criteria are being met and that site runoff (should it occur) would not have a significant impact to water quality (Reference 5.11-4). The discharge limits in the CRN Site's NPDES permit would be developed by TDEC to ensure that surface water quality continues to meet existing guidelines. Given that operational discharges would be managed in accordance with the permit limits established by TDEC, they would be unlikely to combine with the effects of past and present projects in a manner which would result in exceedance of existing guidelines. Therefore, the incremental contribution of SMR operation on surface water quality would be SMALL.

5.11.3.3.2 Groundwater Quality Impacts

Section 2.3 describes the groundwater affected by the proposed SMR project at the CRN Site. In general, groundwater at the CRN Site recharges through precipitation with periodic recharge from the Clinch River arm of the Watts Bar Reservoir during high water stages.

Subsection 5.2.2.1.2 describes impacts to the groundwater during operation of the proposed CR SMR Project. Because groundwater would not be used for safety-related or for non-safety-related water supply purposes during anticipated operation and maintenance activities of the proposed CR SMR Project, impacts to groundwater quality would be SMALL.

This cumulative analysis considers impacts from routine operation and maintenance activities along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts to the quality of groundwater within the geographic area of interest, the area most likely to be affected by the proposed CR SMR Project. The geographic area of interest for cumulative impacts to the quality of groundwater is the Lower Clinch River Watershed from Melton Hill Reservoir down to the confluence of the Clinch, Emory, and Tennessee Rivers near Kingston; the same as the groundwater use geographic area of interest.

Subsection 2.3.3.2.2.2, discusses the baseline groundwater sampling for the CRN Site. Legacy radionuclides strontium-90, tritium, and technetium-99 were detected along with legacy metals arsenic, barium, cadmium, and chromium at the CRN Site. No mercury or uranium was detected at the CRN Site.

As discussed in Subsection 2.3.3.2.2.2, legacy contamination from operations at the ORR has resulted in contaminated groundwater plumes in areas of the Reservation. Contaminant plumes on ORR include VOCs along with cesium-137, strontium-90, and tritium at the ORNL along with uranium, nitrate, and mercury at Y-12. Plumes at the ETTP also include chromium-6 and technetium-99. In addition, the regularly maintained and monitored fenced complex of White Oak Dam and its 25 acre lake continue to settle legacy ORNL contaminants into the sediment; thus contributing to cumulative impacts to groundwater.

Further, legacy groundwater contamination from the American Nuclear Corporation includes cobalt-60 and cesium-137. And groundwater contamination at the former Anderson County Landfill includes radionuclides and VOCs along with arsenic, beryllium, and cadmium. These legacy sites may potentially impact the groundwater in the Clinch River watershed.

In addition to these legacy contaminants possibly contributing to cumulative impacts to groundwater quality during normal operations and maintenance activities for the proposed project at the CRN Site, anticipated climate change may also contribute to groundwater quality impacts. As mentioned in Subsection 4.7.3.2.2, the increased incidence of both drought and flooding events predicted by some of the models would reduce the amount of infiltration recharging the groundwater system and thus possibly changing the favored flow patterns. These changes may include changes in contaminant transport through the groundwater system, thus changing water quality in the geographic area of interest.

Past and present projects listed in Table 4.7-1 and discussed above have cumulatively impacted the groundwater within the geographic area of interest. The cumulative impact of these projects has been MODERATE. In addition, although modern practices are anticipated to minimize impacts to groundwater quality from future projects; thus making their projected incremental impact SMALL, lingering impacts from legacy contaminants are anticipated to continue providing a MODERATE impact to future groundwater quality in the region. However, given that the impact of project operation on groundwater would be SMALL, the cumulative contribution from SMR operations to the overall impact on groundwater would also be SMALL.

5.11.4 Cumulative Ecological Impacts

This subsection describes the cumulative impacts on terrestrial and aquatic ecological resources that may result from operation of the proposed CR SMR Project at the CRN Site. The analysis considers these impacts in conjunction with other past, present, and reasonably foreseeable future activities within the geographic areas of interest for these resources. Subsection 4.7.4 discusses the geographic and temporal aspects of the cumulative analysis of ecological impacts; the cumulative impacts from relevant projects and activities, including global climate change, on ecological resources; and the incremental contribution of preconstruction and construction activities to those cumulative impacts. This subsection addresses the incremental contribution to those cumulative impacts from operation of the CR SMR Project. Terrestrial and aquatic ecology impacts are discussed separately below.

5.11.4.1 Terrestrial Ecology and Wetlands Impacts

Subsection 2.4.1 describes the terrestrial ecology resources, including wetlands, potentially affected by the proposed SMR Project at the CRN Site and provides the baseline for analysis of cumulative impacts to terrestrial ecology. Subsection 5.3.3.2 describes impacts to terrestrial ecosystems from operation of the system for discharging heat to the atmosphere at the CRN Site, and Subsection 5.6.1 describes impacts to terrestrial ecosystems from operation of the 69-kilovolt (kV) underground transmission line to be installed within an approximately 5-mile (mi) segment of an existing, 500-kV transmission line right-of-way (ROW). For the purposes of this cumulative analysis of SMR operation on terrestrial ecology, the geographic area of interest is defined as the area within approximately a 6-mi radius of the CRN Site. This area encompasses the CRN Site and associated offsite areas (Barge/Traffic Area and underground transmission line), and it is expected to encompass those other projects potentially capable of interacting with the CR SMR Project during its operation to affect terrestrial ecological resources.

Table 4.7-1 identifies the past, present, and reasonably foreseeable projects and facilities considered in the cumulative impacts analysis. Eleven of these are within the geographic area of interest for cumulative impacts on terrestrial ecology. Five of these projects may involve construction activities that potentially could affect terrestrial ecological resources relevant to those affected by the CR SMR Project. These include the following projects: transfer of property on the ETTP to private companies, which could subsequently construct facilities on the ETTP; the Roane Regional Business and Technology Park, where sites could be developed; and three roadway improvement projects by the TDOT on Tennessee State Highway (TN) 95 and TN 73. These five projects could involve localized land clearing and earth moving activities, but these activities would not noticeably contribute to cumulative effects on terrestrial habitats or wetlands also affected by the operation of the proposed CR SMR Project at the CRN Site. The other six projects in the geographic area of interest involve operations at existing facilities and would not measurably contribute to cumulative impacts in conjunction with effects from the operation of the CR SMR Project. The Sludge Buildout Project and the CVMR Corporation relocation would occur in already developed areas; the ORNL and its associated Spallation Neutron Source and High Flux Isotope Reactor have been in operation for many years and would not contribute cumulatively to operational impacts from the CR SMR Project; and the ongoing operation of the Melton Hill Hydroelectric Facility would not have terrestrial impacts. Thus, none of these facilities within the geographic area of interest are likely to have effects on terrestrial ecological resources that would be relevant to the effects from operation of the CR SMR Project.

The terrestrial ecosystems at the CRN Site that could be affected by operation of the SMR system for discharging heat to the atmosphere are described in Subsection 2.4.1. Heat dissipation systems at nuclear power facilities potentially can impact terrestrial ecological communities through effects such as those evaluated and discussed in Subsection 5.3.3.1 (salt deposition; increased precipitation, humidity, fogging, and icing; and plume shading), as well as noise and bird collisions with cooling towers. In Subsection 5.3.3.2, the impacts on terrestrial ecological resources from effects potentially associated with the operation of the CR SMR Project were determined to be very localized and minor. Thus, the incremental contribution of the CR SMR Project to related, cumulative effects from other facilities or activities in the geographic area of interest would be SMALL.

Other electric generating facilities in the region have associated transmission lines that are part of the regional transmission system to which the CR SMR Project would connect. The operation and maintenance of these lines would have similar effects on terrestrial ecological resources in and adjacent to the transmission line ROWs. As discussed in Subsection 5.6.1, TVA has approved methods in place to protect terrestrial habitats from potential adverse effects associated with ongoing transmission line ROW maintenance activities in conjunction with operation of the CR SMR Project. Potential thermal and Electromagnetic Fields (EMF) effects of the proposed underground transmission line on terrestrial habitats are predicted to be negligible. It is expected that the transmission lines associated with the other facilities in the geographic area of interest would continue to be operated and maintained similarly. As discussed in Subsection 4.7.4.1, extensive areas of relatively unfragmented and undisturbed forest habitat exist in the geographic area of interest and the region. The cumulative impacts on terrestrial ecosystems from the operation and maintenance of transmission lines within the relatively small areas of the ROWs in the geographic area of interest would be minimal, and the incremental contribution from the lines associated with the CR SMR Project would be SMALL.

Subsections 4.7.1.2 and 4.7.4 discusses the potential effects of global climate change on terrestrial ecosystems in the southeastern United States, including Tennessee and the region that surrounds the CRN Site. Operation of the CR SMR Project is expected to provide beneficial effects with regard to global climate change by providing needed electricity without the release of carbon dioxide. The magnitude of incremental contributions to adverse cumulative impacts on climate change in the geographic area of interest during the period in which the facility is in operation would be SMALL.

In summary, as discussed in Subsection 4.7.4.1, cumulative impacts on terrestrial ecological resources from past and present activities in the geographic area of interest have occurred, and have been MODERATE. This assessment considered impacts on terrestrial communities from factors such as the operation of the SMR system for discharging heat to the atmosphere, transmission line operation, and global climate change. Based on this analysis, the cumulative impacts on terrestrial ecological resources in the geographic area of interest from past, present, and reasonably foreseeable future actions, including operation of the proposed CR SMR Project on the CRN Site, would also be MODERATE. However, the incremental contribution from operation of the CR SMR Project to these cumulative impacts on terrestrial ecology within the geographic area of interest would be SMALL.

5.11.4.2 Aquatic Ecology Impacts

Subsection 2.4.2 describes the aquatic ecology resources potentially affected by the proposed SMR Project at the CRN Site and provides the baseline for analysis of cumulative impacts to aquatic ecology. Subsection 4.3.2 describes impacts to aquatic ecosystems during preconstruction and construction activities at the CRN Site, on the offsite Barge/Traffic Area, and within the offsite, 500-kV transmission line ROW in which an underground 69-kV transmission line is to be installed.

The geographic area of interest for this analysis of cumulative impacts on aquatic ecological resources is defined as the CRN Site, Barge/Traffic Area, and underground 69-kV transmission line area; and the Clinch River arm of the Watts Bar Reservoir in the vicinity of the CRN Site. This geographic area of interest encompasses drainages associated with the CRN Site and associated offsite areas where ecological effects from the operation of the CR SMR Project would occur. It also includes the limited area within the Clinch River arm of the Watts Bar Reservoir that may be affected by operation of the CR SMR Project as well as other facilities or activities capable of having effects that could interact with the facility to cumulatively impact aquatic ecological resources. This portion of the Clinch River arm of the Watts Bar Reservoir in the vicinity of the site generally includes the area of the reservoir downstream to the confluence with the Emory River arm of the Watts Bar Reservoir and upstream to Melton Hill Dam (approximately Clinch River Mile 5 to 23). The potential for the CR SMR Project to contribute to such impacts is expected to be highest in close proximity to the CRN Site and to decrease substantially with distance away from the CRN Site.

Past uses of the CRN Site and the Clinch River arm of the Watts Bar Reservoir in its vicinity have had cumulative effects on the aquatic ecology of the geographic area of interest. As discussed in Subsection 4.7.1.2, past dam and reservoir projects to regulate the Tennessee River system have substantially altered the natural flow regime of the Tennessee River and its tributaries, including the Clinch River. The Tennessee River system is described in Subsection 4.7.3.2.1. Because the dams and their associated water users have been affecting surface water flow rates since before 1979, the baseline surface water flow conditions described in Subsection 2.3.1.1.2.1 and the ecological community described in Subsection 2.4.2.1.1 represent the cumulative effects from the ongoing operation of the dams in the system on surface water flow in the Clinch River arm of the Watts Bar Reservoir. In addition, because the Reservoir Operations Study included long-range planning for operation of the system to the year 2030, the analysis also represents reasonably foreseeable flow conditions that may contribute to cumulative impacts on aquatic ecology during future operation of the CR SMR Project.

As discussed in Subsection 4.7.4.2, the cumulative effects of the system of dams and reservoirs on surface water flow in the Tennessee River system has had a LARGE impact on the aquatic community that historically existed in formerly free-flowing riverine ecosystems. These impacts, including reductions in nongame fish species and reduced mussel diversity and abundance, are reflected in present conditions in the Clinch River arm of the Watts Bar Reservoir and are expected to continue in the foreseeable future. The evaluation of surface water use in Subsection 5.11.3.2.1 indicates that the maximum consumptive use of water due to operation of the CR SMR Project is expected to be inconsequential compared to the combined average releases from Melton Hill Dam and Fort Loudoun Dam, and the hydrologic impacts of SMR operations on the overall flow and availability of surface water in the Clinch River arm of the Watts Bar Reservoir would be minimal. In addition, the volume of water that would be discharged from the facility during operation would be small relative to the overall flow in the reservoir. Accordingly, the incremental contribution from the operation of the CR SMR Project to cumulative impacts on surface water flow and aquatic habitats in the geographic area of interest would be SMALL.

Surface water and substrate characteristics (such as flow, water depth and temperature, levels of oxygen and contaminants, and sediment composition) are preponderant factors affecting aquatic habitats and the aquatic organisms they support. The impact of facility operation on surface water quality and sediment composition would be SMALL because the characteristics and constituents of the discharge from operation of the CR SMR Project would be maintained within the water quality criteria specified in the NPDES permit. These criteria have been established to prevent constituents in surface water from exceeding concentrations that would adversely affect aquatic life. Limitations on constituent concentrations entering surface water would concomitantly limit the potential for concentrations in sediment to increase from the settling of suspended particles with adsorbed constituents.

As discussed in Subsection 5.3.2.2, the thermal plume from the discharge would be localized within the area of the discharge and would not extend far enough downstream to have cumulative effects in conjunction with discharges from other facilities. As discussed in Subsection 5.3.2.1, the results of hydrothermal modeling of the discharge indicate that, for steady flow in the reservoir at or above 400 cfs, the thermal effluent from the CR SMR Project could be assimilated within regulatory limits at a minimum distance of 50 feet (ft) from the diffuser. There are no other facilities or projects within the geographic area of interest that would impact this limited area of the reservoir in which surface water temperatures would be elevated. Modeling performed at a regional scale to evaluate the discharge in the context of the full extent of Watts Bar Reservoir showed that the discharge would have a negligible (SMALL) impact on temperature (outside of the local area of the mixing zone), algae, and dissolved oxygen in the reservoir. Effects on these parameters from the discharge were predicted not to be detectable. Thus, the incremental contribution from the operation of the CR SMR Project to cumulative impacts on surface water and sediment quality, water temperature, and aquatic habitats in the geographic area of interest would be SMALL.

The results of the analysis in Subsection 5.3.1.2 of effects from the operation of the cooling water intake system on the aquatic community of the Clinch River arm of the Watts Bar Reservoir are consistent with the conclusion by the U.S. Nuclear Regulatory Commission (NRC) that the effects of entrainment on aquatic organisms at nuclear facilities with a closed-cycle, cooling-tower-based heat dissipation system are minor. Based on the use of closed-cycle cooling, the small proportion of water that would be withdrawn, the expected design and location of the intake, and the composition of the aquatic community, the impacts from entrainment, impingement, or other effects on fish and other organisms due to the operation of the cooling water intake system for the CR SMR Project would be minimal. No other water intakes with the potential to cause entrainment or impingement of aquatic organisms are present in or planned for the geographic area of interest. Therefore, the incremental contribution from the operation of the CR SMR Project to cumulative impacts on aquatic organism populations due to mortality from operation of water intakes in the geographic area of interest would be SMALL.

As discussed in Subsection 5.6.2, TVA routinely implements measures to minimize potential adverse effects on aquatic habitats from ongoing transmission line ROW maintenance activities. Potential thermal and EMF effects of the proposed underground transmission line on aquatic habitats are expected to be very localized and minor. Therefore, the incremental contribution to cumulative impacts on aquatic ecosystems from the operation and maintenance of transmission lines would be SMALL.

As discussed for terrestrial ecology in Subsection 4.7.1.2, global climate change may affect temperatures and the timing and magnitude of precipitation; in turn, these changes may have cumulative impacts on aquatic ecological resources. Climate change in the southeastern United States generally is expected to cause relatively small changes in precipitation compared to natural variation. However, predictions of the magnitude and extent of the changes vary. Global climate models have not been used to make predictions at the scale of the State of Tennessee, but regional studies indicate temperatures and rainfall may increase in the southeastern United States. Climate models forecast three trends that may affect aquatic habitats: warmer mean annual temperatures, greater frequency of intense rainfall events, and drier summers with more severe droughts. Such changes may affect water levels and flows in Tennessee reservoirs through increased evaporation. Increases in temperatures and the intensity of storms may affect reservoir water levels and flows. This higher climate variability may result in less predictable management of reservoir hydrology, with resulting effects on fish habitat, abundance, community composition, and population dynamics. (Reference 5.11-5) The effects from operation of the CR SMR Project on surface water flow and aquatic habitats and organisms in the geographic area of interest would be SMALL, and the incremental contribution to adverse aquatic impacts from operation of the CR SMR Project in conjunction with global climate change also would be SMALL. Furthermore, operation of the CR SMR Project is expected to provide beneficial effects with regard to global climate change by providing needed electricity without the release of carbon dioxide.

In summary, as discussed in Subsection 4.7.4.2, cumulative impacts on ecological resources from past and present activities in the geographic area of interest have occurred, and are SMALL to LARGE. This assessment considered impacts on aquatic communities from factors such as the direct effects of operation of the CR SMR Project on aquatic organisms and habitats, consumptive water use, regulation of water levels and flows by dams, operation of other commercial and industrial facilities in the geographic area of interest, and other natural and anthropogenic stressors, including climate change. This assessment indicates that cumulative impacts from past, present, and reasonably foreseeable future actions on aquatic resources in the geographic area of interest would also range from SMALL to LARGE. However, the incremental contribution from operation of the CR SMR Project to impacts on aquatic resources of the water bodies in the geographic area of interest would be SMALL.

5.11.5 Cumulative Socioeconomics and Environmental Justice Impacts

The following subsections describe the evaluation of cumulative impacts on socioeconomics and environmental justice that may result from operation of the proposed CR SMR Project at the CRN Site.

5.11.5.1 Socioeconomic Impacts

Socioeconomic resources addressed in this subsection include physical impacts (air quality, noise, thermal emissions, and visual intrusions) and social and economic impacts.

5.11.5.1.1 Physical Impacts

Sections 2.7 and 2.8 and Subsection 2.5.2.5.1 address air quality, noise, and visual resources, respectively, in the vicinity of the CRN Site and serve as the baseline for analysis of cumulative impacts to these resource areas. Subsection 5.8.1 describes the potential impacts from operation of the CR SMR Project on air quality and noise levels. The following discussions in this subsection address the cumulative impacts of emissions to the atmosphere, noise and visual resources. These discussions consider the incremental impact of the proposed project along with impacts from past, present, and reasonably foreseeable actions that may contribute the project’s geographic area of interest.

Air Quality

Subsection 2.7.2 describes current air quality conditions for Roane County in which the CR SMR Project would be located. Air quality emissions and potential impacts during operations of the CR SMR Project are addressed in Subsection 5.8.1.2.

As discussed in Subsection 2.7.2, the CRN Site location in Roane County is in attainment for all criteria pollutants, indicating pollutant levels are below air quality standards. As identified in 40 CFR 81.57, Roane County is located in the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region. Based on preliminary design information of the CR SMR Project and attainment status of Roane and surrounding counties, the CR SMR Project’s air related geographic area of interest during operations, for criteria pollutants, is expected to fall within Roane County and the surrounding counties of Loudon, Knox, Anderson, and Morgan. Once an SMR design is selected, air quality modeling under the Tennessee air permitting process would detail the project’s air quality geographic area of interest in the context of other nearby sources. Because the project’s supporting equipment, which emits criteria pollutants, would be operated infrequently and for limited periods of time, it is expected the project’s modeling impact area would be within 10 mi. The area out to 10 mi would include Roane County and portions of Loudon, Knox, Anderson and Morgan counties, Tennessee. Also, even though the project area is in attainment of all criteria pollutants, the surrounding nonattainment areas may need to be considered during air permitting. As noted in Subsection 2.7.2, the surrounding counties of Loudon, Knox, Anderson and Blount, along with Census Block Group 47-145-0307-2 in Roane County, are nonattainment for particulate matter with a diameter of 2.5 micrometers or less

($PM_{2.5}$). Once the project design is selected and vendor data are provided to support more detailed air quality analysis, the geographic area of interest would be refined as necessary, at the combined license application (COLA) stage.

Subsection 4.7.5.1.1 addresses air quality related cumulative impacts associated with the preconstruction and construction phases of the CR SMR Project. Air related impacts from emissions of criteria pollutants and greenhouse gases were considered for construction workforce motor vehicles, deliveries to the site, earth moving, and construction equipment. Emissions from these sources, however, would be temporary and mitigated under a construction related mitigation plan.

Subsection 5.8.1.2 provides preliminary estimates of the project's operational air emissions. Generation of electricity associated with the operation of two or more SMRs would not be a source of criteria pollutants or air toxics emissions. Supporting equipment such as cooling towers, emergency diesel generators, auxiliary boilers, standby power gas turbines, and other combustion sources emit criteria pollutants and air toxics. Emission estimates from fossil fuel fired combustion sources indicate the project's emissions would not exceed the "major source" threshold of 250 tons per year for any pollutant. Further, supporting equipment would be used intermittently, thus limiting emissions from these sources.

Motor vehicle emissions would be emitted during the workforce commute, ongoing site maintenance and improvements work, and also from deliveries to the CRN Site. Air impacts from motor vehicle activity during facility operations, as noted in Subsection 5.8.1.2, are expected to be minimal because: (1) mitigation measures would be implemented to reduce vehicular emissions as necessary (measures could include staggered shift times, requiring delivery vehicles to shut down engines during off-loading, restricting idling times of onsite vehicles, use of electric and hybrid vehicles, and supporting and promoting van/carpooling and other commuter programs), (2) with recommended transportation improvements, level of service at the local intersections would be adequate to mitigate vehicle queuing and improve flow through these intersections, (3) emissions from the workforce are not continuous throughout the day and are primarily limited to the hours during which shift changes occur, and (4) the project is currently located in attainment areas for carbon monoxide (CO), particulate matter (PM), nitrogen oxide (NO_x), and ozone (O_3), which are the primary criteria pollutants of concern for motor vehicles.

Table 4.7-1 includes proposed projects and ongoing construction projects that could potentially impact air quality in the CR SMR Project's geographic area of interest. For a cumulative impact assessment, existing major sources must also be identified. Table 5.11-2 provides a list of major sources under the Title V Operating Permit program (40 CFR 70) for Roane, Anderson, Knox, Loudon, and Morgan counties.

Through the state and federal air permitting process, proposed power projects must obtain a permit to construct. In addition, under this process, proposed projects must demonstrate that air quality impacts would not violate state and federal ambient air quality standards. Once a vendor for the project is selected and the technology is defined, the TDEC would be contacted to address air quality permitting and cumulative air quality modeling with other sources, as necessary. The air permitting process, under the authority of the U.S. Environmental Protection Agency (EPA) and TDEC, and the state's air monitoring program are designed to protect against a project causing air quality violations. State and federal air permitting also ensures cumulative impacts from existing and proposed new sources would comply with the Clean Air Act and state air pollution regulations. The details of discussions with the TDEC and required cumulative air quality modeling would be provided at COLA.

Since supporting equipment combusting fossil fuels would have limited use and because of the regulatory oversight and control required under state and federal air regulations, the project's air quality impacts are expected to be SMALL for criteria pollutants.

Because climate change is global in nature and currently focuses on the policies established by national governing agencies, the project's geographic area of interest for greenhouse gases (GHG) needs to be considered in the context of United States policy and national GHG emissions. Further, individual states are developing GHG regulations, thus consideration of GHG emissions under state regulations would in all likelihood also be necessary. Therefore, for GHG emissions, the project's operations geographic area of interest is national (United States) in scale.

In 1992, the United States signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC). Under the UNFCCC agreement, the EPA tracks and periodically publishes GHG emissions. In EPA's recent April 15, 2015 report entitled *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013* (EPA-430-R-15-004), the EPA estimates the United States annual GHG emissions for 2013 were 6673 million metric tons (MMT). (Reference 5.11-6) For the State of Tennessee, the EPA provides a 2012 estimate of 99.91 MMT of carbon dioxide (CO_2) for fossil fuel combustion (Reference 5.11-7). As stated in Subsection 4.7.5.1.1, the State of Tennessee GHG emissions are estimated as 122 MMT of GHGs using a GHG to CO_2 scaling factor of 1.22. (This scaling factor is based on EPA's April 15, 2015 report and national data provided for the year 2012 for the various GHGs.)

Similar to criteria pollutants, project specific GHG emission projections would not be available until a vendor is selected for the project. As noted in Subsection 5.8.1.2, the Nuclear Energy Institute (NEI) provides life cycle (from construction to decommissioning) GHG emission factors for different energy technologies. For nuclear power plants, NEI provides a GHG emission factor of 13 tons per gigawatt-hour. (Reference 5.11-8) A second report provided by the World Nuclear Association provides similar values to NEI, along with an upper value of 30 grams CO2 per kilowatt-hour (33 tons per gigawatt-hour) for a life cycle assuming the processing of low grade uranium ores (Reference 5.11-9). Using this upper value as a worst case CO_2 emission factor, a maximum rating for the CR SMR Project at 800 megawatts (MW), and assuming that the majority of CO_2 emissions over the life time of the facility are associated with operations and the processing of fuel, an annual average CO_2 emissions rate of 210,240 MT per year was determined. Using the same GHG to CO_2 ratio of 1.22, from above, worst case annual GHG emissions during facility operations would be 256,500 MT per year or 0.2565 MMT per year.

Estimated worst case annual GHG emissions from the CR SMR Project (0.2565 MMT per year) are only a small fraction of national (6673 MMT for 2013) and State of Tennessee (122 MMT for 2012) GHG emissions. Because GHG emissions and associated impacts require a global perspective, small incremental changes from individual projects must be evaluated collectively. This is beyond the scope of an individual project and is, therefore, addressed by the United States under the authority of the EPA at the national scale. Mitigation measures, however, provide individual projects with the ability to minimize GHG emissions. Generally, measures to alleviate emissions of criteria pollutants from fossil fuel-fired equipment, would likewise reduce GHG emissions. Although, cumulative GHG impacts are expected to be MODERATE in the geographic area of interest, the incremental addition of the CR SMR Project's emissions are estimated to be SMALL.

Noise

Ambient noise levels at sensitive receptors site within 5 mi of the CRN Site are described in Section 2.8. This discussion provides a baseline for analysis of cumulative impacts on sensitive receptors. As discussed in Subsection 5.8.1.1, the main source of continuous noise at the CRN Site is associated with the mechanical draft cooling towers. The geographic area of interest for noise includes the CRN Site and the areas within 5 mi of the CRN Site. Based on the projected noise levels at the nearest residence, noise impacts from operations at the CRN Site are expected to be SMALL for the surrounding communities and the nearest residents. The transmission lines that serve the CR SMR Project are already operating and it is expected that the noise levels they produce would continue to be acceptable, and the planned underground transmission line would not generate audible noise during operations. Accordingly, the effect of transmission lines on noise would be SMALL. As discussed in Subsection 4.7.5.1.1, 12 of the proposed projects, ongoing construction projects, and operational facilities in the region around Oak Ridge, Tennessee are located within 5 mi of the CRN Site. The closest noise-generating projects or facilities are approximately 3 mi from the CRN Site. Due to the distance, the potential for cumulative impact on noise levels associated with these projects and facilities in conjunction with noise levels generated by operations at the CRN Site would be SMALL.

Thermal Emissions

As discussed in Subsection 5.8.1.3, thermal plumes are released from the CR SMR Project's cooling towers to both the ambient air and back to the Clinch River arm of the Watts Bar Reservoir. The analysis in that subsection determined that there would be no fogging or icing at any distance from the cooling towers and the effects of salt deposition would be limited to the area within 600 meters (m) of the cooling towers. The effects of cooling tower operation on local residents and the public in the surrounding area from precipitation, humidity, fogging or icing, and salt deposition would be SMALL. The geographic area of interest for cumulative impact analysis of thermal discharges to air includes the CRN Site and the areas within 1 mi of the

CRN Site. The past, present, or reasonably foreseeable projects or actions identified within 1 mi of the CRN Site include the industrial facilities within Roane Regional Business and Technology Park. This industrial park is geared toward light to medium industry and could potentially contribute thermal plumes from industrial operations, rather than cooling water use, which would be on a smaller scale than plumes from the CR SMR Project. The incremental contribution of cooling tower thermal emissions, which are localized to within 600 m of the towers, in combination with other nearby sources of thermal plumes to the atmosphere would be SMALL. Therefore, cumulative impacts related to thermal emissions from cooling tower operations to ambient air would be SMALL.

Because the thermal discharge to surface water from the CR SMR Project's cooling towers is managed in accordance with requirements of the TDEC NPDES permit, and the modeling indicates compliance with the thermal water quality criteria, physical effects of the thermal discharge on surface water as discussed in Subsection 5.8.1.3 are considered to be negligible. Accordingly, impacts to the public and recreational users of the Clinch River arm of the Watts Bar Reservoir would be SMALL. As described in Subsection 4.7.3.2.1, for purposes of this cumulative impact analysis, the geographic area of interest for surface water impacts is the Clinch River arm of the Watts Bar Reservoir. Although projects within the drainage basin of the Tennessee River both upstream and downstream of the CRN Site can affect the surface water temperatures throughout the entire basin, the potential for the CR SMR Project to contribute to such impacts on thermal water quality is expected to be highest in close proximity to the CRN Site, and to decrease substantially with distance from the CRN Site. As described in Subsection 5.11.3.2.1, cumulative impacts related to thermal water quality from operation of the CR SMR Project cooling tower discharge would be SMALL. Thus, the incremental contribution of the CR SMR Project to related, cumulative effects from other facilities or activities in the geographic area of interest would be SMALL.

Visual Intrusions

Subsection 2.5.2.5 describes the visual resources potentially affected by the proposed SMR Project at the CRN Site and provides the baseline for analysis of cumulative impacts to visual resources. For the purposes of this cumulative analysis, the geographic area of interest for visual resources includes the 2-mi radius surrounding the CR SMR Project. Subsection 5.8.1.4 evaluates the visual impacts of the CR SMR Project, through use of photographs of existing conditions at locations from which would be visible, and renderings of the tallest facility structures visible as well as the cooling tower plumes at those locations. The visual intrusion due to operation of the CR SMR Project would range from SMALL to MODERATE, due primarily to the visual effect of the plume. Within the 2-mi geographic area of interest, the past, present, and reasonably foreseeable projects and facilities considered in the cumulative impact analysis include industrial parks located approximately 2 mi north of the CRN Site (ETTP) and 0.5 mi south of the CRN Site (Roane Regional Business and Technology Park). These two facilities could potentially be visible from locations that have a view of the CR SMR Project. Accordingly, there would be the potential for SMALL to MODERATE cumulative impacts on visual resources associated with industrial development.

5.11.5.1.2 Social and Economic Impacts

Subsections 2.5.1 and 2.5.2 describe the social and economic characteristics potentially affected by the proposed CR SMR Project, including population, economy, transportation, taxes, land use, recreation, housing, community infrastructure and public services, and education. These discussions provide the baseline for analysis of cumulative impacts to these resource areas. As discussed in Subsection 4.7.5.1.2, cumulative impacts from preconstruction and construction activities at the CRN Site and from other past, present, and reasonably foreseeable future projects within the socioeconomic geographic area of interest could temporarily contribute to MODERATE cumulative effects on transportation. The cumulative economic impact on the geographic area of interest of construction of the CR SMR Project and other ongoing construction projects and reasonable foreseeable projects on employment, income, and taxes would be beneficial and MODERATE.

Subsection 5.8.2 evaluates the social and economic impacts of operations at the CRN Site. This evaluation concluded that impacts associated with operations at the CRN Site would be SMALL, and impacts to three resources would be SMALL and beneficial. Employment of the operations workforce and routine capital expenditures needed to support CR SMR Project operations over the period of operation would have a beneficial impact on the economy of the four-county geographic area of interest. Based on road improvements designed to accommodate the much larger construction workforce, the improved level of service resulting from those improvements would have a SMALL beneficial impact on intersections and local roads. Sales and property taxes as well as TVA tax-equivalent payments would have a SMALL and beneficial economic impact within the geographic area of interest.

This cumulative analysis considers impacts from operations along with impacts from past, present, and reasonably foreseeable future actions that may contribute to cumulative impacts to communities within the geographic area of interest, the area most likely to be affected by the proposed CR SMR Project. The geographic area of interest for socioeconomic impacts includes Roane, Anderson, Knox, and Loudon counties. The socioeconomic impacts associated with the operational facilities (past and present projects) listed in Table 4.7-1 have already been addressed in the baseline conditions presented in Subsections 2.5.1 and 2.5.2 and in the impact analysis presented in Subsection 5.8.2. This cumulative impacts evaluation focuses on reasonably foreseeable projects.

Cumulative impacts from operations at the CRN Site and from other reasonably foreseeable future projects within the socioeconomic geographic area of interest are not expected to contribute to cumulative effects on socioeconomic resources. There are 250 operations workers and 1000 temporary refueling outage workers who are assumed to relocate to the geographic area of interest for the proposed CR SMR Project. As discussed in Subsection 2.5.2, a total of 301,164 people were employed in the geographic area of interest in 2011; the total labor force was 325,167 people. From 2001 to 2011, the number of employed people in the geographic area of interest increased an average of 1.0 percent annually. The additional number of employees associated with the other reasonably foreseeable future projects, including development within the Roane Regional Business and Technology Park and the ETTP, various projects within ORR, and relocation of CVMR Corporation, would represent a minor portion of the existing labor force in the geographic area of interest. Operations traffic associated with the CR SMR Project and other reasonably foreseeable future projects could slightly increase the commute time along local roadways, including Bear Creek Road, TN 58, and TN 95. However, the roadway improvements recommended to accommodate the peak construction year traffic for the CR SMR Project would also accommodate the operations staff traffic and traffic associated with the other reasonably foreseeable future projects located near the CRN Site. Accordingly, cumulative impacts on population, land use, recreation, housing, transportation, community infrastructure and public services, and education would be SMALL.

Increased employment, as well as new indirect service jobs created by the spending of the additional workers' income, would produce a positive effect on employment and income in the geographic area of interest. The other reasonably foreseeable future projects would similarly generate increased employment and income. Therefore, the cumulative economic impacts on the geographic area of interest from operation of the CR SMR Project and other reasonably foreseeable projects on employment, income, and taxes would be beneficial and MODERATE. Although the amount of income, sales, and property taxes (as well as TVA tax-equivalent payments) generated by the projects would be large in absolute terms, it would be SMALL when compared to the total amount of taxes collected within the geographic area of interest.

The effect of climate change on the economy would be evident in changes to water quality and availability. As discussed in Subsection 3.6.3.2, NPDES-managed nonradiological wastewater and stormwater discharges to the Clinch River Arm of Watts Bar Reservoir would result in SMALL impacts to the water. As discussed in Subsection 4.7.3.2.1, cumulative impacts include releases from industry, agriculture, and urbanization, thus making the impact to water SMALL to MODERATE. Coupled with anticipated climate change phenomena of increased severe storms and less regular precipitation leading to increased water pollution and reduced water availability, impacts upon the water could become more pronounced (Reference 5.11-2). Impacts to the economy become apparent as global changes in climate result in decreasing availability of food and water; thus negatively impacting water quality and availability through increased competition for more limited resources (Reference 5.11-2). Although cumulative impacts to the economy from projected climate change, with increased competition for limited resources, are expected to be MODERATE in the geographic area of interest, the incremental impact to water from nonradiological wastewater generated during operational activities at the CRN Site is estimated to be SMALL.

5.11.5.2 Environmental Justice Impacts

Executive Order 12898 (59 FR 7629) directs federal executive agencies to consider environmental justice under the NEPA. This Executive Order ensures that minority and/or low-income populations do not bear a disproportionate share of adverse health or environmental consequences of a proposed project.

Subsection 2.5.4 provides baseline information on minority and low-income populations within the region (i.e., within a 50-mi radius of the CRN Site) for the cumulative impacts assessment of environmental justice. As shown in Figure 2.5.4-1, the spatial distribution of block groups with minority populations in the region is clustered in the City of Knoxville, in Knox County, Tennessee and the City of Alcoa, in Blount County, Tennessee. No block groups in Roane County (in which the CRN Site is located) or in Anderson County contain minority populations as defined in Subsection 2.5.4.2. The identified aggregate minority population closest to the CRN Site is located approximately 20 mi to the east in Blount County, Tennessee. The closest Hispanic minority population is located in Loudon County, Tennessee, approximately 9 mi southeast of the CRN Site. As shown in Figure 2.5.4-2, the majority of the low-income population in the geographic area of interest is in the City of Knoxville, in Knox County, Tennessee. There is one low-income population block group within Roane County, Tennessee and one within Anderson County, Tennessee. The closest low-income population block group is located in Loudon County, Tennessee, approximately 7 mi southeast of the CRN Site. No other populations or groups (e.g., subsistence populations) were identified that represent environmental justice populations in the region.

Subsections 4.7.5.2 and 5.8.3 evaluate the potential environmental justice impacts from preconstruction and construction activities and from operations at the CRN Site, respectively. Because of the spatial distribution of the minority and low income populations across the region, the potential for disproportional impacts to low-income and minority populations from operations activities is SMALL. No uniquely vulnerable low-income or minority community, such as a subsistence population, was identified in the region. In summary, the overall SMALL impact of the CR SMR Project, combined with the spatial distribution of the low-income and minority population, results in a SMALL potential for adverse socioeconomic impacts that would disproportionately affect low-income and minority communities.

The cumulative analysis considers impacts from operations of the CR SMR Project along with past, present, and reasonably foreseeable actions that could cause disproportionately high and adverse impacts on minority and low-income populations. The geographic area of interest for environmental justice impacts is the area within 50 mi of the CRN Site. The environmental justice analysis presented in Subsection 5.8.3 provides a baseline comparison for consideration of cumulative environmental justice impacts associated with the projects and activities listed in Table 4.7-1. The spatial distribution of block groups with minority and low-income populations in the geographic area of interest is clustered in the City of Knoxville, in Knox County, Tennessee. The reasonably forseeable projects identified in Table 4.7-1 are in locations other than Knoxville, and would be expected to have a SMALL impact on minority or low-income populations. The incremental additional impacts from future projects in combination with operations activities at the CRN Site would be SMALL.

In summary, there would be no disproportionately high or adverse cumulative impacts to minority or low-income populations within the 50-mi geographic area of interest. Therefore, there would be no cumulative environmental justice effects and the impacts would be SMALL.

5.11.6 Cumulative Historic Properties Impacts

Subsection 4.7.5.3 summarizes the geographic and temporal scope of the cumulative analysis. The geographic area of interest for analysis of cumulative impacts to historic properties includes:

- The archaeological resources and historic properties within the CR SMR Project Area of Potential Effect (APE) defined in Subsection 2.5.3 as the approximately 1200-ac Clinch River Property, an additional approximately 105 ac northwest of the property near the CRN Site entrance and along Bear Creek Road and Tennessee State Highway (TN) 58, the Melton Hill Dam, and a 0.5 mi radius around the Melton Hill Dam.
- The Historic Architecture APE is 0.50-mi radius surrounding the proposed cleared areas.
- The historic properties (those eligible for listing on the NRHP) within a 10-mi radius of the center of the CRN Site (Figure 2.5.3-2).

This section examines the cumulative impacts associated with the past, present, and reasonably foreseeable future projects, including global climate change, on historic and cultural resources; and the incremental contribution of preconstruction and construction activities to those cumulative impacts. This subsection addresses the incremental contribution of SMR operation to those cumulative impacts.

Subsection 5.1.3 describes impacts to historic and cultural resources during operation of the SMRs. As discussed in that section, impacts of the operation of the SMRs on historic and cultural resources at the CRN Site and in the vicinity would be SMALL to MODERATE. Modifications to the Melton Hill Dam could be required to accommodate anticipated modification of the flow of the Clinch River as described in Subsection 3.4.2.5. The Melton Hill Dam, and associated structures, is eligible for the NRHP. Implementation of the mitigation measures as stipulated in the PA would minimize the potential for LARGE impacts to historic structures. Because the nature of the modifications required is unknown at this time, impacts to historic structures as a result of implementation of SMR operation would be SMALL to MODERATE.

As discussed in Subsection 4.7.3.1, global climate change is unlikely to have a substantial impact on historic and cultural resources, but past and present projects listed in Table 4.7-1 have cumulatively impacted historic and cultural resources throughout the region. Cultural resources are nonrenewable and therefore impacts are cumulative in nature. Some of these projects have resulted in the destruction, removal, and/or disturbance of historic and cultural resources within the geographic area of interest. Therefore, the cumulative impact of these projects has been MODERATE. However, given that the direct and indirect impacts of project operation on historic properties would be SMALL, their incremental cumulative contribution of SMR operations would also be SMALL.

Cumulative impacts from the CR SMR Project construction and operations must be considered in relation to other reasonably foreseeable future projects, including development within Roane

Regional Business and Technology Park and the ETTP, various projects within ORR, and relocation of CVMR Corporation. Most of these projects are located within areas previously developed and therefore have a limited potential to impact historic properties within the geographic area of interest. Several of these projects are also located on federal land and would therefore be subject to Section 106 reviews to examine the potential for impacts to historic properties. Therefore, cumulative impacts to historic properties in association with the CR SMR Project and these potential future projects would be SMALL.

5.11.7 Cumulative Impacts of Postulated Accidents

As described in Chapter 7, the potential environmental impacts (i.e., risks) of a postulated accident from the operation of CRN Site would be SMALL. Chapter 7 considers both design basis accidents (DBAs) and severe accidents. A detailed accident analysis is to be performed at COLA when the technology is chosen and the facility configuration is known.

Offsite doses are conservatively estimated using the highest post-accident dose from vendor analysis. As shown in Section 7.1, offsite doses due to postulated loss of coolant accidents (LOCA) are expected to have a greater magnitude than more common DBAs. A LOCA is therefore modeled as the bounding DBA for offsite atmospheric release for comparison against the 25 rem total effective dose equivalent limit specified in 10 CFR 52.17. As a result, the site is in compliance and the impact is SMALL.

Environmental impacts from severe accidents with damage to the reactor core and degradation of the containment system are evaluated in Section 7.2 using an SMR design that represents the largest SMR considered for the CRN Site. Reasonable, representative estimates are determined for the CRN Site using MACCS2 code with surrogate SMR specifications along with site-specific meteorology, population, land usage, watershed index, and economic data. Economic costs, including relocation, decontamination, and interdiction, were determined along with human health impacts for a severe accident for the population within a 50-mi radius of the CRN Site. The MACCS2 modeling provided dose from the air pathway and from water ingestion; other pathways were evaluated qualitatively. As discussed in Subsection 7.2.3, dose from the groundwater pathway is considered small or non-existent, dose from surface water recreation is smaller than dose from aquatic food ingestion, which is, in turn, smaller than dose from the air pathway. As discussed in Subsection 7.2.4, because the risk of cancer fatalities as determined using the surrogate’s total calculated dose risk from the air pathway is less than one-tenth of one percent of the overall probability of a cancer-related fatality, the site is in compliance and the health impact of postulated severe accidents is SMALL.

The cumulative analysis considers risk from potential severe accidents at other existing and proposed nuclear power plants that have the potential to increase risks at any location within the geographic area of interest of 50 mi of the proposed CRN Site. The 50-mi radius was selected to cover potential risk overlaps from two or more nuclear plants. Existing operating nuclear power plants that contribute to risk within this geographic area of interest include Watts Bar

Unit 1 and Sequoyah Units 1 and 2. In addition, an operating license for Watts Bar Unit 2 has been issued by the NRC.

The ORR has been a participant in nuclear projects since World War II. ORNL, Y-12 National security Complex, The ETTP, and Transuranic (TRU) waste processing center (TWPC) are part of the reservation. High Flux Isotope Reactor (HFIR), an operating 85-megawatt thermal reactor built for the production of californium and other heavy elements, is located within the boundaries of the adjoining ORNL. The Highly Enriched Uranium Materials Facility at the Y-12 National Security Complex is the nation's central repository for highly enriched uranium. A Uranium Processing Facility is expected to be a part of Y-12 at Oak Ridge. The ETTP used to be Oak Ridge Gaseous Diffusion Plant. Its original mission was to enrich uranium for the commercial nuclear industry from 1945 to 1985, and was permanently shut down in 1987. The U.S. Department of Energy (DOE) established the TWPC as a regional center for the management, treatment, packaging and shipment of DOE TRU waste legacy inventory.

This cumulative analysis considers impacts from postulated accidents for the proposed project at the CRN Site along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts within the geographic area of interest. Tables 7.2-5 and 7.2-6 in Section 7.2 provide comparisons of estimated risk for the proposed representative SMR at the CRN Site and the current nuclear power plants undergoing operating license renewal reviews. As provided in Tables 7.2-5 and 7.2-6, the estimated population dose risk for the representative SMR at the CRN Site is well below values for other reactor sites. In addition, estimates of average individual early fatality and latent cancer fatality risks are well below the NRC's safety goals set by the NRC's Safety Goal Policy Statement (51 FR 30028). For existing nuclear generating stations within the geographic area of interest (i.e., Watts Bar Unit 1 and Sequoyah Units 1 and 2) the NRC has determined that the probability-weighted consequences of severe accidents are SMALL (10 CFR Part 51, Appendix B, Table B-1). In NUREG-0498, *Final Environmental Statement: Related to the Operation of Watts Bar Nuclear Plant, Unit 2 - Final Report*, the NRC concluded that the probability-weighted environmental consequences of severe accidents for Watts Bar Unit 2 are SMALL. The HFIR reactor presents a much smaller severe accident risk than a representative SMR at the CRN Site because it has a much smaller reactor core and power level.

The severe-accident risk due to any particular nuclear power plant gets smaller as the distance from that plant increases. However, the combined risk at any location within 50 mi of the CRN Site would be bounded by the sum of risks for all these operating and proposed nuclear power plants and HFIR. Even though several plants could potentially be included in the combination, this combined risk would still be low. On this basis, the cumulative risks from severe accidents at any location within 50 mi of the CRN Site likely would be SMALL.

5.11.7.1 Cumulative Fuel Cycle, Transportation and Decommissioning Impacts

Cumulative impacts from the fuel cycle, transportation activities, and decommissioning activities for the proposed SMR Project at the CRN Site are discussed in this subsection.

5.11.7.1.1 Fuel Cycle

Impacts from the uranium fuel cycle (UFC) for the proposed facility at the CRN Site include impacts from mining and milling uranium ore along with conversion, enrichment, and fabrication of the uranium into fuel and, finally, disposal of the irradiated (spent) fuel. As discussed in Section 5.7, a 1000 megawatt electric (MWe) light water reactor (LWR) was used as a reference plant to determine UFC impacts from operation of the CRN Site; the proposed facility has effectively the same fuel cycle process and the same type of fuel as the reference plant. As discussed in Subsection 5.7.1.1, the land use required for the SMR Project at the CRN Site produces far more power than a similarly sized coal or natural gas plant, which produces 89 and 68 percent less electricity. Similarly, as discussed in Subsection 5.7.1, water usage, effluents, waste, and transport during CRN operations along with occupational dose are relatively small and within limits. As a result, impacts from the UFC during operation of the proposed facility at the CRN Site are SMALL.

This cumulative analysis considers impacts over the UFC associated with operation of the proposed project at the CRN Site along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts within the geographic area of interest, the geographic area most likely to be affected by the proposed SMR Project. The geographic area of interest for impacts of the UFC is nationwide and, with imported uranium, worldwide.

Historically, the majority of uranium has been imported with the majority of domestic uranium mines and mills closing due to market conditions. More than eighty percent of uranium purchased in 2013 for commercial nuclear reactors in the United States was of foreign origin (Reference 5.11-10). Although the DOE plans to continue release of excess uranium from DOE’s Portsmouth and Paducah Gaseous Diffusion Plants, demand for uranium is expected to remain steady at almost sixty million pounds per year (Reference 5.11-11).

NUREG-2157, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel,* examines the incremental impacts of continued storage on each resource area analyzed in NUREG-2157 in combination with other past, present, and reasonably foreseeable future actions. Section 6.5 of NUREG-2157 indicates ranges of potential cumulative impacts for multiple resource areas. These ranges are primarily driven by impacts from activities other than the continued storage of spent fuel at the reactor site; the impacts from these other activities would occur regardless of whether spent fuel is stored during the continued storage period. In the short-term timeframe, which is the most likely timeframe for the disposal of the fuel, the potential impacts of continued storage for at-reactor storage are SMALL and would, therefore, not be a significant contributor to the cumulative impacts. Because the impacts during the short-term timeframe are SMALL, continued storage would not be a significant contributor to the cumulative impacts. In the longer timeframes for at-reactor storage, or in the less likely case of away-from-reactor storage, some of the impacts from the storage of spent fuel could be greater than SMALL. However, other Federal and non-Federal activities occurring during the longer timeframes, as noted in NUREG-2157, include uncertainties as well, contributing to the cumulative impacts. These uncertainties lead to the ranges in cumulative impacts as discussed throughout Chapter 6 of NUREG-2157. The overall cumulative impact conclusions would not be changed if the impacts of continued storage were removed. Based on the analysis and impact determination in NUREG-2157 the cumulative impacts from radiological wastes from the fuel cycle (which includes the impacts associated with spent fuel storage during operation and continued storage period) would be SMALL.

5.11.7.1.2 Transportation

Section 7.4 describes the environmental impacts of postulated transportation accidents assuming all shipments are by truck. Shipments include irradiated (spent) fuel, unirradiated fuel, and radioactive waste. Probable transportation routes were bounded by shipping unirradiated fuel 2282 mi from Washington, shipping irradiated fuel 2265 mi to Nevada, and shipping radioactive waste 1162 mi to Texas. Specifically, 15 shipments per year of new fuel, 57 shipments per year of spent fuel, and 75 shipments per year of radioactive waste were modeled to determine impacts from transport (shipment numbers normalized to the NRC's "reference reactor"). Radiological impacts were determined modeling similarly packaged fuel, the average annual fuel reload, and an estimate of 5000 cubic feet per year radioactive waste. Non-radiological impacts were determined using round-trip distances to determine possible injuries and fatalities from transport by truck over commercial routes. Additional traffic would result from shipments of construction materials and movements of construction personnel to and from the site. The additional traffic increases the risk of traffic accidents, injuries, and fatalities. As shown in Section 7.4, impacts from postulated accidents associated with the transport of fuel and waste for the proposed project at the CRN Site are SMALL.

This cumulative analysis considers impacts from postulated accidents associated with the transportation of fuel and waste for the proposed project at the CRN Site along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts within the geographic area of interest, the area most likely to be affected by the proposed CR SMR Project. The geographic area of interest for impacts of postulated transportation accidents is nationwide.

Non-radiological cumulative impacts of transportation are related to the increased traffic over commercial routes with the attendant increased risk of traffic, accidents, injuries, and fatalities. Geographically, the CRN Site is near two main transportation corridors, the East-West I-40 and the North-South I-75, which historically channel most of the transport in the region. Although the potential cumulative impact to major traffic routes is SMALL, local roads in the immediate vicinity of the CRN Site would experience an increase in load and frequency. Coupled with the proximity of the ORNL, the ETTP, and the Y-12 campuses, future cumulative impacts to the local roads may be noticeable.

Radiological cumulative impacts associated with transportation of fuel and waste from the CRN Site includes impacts from waste shipments from ORNL shipments, ETTP shipments, and Y-12 shipments along with fuel and waste shipments to and from the Watts Bar and Sequoyah nuclear power plants. Like the shipments associated with the CRN Site described in Section 7.4, the impacts from each individual shipment would be minimal and, when combined with the impacts associated with the CRN Site, the total impact would also be minimal. Therefore the cumulative impacts of transporting unirradiated fuel to, along with irradiated fuel and radioactive waste from CRN would be SMALL.

5.11.7.1.3 Decommissioning

Section 5.9 discusses the general environmental impacts of decommissioning the proposed facility at the CRN Site. Decommissioning the facility includes the employment of workers and the final disposal of radioactive waste. Worker dose is comparable to occupational dose during normal operational refueling and maintenance activities. A small amount of land is required for offsite radioactive waste burial. Although the various decommissioning methods and alternatives have different impacts, including impacts from size and transport variations, no adverse effects are anticipated from decommissioning activities at the CRN Site.

This cumulative analysis considers impacts from decommissioning activities at the CRN Site along with impacts from past, present, and reasonably foreseeable actions that may contribute to cumulative impacts within the geographic area of interest, the geographic area most likely to be affected by the proposed CR SMR Project. The geographic area of interest for decommissioning impacts is the 50-mi radius for socioeconomic impacts from the workers and nationwide for the final disposal of the radioactive waste.

The other nuclear facilities within 50 mi of CRN are the ORNL, Y-12, and ETTP sites as well as the Watts Bar and Sequoyah nuclear power plants. In NUREG-0586, *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*, Supplement 1, the NRC found that the impacts from decommissioning due to radiation dose to workers and the public, waste management, water quality, air quality, ecological resources, and socioeconomics would be SMALL.

Regulations allow reactor decommissioning to take up to 60 yr to complete. However, much of that time can be a relatively inactive period after shutdown that allows high radioactivity materials to decay to safer levels. While several major reactor decommissioning periods in within the geographic area of interest could overlap and have a noticeable impact on some resources, the likelihood of major decommissioning activities from multiple reactor sites in the geographic area of interest occurring at the same time is small. Therefore the cumulative impacts from decommissioning the proposed SMR nuclear plant would also be SMALL.

5.11.8 Radiological Health Impacts

As described in Section 5.4, the radiological impacts from operation of the CR SMR Project would be SMALL. Specifically, Subsection 5.4.3, estimates that the total body dose to a hypothetical maximally exposed individual (MEI) from the operation of all four SMRs at the CRN Site would to be 11 mrem/yr. For this analysis of cumulative radiological impacts, the geographic area of interest was considered to be the area within a 50-mi radius of the CRN Site. The NRC historically has used 50 mi as the radius bounding the geographic area for evaluating doses to the public from routine releases from nuclear power plants. Table 4.7-1 summarizes past, present, and reasonably foreseeable future projects and actions that could contribute to cumulative effects. Among these are several radiological projects or facilities. Within the geographic area of interest, planned federal projects on the ORR, including the Transuranic (TRU) Waste Processing Center, Uranium Processing Facility (UPF) at Y-12 complex, and Environmental Management Waste Management Facility (EMWMF), have the potential to contribute to cumulative radiation exposures in conjunction with the CR SMR Project. In addition, currently operating facilities on the ORR include the High Flux Isotope Reactor (HFIR), a nuclear research reactor located at Oak Ridge National Laboratory (ORNL), and the ORNL Spallation Neutron Source. Off the ORR, TVA's Watts Bar Nuclear (WBN) Units 1 and 2 and American Nuclear Corporation will continue to operate. These four facilities also have the potential to contribute to cumulative radiation exposures in conjunction with the CR SMR Project. Each of these facilities would be constructed and operated or continue to operate in accordance with environmental regulations that limit the radiation exposures received by members of the public, as discussed in Subsection 5.4.3.

Ongoing activities within the ORR likely will continue to release small quantities of radionuclides to the environment in the future. The ORR *Annual Site Environmental Report* provides results from a detailed analysis of radiation doses to the MEI from all pathways of exposure to radionuclides released from all DOE facilities on the ORR. The maximum radiation dose that a hypothetical MEI could have received from DOE activities on the ORR in 2014 was estimated to include approximately 0.6 millirem (mrem) from air pathways, 1 mrem from water pathways (i.e., drinking, consuming fish, swimming, and other recreational uses of the water and shoreline), and 1 mrem from consumption of wildlife (e.g., deer, geese, and turkey) harvested on ORR. The annual dose to an MEI from the combination of all these potential exposure pathways was estimated to be approximately 3 mrem. (Reference 5.11-13)

There are several non-DOE facilities on or near the ORR that could also contribute to radiation doses to the public. DOE requested information from these facilities regarding their potential radiation doses to members of the public, and nine facilities responded with information about their dose contributions. DOE estimated that annual doses to members of the public from air and water emissions and external radiation from both non-DOE and DOE sources on and near the ORR were less than 100 mrem. Of the less than 100 mrem total dose, 45 mrem is from direct radiation reported from onsite dose monitors at one of the nine responding facilities. The CRN Site MEI would be outside the physical range of this direct radiation. Therefore, the dose from the non-DOE facilities on or near ORR is estimated at maximum of 55 mrem/yr. (Reference 5.11-13)

This cumulative impact analysis also considers other potential sources of radiological exposures within the geographic area of interest. According to NUREG-0498, *Supplement 2 – Final Environmental Statement: Related to the Operation of Watts Bar Nuclear Plant*, the combination of potential doses from the ongoing operation of WBN Unit 1 with estimated doses from the operation of the new WBN Unit 2 result in a total body dose of 2.6 mrem/yr for an MEI at the WBN site.

Other facilities in the geographic area of interest, such as industrial facilities and hospitals, may use radiological materials but their potential contributions to the cumulative dose received by the CRN Site MEI would be negligible. Because radiation dose is highly location dependent and any one person cannot receive the maximum possible dose from all of the multiple sources, the sum of the doses estimated above is conservative. Summing the doses of 11 mrem/yr from the CRN Site reactors, 3 mrem/yr from DOE facilities, 55 mrem/yr from non-DOE facilities, and 2.6 mrem/yr from WBN Units 1 and 2, provides an estimate of the cumulative dose impact from radiation sources in the geographic area of interest during operation. The CRN Site contribution to this total is well below the annual dose limit of 100 mrem/yr from 10 CFR Part 20.1301, and the total cumulative impact is significantly less than the approximately 300 mrem average annual dose to individuals from natural or background radiation in the United States (Reference 5.11-13). Therefore, the cumulative dose impact will be SMALL.

Radiation doses to aquatic and terrestrial biota were evaluated for the CRN Site in Subsection 5.4.4. The conservative evaluation in Subsection 5.4.4 concluded that the highest dose (0.021 millirad per day [mrad/day]) to aquatic biota from the operation of the SMR facility would be significantly lower than the DOE criterion of 1 rad/day, and the highest dose to terrestrial biota (0.3 mrad/day) would be much lower than the DOE criterion of 0.1 rad/day. The evaluation by DOE of doses to aquatic and terrestrial biota on the ORR in the *Annual Site Environmental Report* also concluded that dose rates to aquatic biota were below levels that could have an adverse impact on plant or animal populations (Reference 5.11-14). Thus, estimated doses were less than levels for the protection of biota when the SMRs and ORR were evaluated separately. Even if it is conservatively assumed that an organism could be exposed to a total dose based on adding the SMR dose to doses at locations on the ORR, the SMR dose would contribute negligibly to the total. Cumulative doses to biota would be lower than protective levels, indicating a negligible risk to either aquatic or terrestrial organisms. Accordingly, cumulative radiological impacts to biota other than members of the public during operation will be SMALL.

5.11.9 Nonradiological Health Impacts

Sections 2.2, 2.3, and 2.7 describe the land, water, and air affected by the proposed SMR Project at the CRN Site. Sections 5.1, 5.2, and 5.5 describe impacts to health and the physical environment during operational activities at the CRN Site. Compliance with the site permits coupled with best management practices (BMPs), would result in SMALL impacts from the proposed CR SMR Project to nonradiological health from operational activities.

Nonradioactive health impacts from operation of the CRN SMR Project include localized impacts from noise, vibrations, and dust along with occupational injuries to the workers. Cumulative nonradiological health impacts would include contributions from current developments (ETTP and Bull Run Fossil Plant), future developments (roadway improvements and urbanization), ORR activities (industrialization, decommissioning, and demolition), and other projects listed in Table 4.7-1.

As described in Subsections 3.6.3.2, the CRN SMR Project's cooling towers would discharge nonradioactive wastewater with small amounts of biocides and corrosion inhibitors into the Clinch River Arm of the Watts Bar Reservoir. As discussed in Subsection 5.3.2.1, thermal effects would not extend far from the diffuser; being assimilated within regulatory limits within 50 ft under steady river flow conditions and within 150 ft under unsteady river flow conditions. As discussed in Subsections 5.2.2.2 and 5.11.3.3, discharge would be in compliance with the Site's NPDES permit. Further, because project discharge would be less than 10 percent of the lowest reservoir flow rate at the CRN Site, impact of the discharge on the water is SMALL and thus the health impact is SMALL. Impacts on water from past, present, and reasonably foreseeable projects in the area include the dams listed in Table 4.7-1 along with legacy contributions from the Manhattan Project that contribute to a MODERATE cumulative impact to human health. Anticipated future projects, like the Sludge Build-Out Project and continued industrial development at ETTP and at the Roane Regional Business and Technology Park, would employ modern business practices following waste minimization and NPDES guidelines; thus having a SMALL impact on water and on nonradiological human health. The incremental additional contributions to nonradiological cumulative health impacts from SMR operations would also be SMALL.

Further nonradioactive health impacts include effects from GHG emissions and particulates from transport of crew and supplies along with gaseous effluents from operational activities at the CRN Site. As described in Subsections 3.6.3.1 and 5.5.1.3, operations of the CRN SMR Project includes gaseous and particulate emissions from cooling towers, auxiliary boilers, diesel generators, and gas turbine generators. Emissions would be managed by federal, state, and local air quality control laws and regulations making emissions within the regulatory limits and thus protective of human health. Cumulative health impacts to workers and the public from these GHG and particulate emissions would include state and national contributors. State and federal air permitting coupled with BMPs would help mitigate contributions from the proposed SMR Project along with current and future projects; thus helping minimize the health impacts from these emissions. The incremental contribution of the operational CRN SMR Project to cumulative nonradiological health impacts is SMALL.

In addition, projected climate change for the region contributes to the potential nonradiological health of the populace in the geographic area of interest. Models for the Appalachian region of East Tennessee often forecast warmer, wetter weather patterns with greater incidence of severe storm events. These severe storms tend to increase water pollution from runoff including increased fertilizers, herbicides, and pesticides along with increased sedimentation impairing the water quality and contributing to adverse health effects. (Reference 5.11-2) Additionally, less regular precipitation events coupled with increased evaporation and transpiration from increased air and water temperatures, may also lead to reduced availability of timely water resources and a need for crop irrigation; thus reducing the local availability of fresh water and food. Further, global changes in climate are expected to result in decreasing availability of food and water and thus negatively impact human health through increased competition for more limited resources. (Reference 5.11-2) Since the human health impact from the projected increase in temperature and storm severity is SMALL and since the nonradiological health impact of operating the proposed CRN SMR Project is also SMALL, the cumulative impact to human health from the projected increase in temperature and storm severity along with impacts from operational activities at the CRN Site would be SMALL.

5.11.10 References

Reference 5.11-1. Tennessee Valley Authority, "Clinch River Small Modular Reactor Site Regional Surface Water Use Study - Revision 2," April 24, 2015.

Reference 5.11-2. U.S. Global Change Research Program, "Climate Change Impacts in the United States," October, 2014.

Reference 5.11-3. U. S. Geological Survey, "Water Quality in the Upper Tennessee River Basin, 1994-1998," Circular 1205, 2000.

Reference 5.11-4. Tennessee Valley Authority, "Clinch River Surface Water Quality Report - Revision 2," July 10, 2015.

Reference 5.11-5. Tennessee Wildlife Resources Agency, "Climate Change and Potential Impacts to Wildlife in Tennessee," September, 2009.

Reference 5.11-6. U.S. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013," EPA 430-R-15-004, April 15, 2015.

Reference 5.11-7. U.S. Environmental Protection Agency, State Energy CO2 Emissions, Website: http://www3.epa.gov/statelocalclimate/resources/state_energyco2inv.html, July 8, 2015.

Reference 5.11-8. Nuclear Energy Institute, Comparison of Lifecycle Emissions of Energy Technologies, Website: http://www.nei.org/Issues-Policy/Protecting-the-Environment/Life-Cycle-Emissions-Analyses/Comparison-of-Lifecycle-Emissions-of-Selected-Ener, 2015.

Reference 5.11-9. World Nuclear Association, Energy Balances and CO2 Implications, Website: http://www.world-nuclear.org/info/Energy-and-Environment/Energy-Balances-and-CO2-Implications/, March, 2014.

Reference 5.11-10. U.S. Department of Energy, 2013 Uranium Marketing Annual Report, Website: http://www.eia.gov/uranium/marketing/pdf/2013umar.pdf, 2013.

Reference 5.11-11. Meade, Thomas B. and Supko, Eileen M., Review of the Potential Impact of DOE Excess Uranium Inventory On the Commercial Markets, Website: http://www.energy.gov/sites/prod/files/2014/05/f15/ERI%20Market%20Analysis.pdf, April 25, 2014.

Reference 5.11-12. Tennessee Department of Environment and Conservation, APC Permits in TN Interactive Report, Website: http://www.tennessee.gov/environment/article/permit-air-title-v-operating-permit, 2015.

Reference 5.11-13. Oak Ridge National Laboratory, "Oak Ridge Reservation Annual Site Environmental Report," DOE/ORO-2502, September, 2015.

Reference 5.11-14. Oak Ridge National Laboratory, "Oak Ridge Reservation Annual Site Environmental Report," DOE/ORO-2473, September, 2014.

Table 5.11-1 (Sheet 1 of 2)
Geographic Areas of Interest Defined for the Analyzed Resource Areas

ER Section	Analyzed Resource	Geographic Area of Interest
4.7.2 / 5.11.2	Land Use	Within a 50-mi radius of the CRN Site
4.7.3.1 / 5.11.3.1	Surface Water Hydrology	Clinch River arm of the Watts Bar Reservoir
4.7.3.2.1 / 5.11.3.2.1	Surface Water Use	Anderson, Knox, Loudon, Meigs, Morgan, Rhea, and Roane counties, Tennessee
4.7.3.2.2 / 5.11.3.2.2	Groundwater Use	Lower Clinch River Watershed from Melton Hill Reservoir downstream to the confluence of the Clinch, Emory, and Tennessee Rivers
4.7.3.3.1 / 5.11.3.3.1	Surface Water Quality	Clinch River arm of the Watts Bar Reservoir
4.7.3.3.2 / 5.11.3.3.2	Groundwater Quality	Lower Clinch River Watershed from Melton Hill Reservoir downstream to the confluence of the Clinch, Emory, and Tennessee Rivers
4.7.4.1 / 5.11.4.1	Terrestrial Ecology and Wetlands	Within a 6-mi radius of the CRN Site
4.7.4.2 / 5.11.4.2	Aquatic Ecology	CRN Site, Barge/Traffic Area, and 69-kV underground transmission line ROW, and Clinch River arm of the Watts Bar Reservoir in the vicinity (within approximately a 6-mi radius) of the CRN Site. This portion of the Clinch River arm of the Watts Bar Reservoir generally includes the area of the reservoir downstream to the confluence with the Emory River arm of the Watts Bar Reservoir and upstream to Melton Hill Dam (approximately Clinch River Mile 5 to 23).
4.7.5.1.1	Socioeconomic/Physical - Air Quality	Within a 6-mi radius of the CRN Site (nationwide, for GHG emissions)
5.11.5.1.1	Socioeconomic/Physical - Air Quality	Roane, Loudon, Knox, Anderson, and Morgan counties, Tennessee (State of Tennessee and nationwide, for GHG emissions)
4.7.5.1.1 / 5.11.5.1.1	Socioeconomic/Physical - Noise	CRN Site and the areas within a 5-mi radius of the CRN Site
5.11.5.1.1	Socioeconomic/Physical – Thermal Emissions (Air)	CRN Site and the areas within a 1-mi radius of the CRN Site

**Table 5.11-1 (Sheet 2 of 2)
Geographic Areas of Interest Defined for the Analyzed Resource Areas**

ER Section	Analyzed Resource	Geographic Area of Interest
5.11.5.1.1	Socioeconomic/Physical – Thermal Emissions (Water)	Clinch River arm of the Watts Bar Reservoir
5.11.5.1.1	Socioeconomic/Physical – Visual Intrusions	Within a 2-mi radius of the CRN Site
4.7.5.1.2 / 5.11.5.1.2	Social and Economic	Roane, Anderson, Knox, and Loudon counties, Tennessee
4.7.5.2 / 5.11.5.2	Environmental Justice	Within a 50-mi radius of the CRN Site
4.7.5.3 / 5.11.6	Archaeological Resources	The approximate 1305-ac area that includes the CRN Site and the Barge/Traffic Area (Area of Potential Effect)
4.7.5.3 / 5.11.6	Historic Architectural Resources	Within a 0.5-mi radius surrounding the proposed cleared areas
4.7.5.3 / 5.11.6	Historic Properties	Within a 10-mi radius of the center of the CRN Site
4.7.6	Radiological Health	Within a 50-mi radius of the CRN Site
4.7.7	Nonradiological Health	Within a 50-mi radius of the CRN Site
5.11.8	Radiological Health	Within a 50-mi radius of the CRN Site
5.11.9	Nonradiological Health	Within a 50-mi radius of the CRN Site
5.11.7	Postulated Accidents	Within a 50-mi radius of the CRN Site
5.11.7.1.1	Postulated Accidents/Fuel Cycle	Nationwide (worldwide, for imported uranium)
5.11.7.1.2	Postulated Accidents/Transportation	Nationwide
5.11.7.1.3	Postulated Accidents/ Decommissioning	Within a 50-mi radius, for socioeconomic; nationwide, for radioactive waste disposal

Table 5.11-2
Title V Operating Permit Sources In Roane, Anderson, Knox, Loudon, and Morgan Counties, Tennessee

Facility	DAPC Permit Number[1]	County
Horsehead Corp	562547	Roane
TVA-Kingston Fossil Plant	560775	Roane
Toho Tenax America Inc.	560018	Roane
Oak Ridge National Laboratory	562765	Roane
Oak Ridge National Laboratory	562860	Roane
Diversified Scientific Services, Inc.	566728	Roane
Isotek, LLC	568276	Roane
Oak Ridge National Laboratory (Draft)	569768	Roane
Chestnut Ridge Landfill/Recycling Center	563001	Anderson
TVA-Bull Run Fossil Plant	567519	Anderson
Carlisle Tire	562998	Anderson
National Nuclear Security Administration Y-12 DOE	562767	Anderson
Chestnut Ridge Landfill/Recycling Center (Pending)	569431	Anderson
Omega Cabinetry (Surrendered)	554290	Anderson
CEMEX	Knox Co. No 8[2]	Knox
Leisure Pools and Spas	Knox Co. No 533[2]	Knox
GERDAU AMERISTEEL	Knox Co. No 568[2]	Knox
Schick Manufacturing	Knox Co. No 842[2]	Knox
Republic Plastics K1, LTD	Knox Co. No 970[2]	Knox
Republic Plastics K2, LTD	Knox Co. No 1065[2]	Knox
Tate & Lyle Loudon	561515	Loudon
Hubbell Lenoir City Inc.	563297	Loudon
Kimberly-Clark Corporation	563319	Loudon
Malibu Boats LLC	563414	Loudon
Viskase Corporation	567428	Loudon
Malibu Boats LLC (Pending)	569925	Loudon
Santek Waste Services, Inc./Loudon Co Landfill	569595	Loudon
Heraeus Metal Processing Inc.	561481	Morgan

1 DAPC - Tennessee Department of Environment and Conservation, Division of Air Pollution Control
2 Knox County Health Department administers Title V Operating Permits.

Source: (Reference 5.11-12)

CHAPTER 6 ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

Chapter 6 presents the details of the environmental monitoring programs that are instituted for the periods prior to application submission (site preparation), during construction, prior to operation (preoperational), and during operation of Clinch River Nuclear (CRN) Site. These monitoring programs establish a baseline of information that allows for the evaluation of future information and provide a method of quantifying the environmental effects of CRN Site operations.

The environmental measurements and monitoring programs are described in the following sections:

- Thermal Monitoring (Section 6.1)
- Radiological Monitoring (Section 6.2)
- Hydrological Monitoring (Section 6.3)
- Meteorological Monitoring (Section 6.4)
- Ecological Monitoring (Section 6.5)
- Chemical Monitoring (Section 6.6)
- Summary of Monitoring Programs (Section 6.7)

Monitoring details (e.g., sampling equipment, constituents, parameters, frequency, and locations) for each specific phase of the overall program are described in these sections.

Monitoring periods are defined as follows.

- Site Preparation Monitoring: These field monitoring and data collection activities are used to support the baseline discipline-specific descriptions presented in the environmental report.
- Construction Monitoring: These monitoring activities evaluate the impacts from site preparation and construction. These activities also detect any environmental impacts and allow comparison to Site Preparation baseline data for assessing the subsequent impacts of site preparation and construction.
- Preoperational Monitoring: These monitoring activities establish a baseline for identifying and assessing environmental impacts resulting from CRN Site operation.
- Operational Monitoring: These monitoring activities establish the impacts of plant operations and detect any environmental impacts.

6.1 THERMAL MONITORING

This section describes the thermal monitoring programs for surface water, which include site preparation monitoring to establish baseline conditions in water bodies potentially affected by the construction and operation of two or more small modular reactors (SMRs), and may include operational monitoring of Watts Bar Reservoir temperatures to identify potential impacts from operation of the SMRs.

6.1.1 Site Preparation Thermal Monitoring

Tennessee Valley Authority (TVA) used temperature monitoring data to obtain baseline information to characterize temperature regimes in the water body potentially affected by construction and operation of SMRs at the Clinch River Nuclear (CRN) Site. The baseline information was used to perform modeling of thermal impacts from the SMR discharge. The data also supports the assessment of circulating water system (CWS) discharge impacts to aquatic communities in Subsection 5.3.2.

A map showing the Clinch River arm of the Watts Bar Reservoir, CRN Site features (including intake and discharge locations), and thermal monitoring stations in close proximity to the CRN Site is shown in Figure 6.1-1. A map showing the locations of the thermal monitoring stations is provided in Figure 6.1-2.

The water body potentially affected by construction and operation of the SMRs is the Watts Bar Reservoir. The proposed intake structure for the CRN Site (CRM 17.9) is 5.2 miles (mi) downstream of Melton Hill Dam (CRM 23.1). The volume and temperature of water released from Melton Hill Dam is a significant factor in determining temperature conditions, and therefore potential thermal impacts, at the proposed discharge location at approximately CRM 15.5 (Reference 6.1-1). Therefore, temperature data from the Melton Hill Reservoir and further upstream also were collected as part of the thermal monitoring effort. Furthermore, to examine potential SMR thermal impacts throughout Watts Bar Reservoir, temperature data were collected downstream of the CRN Site on the Clinch River arm of the Watts Bar Reservoir, on the Emory River arm of the Watts Bar Reservoir, and on the Tennessee River (Watts Bar Reservoir) as far downstream as the discharge from Watts Bar Dam (Chickamauga Reservoir) and as far upstream as the forebay of Fort Loudoun Dam.

Thermal data for the Watts Bar Reservoir and the Melton Hill Reservoir are available from two separate sources: operational support monitoring and site preparation monitoring. Operational support monitoring includes data collection performed by TVA on an ongoing basis to support the operation of the TVA river system and TVA thermal power plants. Site preparation monitoring includes SMR-specific, interim, and temporary data collection performed by TVA to supplement the operational support monitoring. Information from both sources was used to support modeling of the thermal impacts from the SMR discharge.

As part of the routine reservoir operations data collection, water temperature is monitored in both reservoirs. This monitoring has included temperature measurements at 16 existing locations, which are shown in Figures 6.1-1 and 6.1-2 and summarized in Table 6.1-1. Of these locations, the closest to the CRN Site is the sample location near CRM 22.6. The sample near CRM 22.6 is located approximately 0.5 mi downstream of Melton Hill Dam, and represents the temperature of water released from Melton Hill Dam upstream of the proposed intake location, which is at approximately CRM 17.9. Temperature measurements at the 16 locations are made using a variety of different monitoring methods, including grab samples and dataware-plant monitors.

TVA also conducted additional site preparation thermal monitoring of the rivers and reservoirs in the vicinity of the CRN Site from October 2013 through December 2014. The purpose of this additional monitoring was to provide at least 12 months of additional data, consistent with NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*, to assure that sufficient temperature data has been collected to characterize seasonal variations throughout an annual cycle. TVA collected field data to characterize river and reservoir conditions, and to provide additional input data for modeling simulations of the thermal effects of the proposed discharges associated with the construction and operation of the SMRs. Monitoring included temperature measurements upstream, adjacent to, and downstream of the CRN Site for one year, river velocity measurements under specified flow conditions, cross sections to define the river geometry, and monthly water quality sampling of Watts Bar Reservoir. Monitoring was conducted at 16 locations on the Watts Bar and Melton Hill Reservoirs. Of the 16 locations, three are on the Clinch River upstream of Melton Hill Dam, four are adjacent to the CRN Site, and nine are on the Watts Bar Reservoir downstream of the CRN Site. The sample location at CRM 16.1 provides temperature data near the proposed discharge location at approximately CRM 15.5. Temperature measurements were made at 15 minute intervals using monitors at multiple depths. The site preparation thermal monitoring locations are listed in Table 6.1-1, and are also shown in Figures 6.1-1 and 6.1-2.

The site preparation thermal monitoring data were used to establish baseline conditions, and to provide calibration data in two separate modeling efforts, one for thermal impacts in regions near the CRN Site (e.g., intake withdrawal zone and discharge mixing zone) and the other for impacts in regions beyond the CRN Site and throughout Watts Bar Reservoir.

The thermal impacts in regions near the CRN Site were evaluated using an unsteady, three-dimensional computational fluid dynamics (CFD) model for the portion of the Clinch River arm of Watts Bar Reservoir between approximately CRM 13 and CRM 21. The modeling effort for regions near the CRN Site used ambient river conditions based on temperature data from three of the operational support monitoring locations and one site preparation monitoring location. The operational support monitoring locations included the monitors on the taildeck of Melton Hill Dam at CRM 23.1, the monitoring location in the tailrace below the dam at CRM 22.6, and the monitoring locations downstream of the CRN Site at CRM 3.9, located near the Emory River confluence with the Clinch River arm of the Watts Bar Reservoir. The site preparation monitoring locations included the monitoring location at CRM 16.1, which is located near the proposed discharge at approximately CRM 15.5. Data from the operational support monitors were used to develop a time history of the release temperature from Melton Hill Dam for the period of record including 2004 plus 2008 through 2013. For years 2005 through 2007, data were too sparse to develop a trustworthy record of the release temperature. Year 2004 was selected as the beginning of the historical record to be consistent with the current operating policy for the reservoirs on the Clinch River, which is expected to continue into the future. Prior to 2004, the reservoirs on the Clinch River were operated differently, resulting in potentially different seasonal variations in the Melton Hill Dam release temperature. Data for the monitors at CRM 22.6 and CRM 16.1 together were used to estimate the potential amount of summer heating and winter cooling in the Clinch River arm of the Watts Bar Reservoir between the Melton Hill Dam release and the CRN Site.

The modeling effort for regions beyond the CRN Site was conducted using CE-QUAL-W2, a general purpose water quality and hydrodynamic model for rivers and reservoirs. The applicablilty of the CE-QUAL-2 model to the SMR project was verified through a calibration study of the Watts Bar Reservoir, based on a comparison of model results and field measurements for the years 2004, 2008, and 2013. This model was used to assess the laterally-averaged, unsteady buildup of thermal effluent in the Clinch River arm of the Watts Bar Reservoir at the CRN Site, as well as the potential reservoir-wide effects, of operation of the SMRs. The CE-QUAL-W2 model was used not only to examine water temperature, but also to examine dissolved oxygen and algal biomass throughout Watts Bar Reservoir.

6.1.2 Construction and Preoperational Thermal Monitoring

Any discharges would be subject to monitoring to ensure compliance with a National Pollutant Discharge Elimination System (NPDES) permit, and this may include monitoring of the temperature of the discharge. Temporary discharges associated with construction is provided at combined license application (COLA), and will be defined in the NPDES permit application prior to construction. Because site preparation monitoring has been conducted to provide adequate baseline data, no additional preoperational monitoring is planned during construction.

6.1.3 Operational Thermal Monitoring

TVA used the results of the aforementioned unsteady, three-dimensional CFD model to evaluate the effect of operation of the SMRs for extreme summer and extreme winter conditions during various high-flow, low-flow, and reverse-flow events. The modeling results are depicted in Figures 5.3-3 through 5.3-6. The result concluded that the effects of the CRN Site thermal effluent from the SMRs could be managed within regulatory limits by defining a mixing zone of appropriate size for the discharge and by providing a minimum release from Melton Hill Dam. As discussed in Subsection 5.3.2.1, the latter requires a new outlet structure/bypass at the dam to provide the minimum release when the hydropower generating units at the dam are not in service.

The operational monitoring program remains to be developed, pending decisions regarding the design of the facility cooling system and related analyses of the impacts of the cooling system on the receiving water body. Discharge of cooling water and other effluents are subject to monitoring to ensure compliance with a NPDES permit, as specified in Section 2.1, of TVA's Environmental Protection Plan (EPP) (Appendix B) and this includes monitoring of the temperature of the discharge. The permit considers effluent limitations, monitoring requirements, and mitigation measures. Sections 2.3, 4.1, and 4.3 of the EPP describe the process for monitoring onsite mortality, injury, or unusual behavior that may result from thermal discharges, reporting it to NRC and other applicable regulatory agencies, and maintaining records (Appendix B). Specific monitoring requirements, such as the number and location of monitoring stations, types of monitoring equipment and measurements, modeling, and thermal limits, will be developed in consultation with Tennessee Department of Environment and Conservation as part of the NPDES permit application process.

6.1.4 References

Reference 6.1-1. Tennessee Valley Authority, TVA Zone 5 and 6 Review Melton Hill, August, 2007.

Table 6.1-1 (Sheet 1 of 4)
Description of Thermal Monitoring Locations and Data Collection

Approximate Location by River Mile	Source of Thermal Data[1]	Description of Sample	Depth of Temperature Measurement	Start Date of Data Collection	End Date of Data Collection	Approximate Data Collection Frequency
TRM 529.9	TVA operational support	Release temperature from TVA hydro monitoring system at Watts Bar Dam (Reservoir Release Improvement).	Taildeck monitors on Units 1, 3, & 5	pre 1/1/2004	continuing	1 hour
TRM 529.9	TVA operational support	Release temperature at Watts Bar Dam for Watts Bar Nuclear Plant (Thermal Compliance) .	Taildeck monitor at depth about 5' on Unit 3	pre 1/1/2004	continuing	1 hour
TRM 530.1	SMR site preparation support	Onset remote (satellite) water temperature station on pontoon float in forebay of Watts Bar Dam.	Monitors at depths 3', 10', 20', 35', 50', 60', bottom	11/30/2012	2/20/2014	15-minute
TRM 532.5	TVA operational support	Temperature profile grab at about 2.6 mi upstream of Watt Bar Dam (Reservoir Ecological Health).	Grab depths vary from water surface to bottom among sampling dates	pre 1/1/2004	continuing	weekly to monthly from April to late August
TRM 567.0	SMR site preparation support	Onset remote (satellite) water temperature station on pontoon float just downstream of Clinch River confluence with Tennessee River.	Monitors at depths 3', 10', 15', 20', 30', & 40'	11/29/2012	2/3/2014	15-minute
TRM 602.2	TVA operational support	Release temperature from TVA hydro monitoring system at Fort Loudoun Dam (Reservoir Release Improvement).	Taildeck monitors at Units 1 & 4	pre 1/1/2004	continuing	1 hour
TRM 605.5	TVA operational support	Temperature profile grab at about 2.3 mi upstream of Fort Loudoun Dam (Reservoir Ecological Health).	Grab depths vary from water surface to bottom among sampling dates	pre 1/1/2004	continuing	weekly to monthly from April to late August
CRM 2.0	SMR site preparation support	Onset HOBO temperature string on tire float downstream of I-40 and Hwy 70 bridges.	Monitor depths 3', 5', 10', 15', 20', 25', & bottom	11/21/2012	2/3/2014	15-minute
CRM 2.6	SMR site preparation support	Onset HOBO temperature monitor on trash boom in KIF condenser discharge channel in King Creek Embayment, near CRM 3.0.	Monitor depth 3'	12/11/2012	12/19/2013	15-minute

Table 6.1-1 (Sheet 2 of 4)
Description of Thermal Monitoring Locations and Data Collection

Approximate Location by River Mile	Source of Thermal Data[1]	Description of Sample	Depth of Temperature Measurement	Start Date of Data Collection	End Date of Data Collection	Approximate Data Collection Frequency
CRM 3.9[2]	TVA operational support	Water temperature station on pontoon float just downstream of submerged dam and downstream of Emory River confluence with Clinch River for Kingston Fossil Plant (Thermal Compliance).	Monitor depths 5', 15, & 25'	11/1/2012	12/30/2013	1 hour
CRM 4.0	SMR site preparation support	Onset HOBO temperature string on tire float just upstream of submerged dam for Kingston Fossil Plant and downstream of Emory River confluence with Clinch River.	Monitor depths 3', 5', 10', 15', 20', 25', & bottom	11/21/2012	2/3/2014	15-minute
CRM 5.6	SMR site preparation support	Onset HOBO temperature string on tire float upstream of Emory River confluence with Clinch River, across the channel from Blackoak Ridge daybeacon.	Monitor depths 3', 10', 15', 20', 25', 30', & bottom	11/21/2012	2/3/2014	15-minute
CRM 13.0	SMR site preparation support	Onset HOBO temperature string on tire float downstream of transmission line crossing, and about 0.1 mi downstream of water intake of former K-25 gaseous diffusion plant. Actual location of temperature monitor is a bit downstream of CRM 13.0.	Monitor depths 3', 10', 20', & bottom	11/21/2012	2/5/2014	15-minute
CRM 16.1[2]	SMR site preparation support	Onset HOBO temperature string on pontoon float just downstream of Poplar Springs Creek and upstream of proposed SMR discharge. Instrumentation for stage and velocity also included at this location.	Monitor depths 5', 10', 15', & bottom	12/4/2012	2/20/2014	15-minute
CRM 16.2	SMR site preparation support	Onset HOBO temperature string on tire float in Poplar Springs Creek Embayment (creek empties into Clinch River near CRM 16.2).	Monitor depths 2' & bottom	11/21/2012	2/5/2014	15-minute
CRM 16.9	SMR site preparation support	Onset HOBO temperature string on tire float in Caney Creek Embayment (creek empties into Clinch River near CRM 16.9).	Monitor depths 3' & bottom	11/21/2012	2/5/2014	15-minute
CRM 19.0	SMR site preparation support	Onset HOBO temperature string about 1.1 mi upstream of SMR intake and about midway between Grubb Islands and Jones Island.	Monitor depths 3', 10', & 15'	11/21/2012	2/5/2014	15-minute

Table 6.1-1 (Sheet 3 of 4)
Description of Thermal Monitoring Locations and Data Collection

Approximate Location by River Mile	Source of Thermal Data[1]	Description of Sample	Depth of Temperature Measurement	Start Date of Data Collection	End Date of Data Collection	Approximate Data Collection Frequency
CRM 22.6[2]	TVA operational support	Onset remote (satellite) water temperature station on pontoon float in tailrace below Melton Hill Dam for Kingston Fossil Plant (Thermal Compliance).	Monitor depth 3'	5/1/2008	continuing	1-hour
CRM 23.1[2]	TVA operational support	Release temperature at Melton Hill Dam for Kingston Fossil Plant (Thermal Compliance).	Taildeck monitors at Units 1 & 2	pre 1/1/2004	12/31/2006, but very sporadic in 2005 & 2006	1-hour
CRM 23.5	SMR site preparation support	Onset HOBO water temperature station on pontoon float in forebay of Melton Hill Dam. Actual location of temperature monitor is closer to CRM 23.2.	Monitor depths 3', 6', 10', 20', 30', 50', & bottom	11/29/2012	2/10/2014	15-minute
CRM 23.5	TVA operational support	Temperature profile grab at about 0.4 mi upstream of Melton Hill Dam (Reservoir Ecological Health).	Grab depths vary from water surface to bottom among sampling dates	5/13/2004	continuing	bi-weekly to monthly
CRM 47.7	TVA operational support	Temperature monitoring for discharge of Bull Run Fossil Plant (Thermal Compliance).	After condenser discharge	pre 1/1/2004	continuing	1-hour
CRM 48.0	TVA operational support	Temperature monitoring for intake of Bull Run Fossil Plant (Thermal Compliance).	Before CCW pumps	pre 1/1/2004	continuing	1-hour
CRM 48.5	TVA operational support	Temperature string outside of skimmer wall for Bull Run Fossil Plant (Thermal Compliance).	Monitor depths 0.5', 2.5', 5' + Elev 789', 785', 781', 777', 773', & 771'	pre 1/1/2004	continuing	1-hour
CRM 66.3	SMR site preparation support	Onset HOBO water temperature monitor at Highway 61 bridge in Clinton, TN.	Monitor depth river bottom	3/27/2013	2/5/2014	15-minute
CRM 77.2	SMR site preparation support	Water temperature monitor at River Road boat ramp, about 3 mi downstream of Norris Dam and 0.9 mi downstream of the tailwater weir for Norris Dam.	Monitor depth about 3' depth	2/20/2013	11/21/2013	15-minute

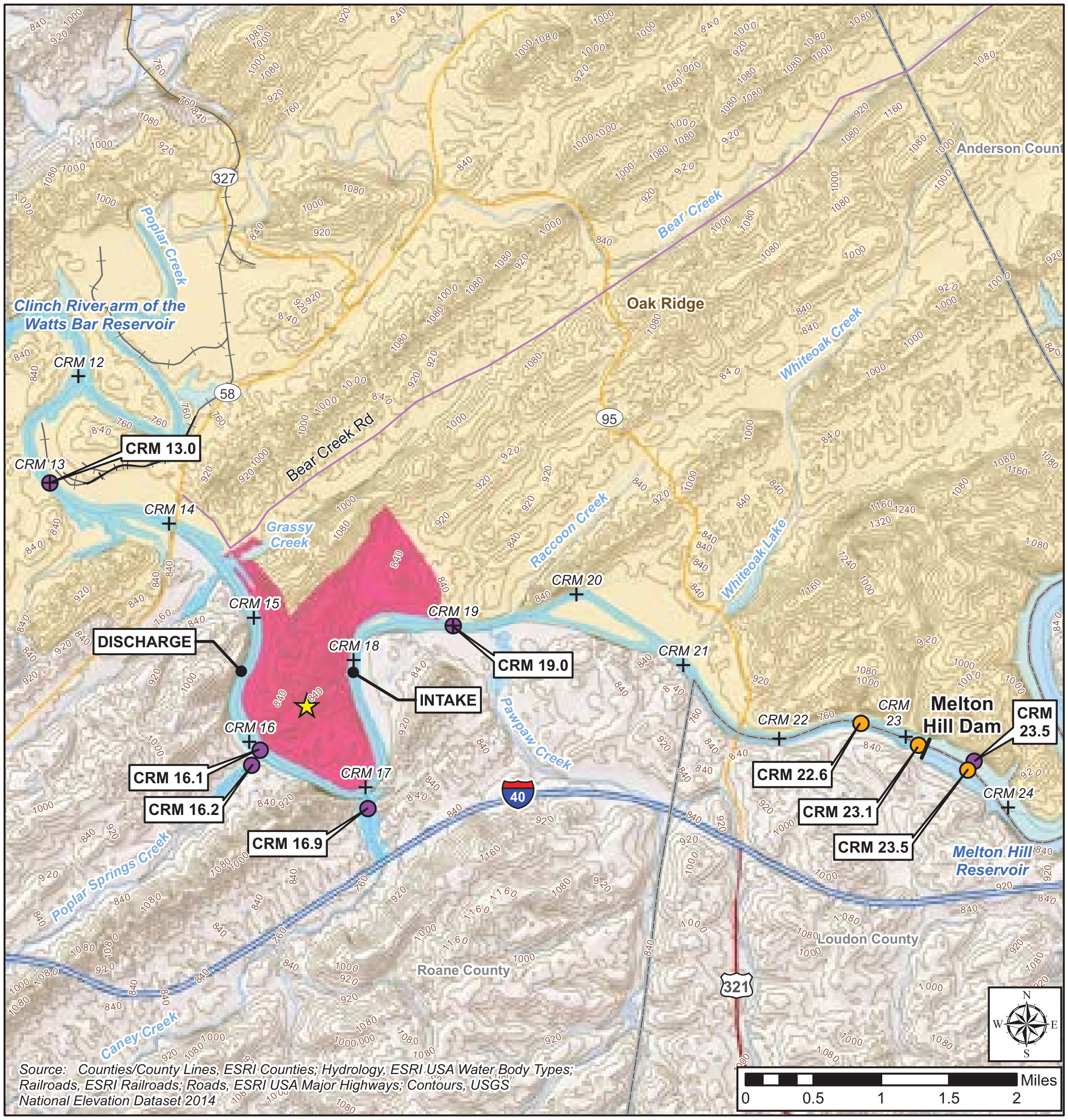
Table 6.1-1 (Sheet 4 of 4)
Description of Thermal Monitoring Locations and Data Collection

Approximate Location by River Mile	Source of Thermal Data[1]	Description of Sample	Depth of Temperature Measurement	Start Date of Data Collection	End Date of Data Collection	Approximate Data Collection Frequency
CRM 77.2	TVA operational support	Water temperature monitor at River Road boat ramp, about 3 mi downstream of Norris Dam and 0.9 mi downstream of the tailwater weir for Norris Dam (Reservoir Releases Improvement) . Data available from TVA hydro monitoring system at Norris Dam.	Monitor depth about 3' depth	11/5/2012	continuing	1-hour
CRM 79.8	TVA operational support	Temperature profile grab at about 1 mi upstream of Norris Dam (Reservoir Ecological Health).	Grab depths vary from water surface to bottom among sampling dates	pre 1/1/2004	continuing	weekly to monthly from April to late August
ERM 1.8	TVA operational support	Temperature monitoring for intake of Kingston Fossil Plant (Thermal Compliance).	Monitors at depth between 15'-20' on Units 2, 5, & 8	pre 1/1/2004	continuing	1-hour
ERM 1.8	SMR site preparation support	Onset HOBO temperature string on tire float outside of intake channel skimmer wall.	Monitors depths 3', 10', 15', 20', 25', 30', & bottom	11/21/2012	2/5/2014	15-minute
ERM 5.0	SMR site preparation support	Onset HOBO temperature string on tire float at transmission line crossing, downstream of Little Emory River confluence with Emory River.	Monitor depths 3', 10', 20, & bottom	11/21/2012	2/5/2014	15-minute
ERM 18.3	TVA operational support	Temperature monitoring at Tennessee State Highway 299 bridge at Oakdale for Kingston Fossil Plant (Thermal Compliance). Located near U.S. Geological Survey stream gage 03540500, "Emory River at Oakdale".	Monitor depth river bottom	pre 1/1/2004	continuing	1-hour

1 TVA operational support refers to routine measurements from instrumentation systems providing data in support of the day-to-day operation of the TVA river system or TVA thermal plants. SMR site preparation support refers to supplemental, interim/temporary measurements provided, as needed, in support of any special studies to evaluate the environmental impact of the SMR plant on the source waterbody.

2 Data point used in site preparation hydrothermal impact analysis.

Notes:
TRM = Tennessee River Mile
CRM = Clinch River Mile
ERM = Emory River Mile



Legend

CRN Site Center Point	CRN Site	Railroads	Bear Creek Road
Clinch River Mile (CRM)	City/Town Boundaries	Interstate	40' Contour Lines
Preapplication Monitoring Locations	Counties	Highway	
Operational Support Monitoring Locations	Rivers and Lakes	Major Road	

Figure 6.1-1. Thermal Monitoring Locations in Close Proximity to CRN Site

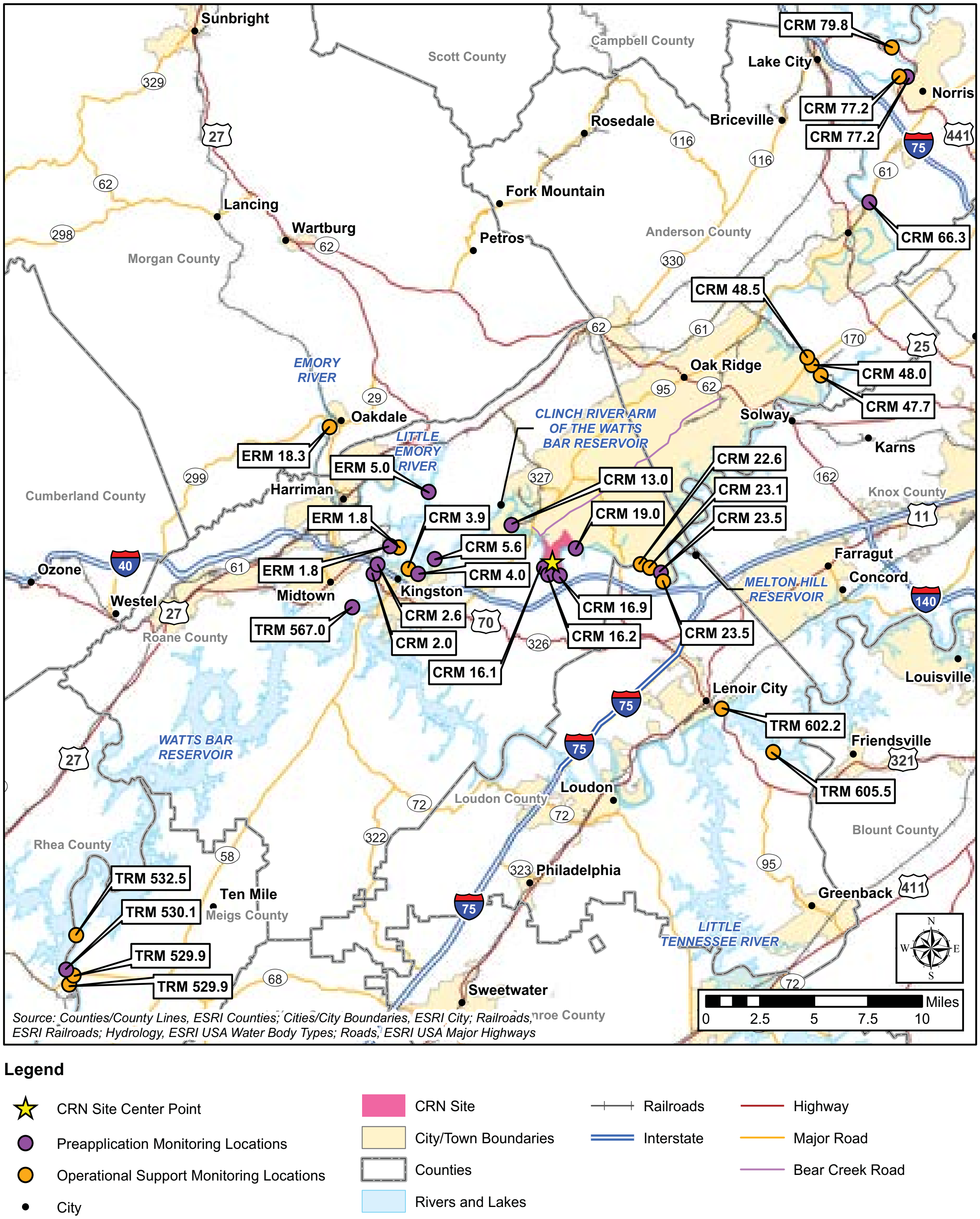


Figure 6.1-2. Thermal Monitoring Locations Used to Evaluate SMRs

6.2 RADIOLOGICAL MONITORING

A Radiological Environmental Monitoring Program (REMP) is used to support the preoperational and operational monitoring needs of a nuclear power plant and to provide baseline information prior to the commencement of plant operation. This section describes key points of a regulatory-compliant REMP and potential monitoring locations for the Clinch River (CR) Small Modular Reactor (SMR) Project.

6.2.1 Introduction

A REMP is designed to adequately characterize the radiological environment of the biosphere in the vicinity of a nuclear power facility. It provides data on measurable levels of radiation and radioactive materials in the site environs and provides baseline data on surveillance of principal pathways of exposure to the public. Programs are based on the guidance provided in U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 4.1, *Radiological Environmental Monitoring for Nuclear Power Plants*, and the requirements of 10 CFR 20.1301. Preoperational monitoring programs are implemented two years before scheduled fuel load. The durations of the two-year preoperational programs for the various media at the Clinch River Nuclear (CRN) Site are given in Table 6.2-1. Because there are no radiological effluents during the preapplication, site preparation, preconstruction, or construction phases, radiological monitoring to assess the impact of radiological effluent releases is not necessary during those phases.

A REMP includes (1) the number and location of sample collection points and measuring devices, and the pathway sampled or measured; (2) sample collection frequency; (3) type and frequency of analysis; and (4) general types of sample collection and measuring equipment. The lower limits of detection for specific analyses are provided in the Off-Site Dose Calculation Manual (ODCM).

6.2.2 Radiological Environmental Monitoring Programs

A REMP is designed to monitor gaseous emissions and liquid effluents as well as direct radiation. The three primary sources of gaseous radioactive emissions include the gaseous radioactive waste management system, exhaust of non-condensable gases at the main compressor in the event of a leak from the primary system to the secondary system, and radioactive discharges from building ventilation exhaust. The plant vent provides the release path for containment venting releases and release from other design-specific areas such as the auxiliary building, the annex building, the radioactive waste building, the spent fuel building, and the gaseous radioactive waste system. In generic pressurized water reactor designs, the turbine building vents also provide a potential release path for the condenser air contaminated by a leak from the primary system to the secondary system. Liquid effluents are mixed with and diluted by the cooling tower blowdown before being discharged to receiving water bodies.

The REMP directs sampling of air, water, sediment, fish, invertebrates and food products, as well as measuring direct radiation. Milk samples are generally not monitored unless it is determined that milk-producing animals are present within 5 miles (mi) of a nuclear power facility. Tennessee Valley Authority's Clinch River land use census determined that there are no milk-producing animals currently present within 5 mi of the CRN Site. As stated in Subsection 6.2.2.2, the land use census is updated annually.

A REMP also includes sampling indicator and control locations within a 20-mi radius of the nuclear power facility. Indicator locations near the facility show any increases or buildup of radioactivity that might occur due to facility operation. Control locations farther away from the site are utilized to indicate the level of only naturally occurring radioactivity. Indicator results are compared to control and preoperational results to assess any impact the plant operation might have had on the surrounding environment. The lower limits of detection are provided in the ODCM.

6.2.2.1 Pathways Monitored

The following radiation exposure pathways are monitored as part of a nuclear power plant's REMP:

- Direct (dosimeters)
- Airborne (iodine and particulates)
- Waterborne (surface water and river sediment)
- Aquatic (fish tissue analysis)
- Vegetation (forage)

A description of the CR SMR Project monitoring and sampling locations to be utilized to monitor the exposure pathways is provided in Table 6.2-2 and approximate locations are shown in Figures 6.2-1 and 6.2-2. Monitoring locations consist of an inner ring of thermoluminescent dosimeters (TLDs) in the general area of the CRN Site with a TLD in each compass direction (T-1 through T-16), and an outer ring of TLDs located approximately 5 mi from the power block area (PBA; T-17 through T-32). In addition, particulate and airborne iodine are monitored close to the Site Boundary in the direction that has the highest calculated annual average ground level deposition. Monitoring is also provided at eight special interest locations identified in Table 6.2-2 (T-33 through T-40).

REMP sampling results and locations are evaluated to determine effects from seasonal yields and variations. Figures 6.2-1 and 6.2-2 show potential local (1-mi radius) and remote (5-mi radius) radiological sampling locations, respectively. Table 6.2-1 provides details of the radiation exposure pathways that are monitored during the preoperational period and the frequency of monitoring. Table 6.2-2 provides remote and local sample descriptions and potential locations. Table 6.2-3 provides the sampling frequencies as described in NUREG-1301, *Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors*.

The ODCM provides a detailed description of the monitoring program including number and location of sample collection points and measuring devices and the pathway sampled or measured, sample collection frequency and sampling duration, type and frequency of analysis, general types of sample collection and measuring equipment, and lower limit of detection for each analysis. Sampling media and sample size are defined in environmental monitoring and laboratory standard operating procedures.

Trending and comparison reviews provide information regarding changes in background levels and determine the adequacy of analytical techniques in light of program results and changes in technology, when being compared to baseline measurements. Changes in program implementation (including sampling techniques, frequencies and locations) may occur as a result of monitoring results.

Inter-laboratory comparison programs verify the accuracy and precision of radioactive analyses of environmental samples. These results are reported in an Annual Radiological Environmental Operating Report.

6.2.2.2 Land Use Census

A land use census is conducted annually, as required by the ODCM. The purpose of this census is to identify changes in land use within 5 mi of the CRN Site that require modifications to the REMP or the ODCM. This census also determines the location in each sector of the nearest residence, animal milked for human consumption, and garden of greater than 500 square feet producing broadleaf vegetation.

A land use census is conducted by:

- Field surveys in each meteorological sector out to 5 mi in order to confirm:
  - Nearest permanent residence
  - Nearest garden and approximate size
  - Nearest milking animal, if any
- Identifying locations on a map, measuring distances to the PBA and recording results on surveillance data sheets
- Comparing current census results to previous results
- Contacting the County Agent for verification of nearest dairy animals

6.2.3 Quality Assurance Program

A REMP is conducted in accordance with NRC RG 4.15, *Quality Assurance for Radiological Monitoring Programs (Inception Through Normal Operations To License Termination) – Effluent Streams and the Environment*. Quality assurance is provided in the REMP through quality training, program implementation by periodic tests, the inter-laboratory comparison program, and administrative and technical procedures.

6.2.4 References

Reference 6.2-1. Tennessee Valley Authority, "Clinch River Small Modular Reactor Site Regional Surface Water Use Study - Revision 2," April 24, 2015.

Table 6.2-1
Duration of Preoperational Program for Specific Media

6 Months	1 Year	2 Years
Airborne iodine	Airborne particulates	Direct radiation
Iodine in milk[1]	Milk[1]	Fish and invertebrates
(while animals are in pasture)	(remaining analyses)	
	Surface water	Food products
	Groundwater	Sediment from shoreline
	Drinking water	

1 Milk samples are generally only collected if milk cattle are determined to be present within 5 mi of the CRN Site.

Table 6.2-2 (Sheet 1 of 3)
Potential Radiological Environmental Monitoring Program Sample Station Locations

Location	Description	Approx. Distance (mi)[1]	Direction Sector
Direct Radiation			
T-1	TLDs	0.2 (near power block area [PBA])	N
T-2		0.2 (near the PBA)	NNW
T-3		0.4 (near the entrance to the site)	NW
T-4		0.4 (near the holding pond)	WNW
T-5		0.2 (near the cooling tower)	W
T-6		0.2 (near the cooling tower)	WSW
T-7		0.2 (near the cooling tower)	SW
T-8		0.3 (near the cooling tower)	SSW
T-9		0.3 (near the cooling tower)	S
T-10		0.4 (near the holding pond)	SSE
T-11		0.2 (near the PBA)	SE
T-12		0.1 (near the PBA)	ESE
T-13		0.1 (near the PBA)	E
T-14		0.1 (near the PBA)	ENE
T-15		0.1 (near the PBA)	NE
T-16		0.1 (near the PBA)	NNE
T-17		5.0 (5-mi ring around the PBA)	N
T-18		5.0 (5-mi ring around the PBA)	NNW
T-19		5.0 (5-mi ring around the PBA)	NW
T-20		5.0 (5-mi ring around the PBA)	WNW
T-21		5.0 (5-mi ring around the PBA)	W
T-22		5.0 (5-mi ring around the PBA)	WSW
T-23		5.0 (5-mi ring around the PBA)	SW
T-24		5.0 (5-mi ring around the PBA)	SSW
T-25		5.0 (5-mi ring around the PBA)	S
T-26		5.0 (5-mi ring around the PBA)	SSE
T-27		5.0 (5-mi ring around the PBA)	SE
T-28		5.0 (5-mi ring around the PBA)	ESE
T-29		5.0 (5-mi ring around the PBA)	E
T-30		5.0 (5-mi ring around the PBA)	ENE
T-31		5.0 (5-mi ring around the PBA)	NE
T-32		5.0 (5-mi ring around the PBA)	NNE

Table 6.2-2 (Sheet 2 of 3)
Potential Radiological Environmental Monitoring Program Sample Station Locations

Location	Description	Approx. Distance (mi)[1]	Direction Sector
Direct Radiation			
T-33	TLDs	0.8 mi (near a close residence)	E
T-34		1 mi (close to residence)	W
T-35		0.8 mi (near a garden)	NE
T-36		4.7 mi (Oak Ridge National Laboratory)	NE
T-37		3.5 mi (Four Season Campground)	WSW
T-38		6.0 mi (Kingston Elementary School)	WSW
T-39		6.0 mi (Eatons Elementary School)	SE
T-40		2.5 mi (Poplar Springs Church)	WSW
Waterborne			
W-1	Surface Water	Approximately Clinch River Mile (CRM) 15.5 - Discharge Location	WNW
W-2		Approximately CRM 17.9 - Intake Location	NE
W-3	Groundwater	Samples to be taken from two of the 21 groundwater wells at the CRN Site if they are likely to be affected	TBD
W-4			TBD
W-5	Drinking	No drinking water samples are being taken because no water supplies would be affected by the discharge from the plant within 15 mi downstream	NA
W-6	Sediment from Shoreline	1.5 mi (Gallaher Recreational Area)	NNW
Airborne			
A-1	Airborne: Radioiodine and Particulates	Three samples from close to the three site locations, in different sectors, of the highest calculated annual average groundlevel D/Q; 0.25 mi (average D/Q 5.80E-08)	ENE
A-2		0.25 mi (average D/Q 5.98E-08)	ESE
A-3		0.25 mi (Average D/Q 5.49E-08)	SE
A-4		One sample from the vicinity of a community having the highest calculated annual average groundlevel D/Q 1 mi (D/Q 6.38E-09)	ESE
A-5		One sample from a control location, as for example 15 to 30 km from the site boundary, and in the least prevalent wind direction. As the least prevalent winds are from the NNW direction	SSE

Table 6.2-2 (Sheet 3 of 3)
Potential Radiological Environmental Monitoring Program Sample Station Locations

Location	Description	Approx. Distance (miles)[1]	Direction Sector
Ingestion			
M-x	Milk	The survey done in accordance with the guidance provided in NRC NUREG-1301 did not find any locations where milk was being produced for human consumption	NA
F-1-x	Fish and Invertebrates	One sample of representative commercially and recreationally important species identified in the Table 2.4.2-1 to be taken from the vicinity of plant discharge area	TBD
F-2-x		One sample of representative commercially and recreationally important species identified in the Table 2.4.2-1 to be taken from area not influenced by discharge	TBD
FP-1	Food Products	One sample of each principal class of food products from any area that is irrigated by water in which liquid plant wastes have been discharged. Vegetation sampled during growing season.	TBD
FP-2		Samples of three different kinds of broad leaf vegetation grown nearest each of two different offsite locations of highest predicted annual average ground level D/Q, if milk sampling is not performed. Vegetation sampled during growing season. 1 mi (D/Q 6.38E-09)	ESE
FP-3		0.75 mi (D/Q 5.57E-09)	NE
FP-4		One sample of each of the similar broad leaf vegetation grown 15 to 30 km distant in the least prevalent wind direction if milk sampling is not performed. Vegetation sampled during growing season.	S

[1] All distances in the table are approximate and measured from the center of the site unless otherwise noted.

Notes:
T = TLD (direct radiation)
W = Waterborne
A = Airborne (particulates and iodine)
M = Milk
F = Fish
FP = Food Products (other than fish and milk)
km = kilometers
TBD = To Be Determined
NA = Not Applicable

Source: (Reference 6.2-1)

Table 6.2-3 (Sheet 1 of 2)
Site Preparation, Construction/Preoperational, and Operational Radiological Environmental Monitoring Program[1]

Exposure Pathway and/or Sample	Number of Representative Samples and Sample Locations[2,3]	Sample and Collection Frequency[4]	Type and Frequency of Analysis[4]
1. Direct Radiation[5]	40 Monitoring Locations	Continuous monitoring with sample collection quarterly[6]	Gamma exposure rate – quarterly
2. Airborne Radioiodine and Particulates	Five Locations	Continuous sampler operation with sample collection at least weekly or more frequently if required by dust loading	Radioiodine Canister - Analysis for I-131 weekly Particulate Sampler - Gross beta radioactivity analysis following filter change[7]; Gamma isotopic analysis[8] of composite[7] (by location) quarterly
3. Waterborne			
a. Surface	Two Locations[10]	Monthly	Gamma isotopic[8] and tritium analysis monthly. Composite for tritium quarterly
b. Ground	Two Locations	Quarterly	Gamma isotopic[8] and tritium analysis Quarterly
c. Drinking[9]	None	None	
d. Sediment from Shoreline	One sample from downstream area	Semiannually	Gamma isotopic analysis semi-annually
4. Ingestion			
a. Milk	None	Semimonthly when animals are on pasture; monthly at other time	Gamma isotopic and I-131
b. Fish and Invertebrates	One sample of representative commercially and recreationally important species in vicinity of plant discharge and another sample from the area not influenced by the discharge.	Sample in season, or semiannually if they are not seasonal.	Gamma isotopic analysis[8] on edible portions.
c. I Food products (irrigation)	Samples depend on food products that are irrigated by the water in which the liquid wastes are discharge.	At the time of harvest.	Gamma isotopic analysis[8] and I-131 analysis.
c. II Food Products (broadleaf vegetation – near site)	Broadleaf vegetation grown nearest highest predicted annual average ground level D/Q	Monthly during growing season.	Gamma isotopic analysis[8] and I-131 analysis.

Table 6.2-3 (Sheet 2 of 2)
Site Preparation, Construction/Preoperational, and Operational Radiological Environmental Monitoring Program[1]

Exposure Pathway and/or Sample	Number of Representative Samples and Sample Locations[2,3]	Sample and Collection Frequency[4]	Type and Frequency of Analysis[4]
c. III Food Products (broadleaf vegetation - background)	One sample of each of the similar broad leaf vegetation grown in the least prevalent wind direction.	Monthly during growing season.	Gamma isotopic analysis[8] and I-131 analysis.

1 Deviations are permitted from the required sampling schedule if specimens are unobtainable due to circumstances such as hazardous conditions, seasonal unavailability, and malfunction of automatic sampling equipment or other legitimate reasons. If specimens are unobtainable as a result of sampling equipment malfunction, corrective action shall be taken before the end of the next sampling period. All deviations from the sampling schedule will be documented in the Annual Radiological Environmental Operating Report pursuant to Control 1.4.

2 Specific parameters of distance and direction sector from the centerline of the plant vent stack and additional description where pertinent, will be provided for each and every sample location in tables and figure(s) in the ODCM.

3 At times, it may not be possible or practicable to continue to obtain samples of the media of choice at the most desired location or time. In these instances, suitable alternative media and locations may be chosen for the particular pathway in question and appropriate substitutions made within 30 days in the Radiological Environmental Monitoring Program given in the ODCM.

4 The following definition of frequencies shall apply to Table 6.2-3 only:

a. Weekly: Not less than once per calendar week. A maximum interval of 11 days is allowed between the collection of any two consecutive samples.

b. Semimonthly: Not less than 2 times per calendar month with an interval of not less than 7 days between sample collections. A maximum interval of 24 days is allowed between collection of any two consecutive samples.

c. Monthly: Not less than once per calendar month with an interval of not less than 10 days between collection of any two consecutive samples (maximum interval of 31 days).

d. Quarterly: Not less than once per calendar quarter (maximum interval of 92 days).

e. Semi-annually: One sample each between calendar dates (January 1 to June 30) and (July 1 to December 31). An interval of not less than 30 days will be provided between sample collections. The frequency of analyses is to be consistent with the sample collection frequency.

5 One or more instruments, such as a pressurized ion chamber, for measuring and recording dose rate continuously may be used in place of, or in addition to, integrating dosimeters. For the purposes of this table, a TLD is considered to be one phosphor; two or more phosphors in a packet are considered as two or more dosimeters.

6 Refers to normal collection frequency. Most frequent sample collection is permitted when conditions warrant it.

7 Airborne particulate sample filters are analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thorium daughter decay. In addition to the requirement for a gamma isotopic on a composite sample, a gamma isotopic is also required for each sample having a gross beta radioactivity which is >1.0 pCi/m^3 and which is also >10 times that of the most recent control sample.

8 Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the facility.

9 Discharges to the Clinch River arm of the Watts Bar Reservoir do not influence drinking water quality (see Subsection 5.2.2).

10 Offshore grab samples.

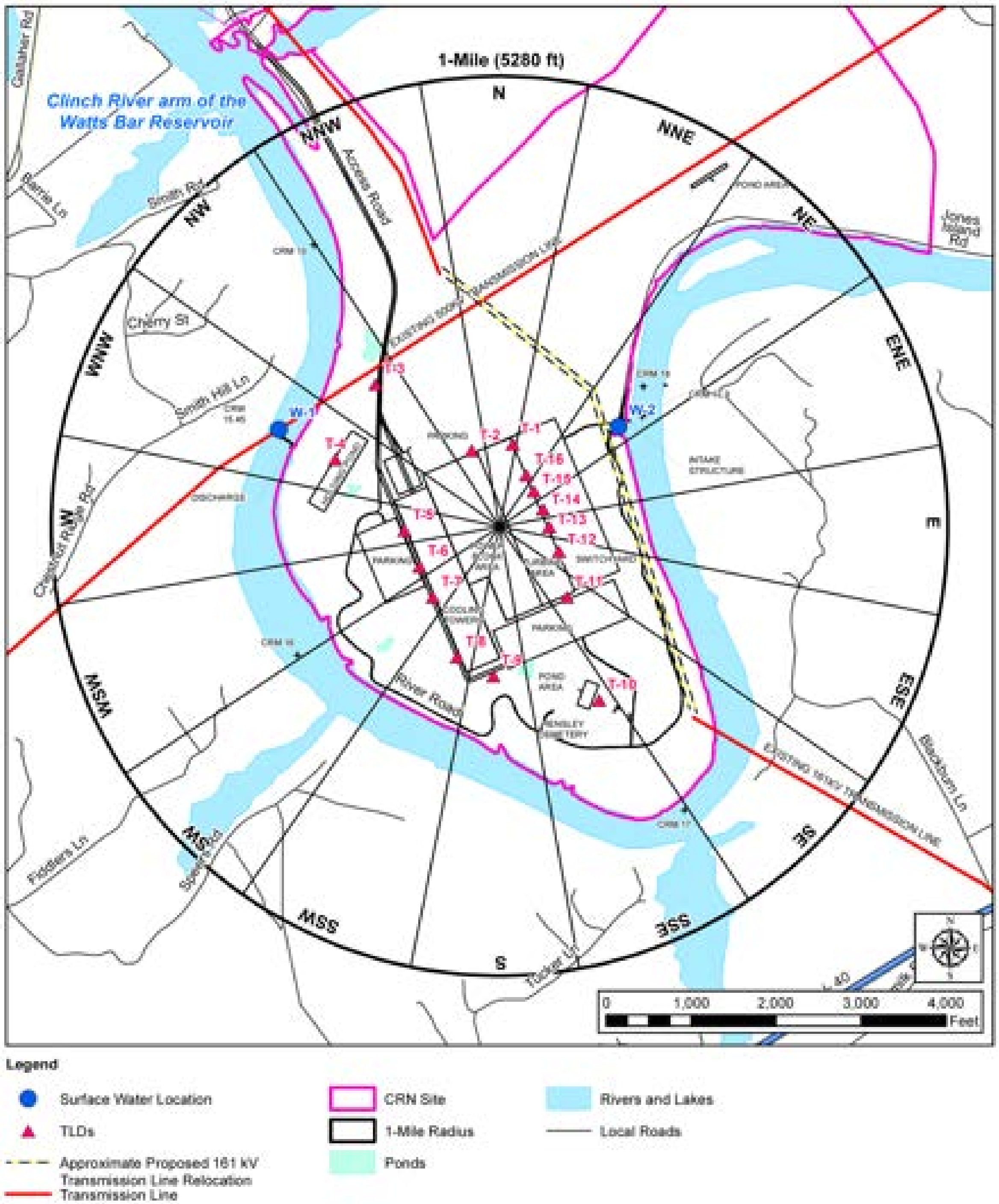


Figure 6.2-1. CRN Site Local Radiological Sampling Locations (1-Mile Radius)

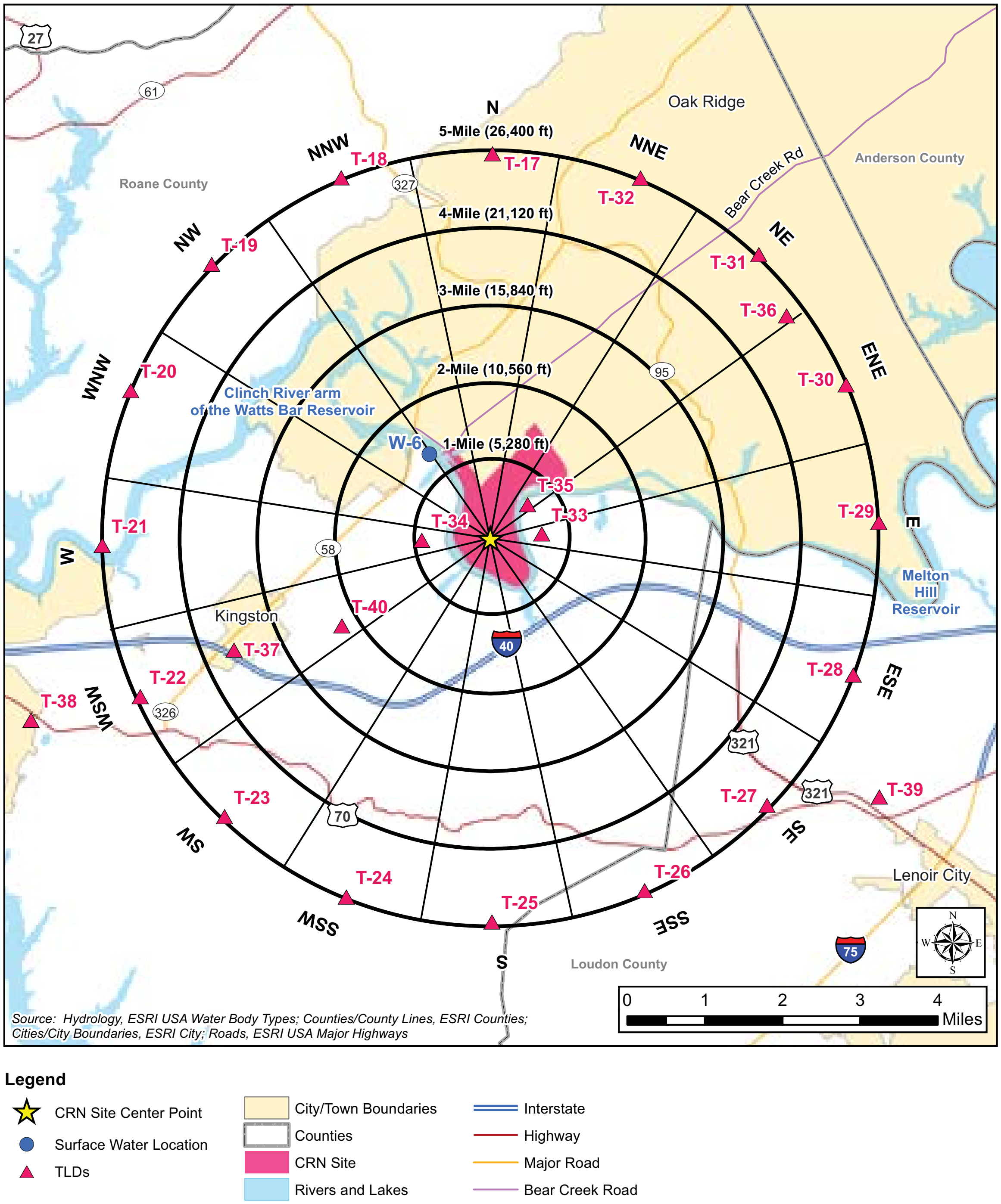


Figure 6.2-2. CRN Site Remote Radiological Sampling Locations (5-Mile Radius)

6.3 HYDROLOGICAL MONITORING

This section describes the hydrological monitoring program at the Clinch River Nuclear (CRN) Site. Discussions related to historic and current water use at and near the CRN Site are found in Subsections 2.3.2 and 2.3.3 and water use at the CRN Site for the Clinch River (CR) small modular reactors (SMR) Project is discussed in Section 3.3. Potential discharges from the CR SMR Project are discussed in Sections 3.4, and 3.6. Baseline environmental water quality is described in Subsection 2.3.3. As shown on Figure 3.3-1, effluent from the CRN Site discharges to the Clinch River arm of the Watts Bar Reservoir. Effluent discharges to navigable water bodies are governed by several regulations including the Clean Water Act (CWA), Title 40 of the Code of Federal Regulations (40 CFR) Part 122, 40 CFR Part 423, and state water quality standards. In order to discharge effluents to navigable streams, a National Pollutant Discharge Elimination System (NPDES) permit pursuant to Section 402 of the CWA is required. Prerequisites for obtaining an NPDES permit include collecting adequate baseline monitoring samples and providing a plan for collection of operational monitoring samples. The proposed hydrological monitoring program at the CRN Site is divided into four phases as outlined below:

1. Site preparation/preapplication monitoring on a seasonal basis to verify the existing hydrologic conditions, validate the design assumptions for hydrologic impacts, and validate the baseline hydrologic descriptions presented in Subsection 2.3.1.1.1
2. Construction monitoring to assess anticipated impacts from construction activities, and identify unexpected impacts
3. Preoperational monitoring to establish a post-construction baseline as a point of comparison in order to identify hydrologic impacts that may result from operation of the proposed SMRs
4. Operational monitoring to assess impacts to water quality resulting from operation of the SMRs

6.3.1 Site Preparation Monitoring

The purpose of the site preparation monitoring program is to provide data to support the assessment of potential impacts that may result from the construction and operation of the proposed SMRs at the CRN Site. The site preparation hydrologic monitoring process involved the collection and analysis process for surface water and groundwater data as described in Subsections 6.3.1.1 and 6.3.1.2, respectively.

6.3.1.1 Surface Water

The hydrology of the area around the CRN Site was described in Subsection 2.3.1.1.1. The following site preparation surface water monitoring tasks were conducted to verify hydrologic conditions.

- Hydrographic surveys of the Clinch River arm of the Watts Bar reservoir were performed from CRM 13 to CRM 21 in June 2013. The results of this survey, including a figure depicting the bathymetry in the vicinity of the CRN SMR diffuser, are included in Subsection 2.3.1.1.2.8.

- An evaluation of the historical stream flow data for the Watts Bar Reservoir from 2004 through 2013 was conducted. A summary of this information is summarized in Subsection 2.3.1.1.2.4.
- Local surface water quality in the Upper Tennessee River Basin from 1994 to 1998 was evaluated and is summarized in Subsection 2.3.3.1.1.

Figure 2.3.1-14 shows the CRN Site features including boundaries and bathymetry of all surface-water bodies. Figure 2.6-2 shows the physiography of local region surrounding the CRN Site and the geologic features of the CRN Site are included on Figure 2.6-4. The locations of streams, ponds, and wetlands are shown on Figure 2.4.1-2, and the sampling locations for surface water and stormwater monitoring in the immediate vicinity of the CRN Site are shown in Figure 2.3.3-1. As stated in Subsection 2.3.1.1.2.9, there are currently no site-specific data available on erosion and sediment transport in the vicinity of the CRN Site. This information is to be addressed at the time of the combined license application.

6.3.1.2 Groundwater

As part of the site preparation monitoring, TVA collected samples to characterize groundwater quality at the CRN Site. Sampling was conducted on a quarterly basis to satisfy requirements for the preapplication monitoring program and to provide information regarding existing groundwater conditions. The list of parameters analyzed to characterize the groundwater at the CRN Site included:

- Volatile Organic Compounds
- Semivolatile Organic Compounds
- Pesticides/Polychlorinated Biphenyls
- Total Petroleum Hydrocarbons
- Metals, cyanide, and radionuclides
- Acid/base/neutral compounds, including Polycyclic Aromatic Hydrocarbons
- Field water-quality parameters (Reference 6.3-1)

In the fall of 2013, 37 observation wells were installed on the CRN Site, consisting of 15 clusters of two to three wells each. Each cluster consists of an upper and lower well, with some clusters containing an additional deep well. Sampling was performed in December 2013 to January 2014, April 2014, August 2014, and November 2014. The data were also used to help TVA to determine the potential for direct, indirect, and cumulative effects from operating a SMR at the CRN Site. (Reference 6.3-1)

As discussed in Subsection 2.3.1.2.1.4.2, site groundwater characterization activities included drilling 82 boreholes, installing 44 wells, monitoring groundwater level, performing packer tests in boreholes, performing slug tests in monitoring wells, performing an aquifer pumping test, and collecting groundwater geochemical samples. Groundwater level monitoring is discussed in Subsections 2.3.1.2.2.2 and 2.3.1.2.2.3, aquifer properties are discussed in Subsection 2.3.1.2.2.4, and geochemical results are discussed in Subsection 2.3.3.2. The groundwater characterization described in Subsection 2.3.1.2.1.4.2 was in addition to the site preparation monitoring conducted in 2013 and 2014.

6.3.2 Construction and Preoperational Monitoring

Hydrological monitoring is conducted during preconstruction and construction activities in order to assess and control the impacts from preconstruction and construction activities. During the preoperational monitoring period, data from ongoing monitoring programs may be used and evaluated as appropriate to establish a hydrological baseline. The following subsections outline general surface water and groundwater monitoring activities that may be conducted during the preconstruction/construction and preoperational monitoring periods. Site specific construction/preconstruction and preoperational surface water and groundwater monitoring plans are developed in accordance with all applicable regulations.

6.3.2.1 Surface Water

Surface water monitoring requirements for preconstruction and construction activities are developed as part of the permit application for an NPDES construction stormwater permit for discharges of stormwater associated with construction activities issued by the Tennessee Department of Environment and Conservation (TDEC). Additionally, prior to initiation of preconstruction activities, a completed and signed Notice of Intent for Construction Activity Stormwater Discharges and an associated Surface Water Pollution Prevention Plan (SWPPP) will be submitted to TDEC. Typical surface water discharges that may occur during preconstruction and construction activities include stormwater runoff and construction dewatering discharges. A SWPPP includes procedures to limit erosion, sedimentation, and other impacts to surface water as a result of preconstruction and construction activities. SWPPPs usually include erosion and sediment control measures and periodic inspections to ensure those measures are protective of site surface water. Additional monitoring activities may also be conducted as required by applicable permits.

6.3.2.2 Groundwater

Groundwater monitoring is conducted when preconstruction and/or construction activities have the potential to adversely affect site groundwater. Potential hydrologic effects resulting from construction activities could include increased groundwater recharge as a result of seepage from the cooling system holding pond and other stormwater retention ponds, changes in groundwater elevations caused by dewatering of foundation excavations, and/or general changing of the groundwater table due to topographic alterations.

Two years of quarterly sampling precedes the preconstruction and construction period. Eight quarterly sampling events provide a solid preoperational baseline dataset. Current plans include collecting samples from 19 existing wells, eight of which are to be redeveloped due to high turbidity issues. During the interim, the wells are locked and inspected. Groundwater monitoring during preconstruction and construction may also involve measuring water levels to monitor potential draw down caused by preconstruction and construction activities, sampling for the presence of new contaminants, and sampling for increased concentrations of known contaminants relative to site preparation monitoring results.

6.3.3 Operational Monitoring

In general, operational monitoring programs are designed to assess impacts to the surface water parameters (surface water flow, groundwater flow, sediment transport, and/or water quality) resulting from facility operations. Monitoring requirements for the surface water parameters are defined in the NPDES permit, as specified in Section 2.1, of TVA’s Environmental Protection Plan (EPP) (Appendix B). The permit considers effluent limitations, monitoring requirements, and mitigation measures. Sections 2.3, 4.1, and 4.3 of the EPP describe the process for monitoring onsite mortality, injury, or unusual behavior that may result from hydrologic modifications, reporting it to NRC and other applicable regulatory agencies, and maintaining records (Appendix B). Details related to the operation of the proposed CR SMR Project at the CRN Site have not been yet been finalized; however, operational monitoring programs are designed to comply with all applicable regulatory requirements.

6.3.4 References

Reference 6.3-1. Tennessee Valley Authority, "Groundwater Quality Monitoring Report," Rev. 1, April 20, 2015.

6.4 METEOROLOGICAL MONITORING

The section describes the meteorological monitoring program at the Clinch River Nuclear (CRN) Site. This section also evaluates the program's adequacy for characterizing atmospheric transport and diffusion conditions representative of the CRN Site and surrounding area and providing a meteorological database for evaluation of the effects of construction and operation of two or more small modular reactors (SMRs) to potentially be built at the CRN Site.

This section provides a description and evaluation of the meteorological monitoring program, which includes:

- Meteorological tower location and instrument siting
- Meteorological parameters measured
- Meteorological Sensors
- Data recording and transmission
- Instrument maintenance and calibration
- Data acquisition and reduction
- Data screening and validation
- System accuracy

This evaluation demonstrates that the meteorological monitoring program for the CRN Site meets the relevant requirements of Title 10 of the Code of Federal Regulations (10 CFR) 50, Appendix I; 10 CFR 51.45(c); 10 CFR 51.50; 10 CFR 52.17(a)(1); 10 CFR 100.20(c)(2); the guidance in Section C of U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.23, *Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants*; Section C.4 of NRC RG 1.111,, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*; and NRC RG 1.21, *Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste*.

The nominal temperature and wind sensor heights are 10 and 60 meters (m), although other heights may be stated in this document or reference documents. Exact measurement heights are given in the Environmental Data Station (EDS) Manual. (Reference 6.4-1)

6.4.1 Historical Data Collection at the CRN Site

The meteorological monitoring program at the CRN Site began in 1973 for the Clinch River Breeder Reactor Project (CRBRP) and ended in 1983. Subsequently, data were collected for the CRN Site Early Site Permit Application (ESPA) from 2011 until 2013. Various meteorological parameters were recorded from three meteorological towers originally installed to support the CRBRP. The locations of these meteorological towers are shown in Figure 6.4-1 and the data collected at these towers during various time periods are summarized in Table 6.4-1 (Reference 6.4-1). Meteorological Tower 1 (Mt) was located on the west side of the CRN Site; data were recorded at Meteorological Tower 1 from April 11, 1973 to April 2, 1974 and from April 3, 1974 to March 2, 1978. Meteorological Tower 2 (Ms) was located along the north side of the CRN Site; data were collected from Meteorological Tower 2 from February 16, 1977 to March 6, 1978 and again from March 25, 1982 to November 4, 1983. Meteorological Tower 3 (Mp) was located on the southeast side of the CRN Site; data were collected at Meteorological Tower 3 from February 16, 1977 to March 6, 1978; March 25, 1982 to November 4, 1983; and again from April 21, 2011 to July 9, 2013 (Reference 6.4-1).

Meteorological Towers 1 and 2 have been removed. Meteorological Tower 3 was already present on the CRN Site when the ESPA was initiated and it met many of the current NRC requirements for placement of meteorological monitoring instruments. Therefore, Meteorological Tower 3 was refurbished in 2011 to meet NRC requirements and used to provide the meteorological monitoring data for the preapplication and preoperational phases of the ESPA (Reference 6.4-1). Meteorological Tower 3 was then removed in 2014. A new meteorological tower for the operational phase is expected to be constructed at the same location as the former Meteorological Tower 3.

6.4.2 Site Preparation Monitoring

For the CR SMR Project's site preparation meteorological monitoring program, the meteorological data collection system at Meteorological Tower 3 was refurbished in 2011 to meet NRC RG 1.23 and other requirements, as outlined in Tennessee Valley Authority's (TVA's) Specifications for Meteorological Monitoring for TVA Nuclear Plants (Reference 6.4-1; Tennessee Valley Authority 2013). The site preparation meteorological monitoring program for the proposed SMRs is described in the following subsections.

6.4.2.1 General Site Description

The CRN Site is situated in a valley between two major mountain regions: to the northwest lie the Cumberland Mountains and to the southeast are the Great Smoky Mountains. These mountain regions orient this valley in a southwest to northeast alignment. (Reference 6.4-3) Locally, the Clinch River arm of the Watts Bar Reservoir runs along the east, west and south sides of the CRN Site. As stated in Subsection 2.2.1.1, the elevation of the CRN Site ranges from approximately 745 feet (ft) above mean sea level (msl) to approximately 940 ft msl.

The description of the topographic features of the CRN Site provided in Section 2.2, combined with the description of dispersion characteristics provided in Section 2.7, form the basis for assessing the adequacy of the meteorological monitoring program for the CRN Site.

6.4.2.2 Meteorological Tower Description, Location, and Exposure

TVA's onsite EDS was used for meteorological data collection and transmission. The EDS included a 110-m meteorological tower (Meteorological Tower 3, with meteorological sensors located at the 10-m and 60-m levels), surface meteorological sensors, and a small building equipped with office space, a computer/data logger, cellular modem, and related equipment. (Reference 6.4-1)

The meteorological tower was designed to withstand the simultaneous loads of the following:

- Wind velocity of 90 miles (mi) per hour (mph; 3-second gust), which is equivalent to a 50-year recurrence interval (per pressure loads given by Electronic Industries Association Code TIA-222-G).
- A vertical weight load of the tower, guy wires, and equipment. (Reference 6.4-1)

A system of lightning and surge protection circuitry with proper grounding was included in the facility design (Reference 6.4-1).

Meteorological Tower 3 was located at UTM coordinates 3974.21 kilometers (km) (Northing) and 736.88 km (Easting) on UTM Zone 16, approximately 830 ft to the south of the proposed facility area (Figure 2.1-1). The meteorological tower's base elevation was at 799.9 ft msl and the facility grade elevation is approximately 821 ft msl. The instrument building was located to the east-southeast of the meteorological tower. Because the area around the meteorological tower is relatively flat, the instrument building's base elevation was comparable to that of the meteorological tower's base elevation. The solar radiation instrumentation, not situated on the meteorological tower, was located near the meteorological tower at an elevation of 799.5 ft msl. (Reference 6.4-1)

The existing Meteorological Tower 3 and surface instruments were used to provide data that are representative of atmospheric conditions at the CRN Site, as well as the surrounding area. The meteorological tower location was such that the instrument sensors were not adversely influenced by buildings, man-made structures, obstructions, terrain, vegetation (as trees), and other activities onsite or in the surrounding area. The suitability of the meteorological tower location was confirmed by meteorologists knowledgeable of the surroundings and conditions that might affect the collection of meteorological data. The meteorological tower and surface sensor locations were reviewed annually in relation to their surroundings to compensate for changes and/or take corrective actions as necessary.

6.4.2.3 Potential Obstructions Surrounding Meteorological Tower

In accordance with NRC RG 1.23, wind measurements should be made at locations that avoid large buildings, man-made structures or natural obstructions. General guidance states that "sensors should be located over level, open terrain at a distance of at least 10 times the height of any nearby obstruction if the height of the obstruction exceeds one-half the height of the wind measurement." Since the lowest level wind measurement height was 10 m above the base of the meteorological tower, nearby obstructions with heights at or over 5 m (16.4 ft) above the meteorological tower base elevation out to a distance of 10 times the height of the nearby obstructions were evaluated.

Meteorological Tower 3 was situated on the southeastern portion of the CRN Site, which is characterized as a relatively flat plateau (Reference 6.4-4). The ground surface surrounding the location of the meteorological tower is characterized as an open, level field consisting of a mix of grasses, scattered low shrub-like plants, and bare dirt. A gravel road provides access to the meteorological tower site. The meteorological tower's location conformed to guidance regarding surface characteristics and also avoided the effects of parking lots and large paved areas that could potentially modify temperature measurements.

Both local terrain and the region's topography may potentially influence meteorological conditions at a project site. The meteorological tower was located on a plateau at an elevation of approximately 800 ft msl, similar to the grade of the proposed facility area. Because both the proposed facility area and meteorological tower location are on the south side plateau of the CRN Site, exposures are similar. Figure 6.4-2 shows the location of the former meteorological tower and a 6-mi radius. The location of the former meteorological tower on the plateau area provided good exposure to air flow for winds along the general southwest-northeast orientation of the terrain in the Oak Ridge region. This orientation aligns with the prevailing winds. Because terrain in some locations of the Oak Ridge area rises to near 1200 ft msl, the 60-m level represents exposure to regional conditions. The local surroundings of the CRN Site, including the combination of the Clinch River arm of the Watts Bar Reservoir and terrain along its shore, influenced wind readings at the meteorological tower under certain atmospheric conditions. Thus, it is concluded that the 10-m level represents the CRN Site's meteorological conditions.

As shown on Figure 6.4-3, potential wind measurement obstructions around the meteorological tower included: an instrument building, a small stand of trees to the southeast, a power line transmission tower, and the tree line at the edge of the open field in which the meteorological tower was situated.

The instrument building was located approximately 150 ft to the southeast of the meteorological tower at about the same base elevation as the meteorological tower (Reference 6.4-1). The height of the instrument building was approximately 10 ft. This height does not exceed "one-half the height of the lower wind measurement" (16.4 ft) stated as guidance in NRC RG 1.23. Therefore, it is concluded that the instrument building did not influence wind measurements taken at the meteorological tower.

The stand of trees is situated beyond where the instrument building was located and is approximately 225 ft to the southeast of the former location of the meteorological tower (Reference 6.4-1). This area is surrounded by a chain link fence with trees inside the fenced area. The chain link fence is approximately 6 ft high. At this height, the chain link fence is not an obstruction to wind measurements.

Both the trees within the fenced area and the nearby power line transmission tower were evaluated in detail by TVA as potential obstructions to measurements collected from the meteorological tower. The power line transmission tower is located approximately 400 ft northeast of the meteorological tower. Prior to initiating monitoring for the ESPA, TVA meteorologists evaluated these obstructions and determined they would have minimal impact on data collected from the meteorological tower. TVA meteorologists also used sigma theta measurements to identify the potential impact of these two obstructions on measurements from the meteorological towers. ANSI-ANS-3.11-2005 defines sigma theta as "the standard deviation of the horizontal wind direction." Sigma theta is an indicator of wind turbulence. Sigma theta values tend to be greater for winds from obstructed wind directions compared to winds from unobstructed wind directions. For the CRN Site, there was no indication of an increase in sigma theta for wind directions associated with potential obstructions compared to unobstructed wind directions on either side of the obstruction. It was concluded that the transmission tower and trees have minimal impact on the wind measurements at the CRN Site.

Trees line the open field surrounding the meteorological tower in an approximate circular manner. The tree line was approximately 310 ft to 440 ft from where the meteorological tower was located, depending on direction, with the only exception being the small stand of trees discussed above. Trees and other vegetation were evaluated during periodic meteorological monitoring site inspections of the meteorological tower. Four inspections were conducted to determine conformance with requirements of the meteorological tower within the context of its surroundings. These were performed by TVA on January 19, 2011 (preoperational); April 26, 2011; August 7, 2012; and April 9, 2013. Inspections demonstrated the meteorological measurement site was conditionally acceptable during the initial preoperational inspection and acceptable during the three later operational inspections.

6.4.2.4 Meteorological Measurements

The meteorological measurement program for the CRN Site was developed consistent with regulatory requirements. Prior to initiation of the meteorological monitoring program beginning in April of 2011, the data collection system was refurbished to meet NRC RG 1.23 and other specifications (Reference 6.4-1).

Meteorological sensors were located at the following levels:

- Wind speed and direction: 10-m and 60-m
- Dry bulb temperature: 10-m and 60-m
- Dew point temperature: 10-m and 60-m
- Solar Radiation: 1-m
- Rain Gauge: 1-m (Reference 6.4-1)

The wind speed and wind direction sensors were Vaisala Model 425 ultrasonic wind sensors. The wind speed sensor provided a digital signal, and had a resolution of 0.1 mph, and an operating range of 0.1 to 144 mph. The wind direction sensor also produced a digital signal, and had a resolution of 1 degree and operating range of 0 to 360 degrees. Note that the output or recording range from the EDS computer was 0 to 99.9 mph for wind speed and 0 to 359 degrees for wind direction. (Reference 6.4-1)

Air temperature was measured using Weed Instrument Company, Model 101, platinum wire resistance temperature detectors (RTDs). The RTDs provided analog signals to the data logger in the range of 86 to 120 ohms. The output (recording) range of the temperature measurements were -30.00 degrees Fahrenheit (ºF) to +120.00ºF. The resolution of the temperature measurement was 0.01ºF. The temperature sensors were mounted within aspirated shields (R.M. Young Company, Model 43408). The solar radiation shields operated with an aspiration flow rate of 3.5 to 7.6 meters per second (m/s). The aspirated shields had a maximum radiation error of 0 to +0.4ºF. (Reference 6.4-1)

Delta-temperature is not provided directly as a meteorological tower measurement but was calculated using the meteorological monitoring program's computer software and the 60-m and 10-m recorded air temperature measurements. Delta-temperature was considered valid if both the 60-m and 10-m air temperatures were valid. (Reference 6.4-1)

The dew point sensors were a Vaisala, Model HMT337, Humidity and Temperature Transmitter for High Humidity Applications. The Vaisala unit was a capacitive humidity sensor with a warmed probe head and was mounted in a R.M. Young Company solar radiation shield (Model 43502). The aspiration shield flow rate was 5 to 10 m/s. The dew point sensors provided an analog signal (2.000 to 5.300 volts) to the EDS computer/data logger. The output (recording) range of the dew point temperature measurements was -4.00ºF to 85.00ºF, with a resolution of 0.01ºF. (Reference 6.4-1)

Solar radiation was measured with an Eppley Laboratories Model 8-48 pyranometer. The unit had a sensitivity of 0.001 Langleys per minute (ly/min) and response time of 5 seconds. The unit provided an analog signal to the EDS computer/data logger from -0.02 to 30.0 millivolts (mVolts). The output (recording) range from the EDS computer was 0.00 to 3.00 ly/min with a resolution of 0.01 ly/min. (Reference 6.4-1)

The meteorological monitoring program also included a Sutron Corporation, Model 5600-0420-1h, heated tipping bucket rain gauge. The rain gauge had a resolution of 0.01 inches (in.) of water and range of 0.00 to 10.00 in. of water (Reference 6.4-1). However, during the 27-month period from April 21, 2011 to July 9, 2013, there were repeated problems with the onsite rain gauge. NRC RG 1.23 requires annual 90 percent data recovery rates for proposed nuclear plant sites. Therefore, for this 27-month data collection period, TVA determined that the onsite precipitation data were invalid. Repeated instrument and power supply problems rendered the rainfall data collected onsite as unreliable for two periods which represent almost half of the data collection period. As a result, it was determined that the precipitation data collected onsite during this period would not be used for regulatory applications. Instead, near coincident hourly data from the Oak Ridge National Weather Service was used to describe rainfall for the CRN Site and its surroundings during that 27-month period. The Oak Ridge National Weather Service (NWS) Station is located 12 mi to the northeast of the CRN Site and is a standard NWS Automated Surface Observing System. During the 27-month ESPA data collection period, the Oak Ridge NWS Station data indicated only 3 days of missing data (based on hourly observations versus daily totals). Hourly precipitation data for Oak Ridge NWS Station were taken from monthly Local Climatological Data publications produced by the National Climatic Data Center (NCDC). NCDC serves as a national clearinghouse which provides validated meteorological data for NWS Stations around the United States.

6.4.2.5 Meteorological Sensor Orientation

NRC RG 1.23 provides guidance with regard to situating sensors on a meteorological tower to alleviate potential tower effects on sensor readings. The CRN Site meteorological tower was designed in accordance with NRC RG 1.23 and other specifications (Tennessee Valley Authority 2013).

Wind sensors were situated at both the 10-m and 60-m levels of the meteorological tower. For areas such as the CRN Site located in a valley (oriented southwest to northeast, between the Cumberland Mountains and Great Smoky Mountains) and having “two distinct” prevailing wind directions, NRC RG 1.23 states wind “sensors should be mounted in a direction perpendicular to the primary two directions.” Consistent with this requirement, the wind sensor booms extended to the southeast of the meteorological tower to avoid influence of the tower on wind measurements. The originally installed sensor mounting arms were too short, being installed at 91 in. The sensors were moved to 100 in. from the meteorological tower on October 18, 2011. At 100 in. from the meteorological tower, the sensors were located 2.08 tower widths from the meteorological tower. (Reference 6.4-1)

In accordance with NRC RG 1.23, the air temperature sensors (at both 10-m and 60-m) were mounted in downward pointing radiation shields to avoid modification of heat sources. The sensor inlet was positioned to the east, 72 in. from the meteorological tower or equivalent to 1.50 tower widths from the meteorological tower. The dew point sensors were also placed in downward pointing shield and located at approximately 1 m directly above the air temperature sensor. (Reference 6.4-1)

The solar radiation pyranometer was located approximately 55 ft to the south of the meteorological tower, 4 ft above ground level (Reference 6.4-1).

6.4.2.6 Data Recording

The EDS consisted of an automated system that scans and records the meteorological sensors at constant intervals and Microsoft Windows™ based computer/data logger that collects, processes, transmits, and records meteorological data from the CRN Site. The EDS computer/data logger and associated equipment were serviced bi-weekly, at a minimum, in accordance with TVA Emergency Preparedness Field Support Procedures. In addition, unscheduled and non-routine maintenance was conducted as necessary. (Reference 6.4-1)

Data acquisition was performed onsite using a data logging system operated on the EDS computer. The data logger recorded, processed, and then transmitted data to a Remote Access Computer (RAC). Transmission of data from the EDS computer to the RAC was via cellular modem and TVA's external FTP server located in Chattanooga, Tennessee. (Reference 6.4-1)

The data logger, located on the EDS computer, was a Microsoft Windows™ based server running a Digital Equipment Corporation VAX/VMS real time emulator, an instrument multiplexer, a data acquisition switching unit and communications equipment (Reference 6.4-1). The data logger interrogated each meteorological sensor periodically and stored the instrument readings on the computer. The meteorological sensors, except the rain gauge, were interrogated every five seconds providing 720 readings per hour (Reference 6.4-1). The rain gauge was interrogated for the number of counts at 15 minute intervals. Analog signals from the temperature sensors and solar radiation sensor, along with counts from the rain gauge, were converted to digital form using an Agilent 34970A Data Acquisition Switch Unit (DASU). The output readings, along with digital signals from the wind sensors, were then processed by the EDS computer. Data were archived locally and periodically transferred for storage offsite. Data collected and maintained at the EDS computer was available, via cellular modem and the TVA FTP server, to the RAC. A two-part process was used to communicate the data to RAC. Hourly and 15-minute observations were copied to TVA's external FTP server. The FTP site maintained the data received from the EDS Computer. The RAC obtained the data from the FTP server, posted it on the EDS website, and saved the data for later FTP access (for data validation). Unvalidated data were also accessible through the FTP server located in Chattanooga. (Reference 6.4-1)

The meteorological monitoring system also included an uninterruptible power supply system (UPS) which consisted of internal batteries and DC-to-AC converter. This system had the capability of providing up to 30 minutes of power in case of a utility power interruption. Also, under normal conditions the UPS was used to control power to the instruments by removing electrical spikes, sags, surges, and noise. When utility power failed, the UPS provided AC power from its internal batteries. (Reference 6.4-1) The EDS also included a liquid propane-powered generator which could provide backup power to the meteorological equipment if needed (Reference 6.4-5).

Computer programs on the EDS computer received raw data from the meteorological sensors and processed meteorological parameters into 15-minute and hourly time averaged values (Reference 6.4-1). Time averaged values were transmitted to the RAC. Raw data were scanned from the meteorological sensors at 5 second intervals providing 720 instantaneous readings per hour (except for the rain gauge which provided counts at 15 minute intervals). The minimum number of raw data points required to compute a 15-minute time average is 45 instantaneous readings, and the minimum number of readings necessary to calculate an hourly average is 180. Output from the EDS computer program provided 15-minute and hourly average wind speed in mph, wind direction in degrees clockwise from north, temperatures in ºF, and solar radiation in Langley's per minute. (Reference 6.4-1)

Computer programs were developed, modified, and maintained in accordance with TVA's quality assurance program. This included verifying that code operated properly prior to use through a number of benchmark tests or independent reviews. The Computer Process Engineer was also responsible for data handling and processing at the RAC. (Reference 6.4-1)

6.4.2.7 Meteorological Data Analysis Procedure

Time-averaged data were sent hourly from the EDS computer to the RAC for review and the archiving of validated data. As noted above, checks were also performed every workday on the data archival channel.

The Environmental Monitoring and Analysis (EMA) team was responsible for the review and validation of meteorological data. The EMA reviewed data every workday, and if any problems were noted the EMA was responsible for contacting the appropriate personnel to resolve issues. Meteorological data were also validated by the EMA, prior to data being archived, to ensure the validated data satisfied minimum data collection requirements and the necessary recovery rates. (Reference 6.4-1)

NRC RG 1.23 requires 90 percent data recovery for joint frequency distributions (i.e., 90 percent data recovery for the composite of wind speed, wind direction and stability class) and 90 percent data recovery for the other individual meteorological parameters (Reference 6.4-1). Table 6.4-2 provides data recovery rates for the wind speed and wind direction data for the collection period from May 2011 to June 2013, along with data recovery rates for ΔT (temperature difference between 60-m and 10-m) for 2011, 2012, and 2013. Table 6.4-3 presents the data recovery rate for valid hours that concurrent wind speed, wind direction and stability class data were available for the generation of joint frequency distributions. Joint frequency distributions by stability class are based on the data collected at the 10-m level for the two year period from June 2011 through May 2013. These data demonstrate that all recovery rates exceed the 90 percent requirement. The inspection, servicing, and maintenance program for meteorological instrumentation and associated equipment had the objective of ensuring an annual joint data recovery of 90 percent for atmospheric stability (ΔT, temperature difference), wind speed, and wind direction at levels representing effluent release points.

Following validation, data were archived electronically as a permanent record.

6.4.2.8 Instrument Calibration and Maintenance

Calibration and maintenance of the meteorological monitoring program was designed to ensure the NRC RG 1.23 requirement of 90 percent data recovery was achieved. Both maintenance and calibrations were regularly scheduled to keep systems properly operating.

A schedule of calibration due dates was maintained at the responsible field office. Signal processing units were calibrated in place. The DASU, wind sensors, air temperature sensors, the dew point temperature sensor, and Eppley pyranometer were exchanged and laboratory calibrated. (Reference 6.4-1)

Sensor calibrations were performed using quality assurance procedures in accordance with the Nuclear Power Group specifications for calibrations and instrument servicing. These procedures include specific calibration instructions and report forms for recording calibration results. (Reference 6.4-1)

Sonic wind sensors, air temperature sensors, and dew point sensors remained in service no longer than 184 days or beyond the calibration due date, whichever came first. Eppley pyranometers were exchanged within one year of the last calibration (Reference 6.4-1). Table 6.4-4 provides a summary of the calibrations performed on the sensors and DASU which was also calibrated at least every six months. The DASU was used to take the analog signal from the temperature sensors and converted these signals to digital readings. The DASU was calibrated to the manufacturer’s certification requirement.

Data traceability was also checked through calibrations and data checks that evaluated the entire channel from the sensor to data archival. This involved evaluating the following channel segments:

- Sensor Channel to Data Logger (EDS Computer)
- Data Logger (EDS Computer)
- Data Logger to Remote Access Computer
- Remote Access Computer to TVA Meteorological Data Archives

Channel checks/calibrations were also conducted at least every six months and whenever required following the completion of maintenance on the system. Checks were conducted on the archival channel each workday. (Reference 6.4-1)

Maintenance on the meteorological monitoring system was performed and the EDS computer was serviced, at a minimum, biweekly in accordance with TVA Emergency Preparedness Field Support (EPFS) procedures. In addition, non-routine maintenance was performed to any component of the meteorological monitoring system when necessary. A spare parts inventory was maintained to minimize extended periods of system outage. This included a spare EDS computer, spare sensors, and spare equipment components. (Reference 6.4-1)

6.4.2.9 System Accuracy

Based on Regulatory Position 4 in Section C of NRC RG 1.23, determining the accuracy of time-averaged data from digital measurement systems should account for errors introduced by sensors, cables, signal conditioners, temperature environments for signal conditioning and recording equipment, recorders, processors, data displays, and the data reduction process.

System accuracy reflects the performance of the total system, from the sensors, through all processing components, to the display of measured values in their final form. System accuracy can be estimated by performing system calibrations or by calculating the overall accuracy based on the system's individual components. Accuracy tests involve configuring the system to near normal operation, exposing the system to multiple known operating conditions representative of normal operation, and observing the results. Industry guidance on methods for calculating system accuracy is provided in ANSI/ANS-3.11-2005

Table 6.4-5 provides information pertaining to each of the onsite meteorological sensors' accuracy and NRC RG 1.23 specifications. Information presented in Table 6.4-5 demonstrates compliance with NRC RG 1.23 specifications.

6.4.3 Operational Monitoring

Meteorological Tower 3 along with supporting equipment and structures used to collect data for the ESPA from April 2011 through July 2013 were removed from the CRN Site in October 2013. As mentioned above, Meteorological Tower 3, constructed in the 1970's, was refurbished for the collection of 24 months of meteorological data in support of the CRN Site ESPA. However, due to a number of issues regarding the structural and functional integrity of the meteorological tower and the meteorological tower not meeting all Federal Aviation Administration marking requirements, it was determined the meteorological tower would not be suitable for the long term operational phase of the CR SMR Project. A new meteorological tower is expected to be constructed at the location of the meteorological tower from which the 2011 through 2013 data were collected for collection of data during the operational phase of the CR SMR Project.

Although details related to the new meteorological tower are not finalized, the new meteorological tower and the new meteorological monitoring programs are expected to meet the same TVA and regulatory requirements satisfied by the preapplication/preoperational meteorological monitoring program, including TVA's Specifications – Meteorological Monitoring for TVA Nuclear Plants, Federal Aviation Administration requirements for ground obstructions, and NRC RG 1.23. This includes "life-of-the-program" routine inspections of the meteorological monitoring site, tower, and system components.

6.4.4 References

Reference 6.4-1. Tennessee Valley Authority, "Clinch River Nuclear Plant Environmental Data Station Manual," September, 2012.

Reference 6.4-2. Tennessee Valley Authority, Specifications - Meteorological Monitoring for TVA Nuclear Plants, Rev. 21, 2013.

Reference 6.4-3. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Oak Ridge, Tennessee, Website: http://www.ncdc.noaa.gov/IPS/lcd/lcd.html, 2015.

Reference 6.4-4. AECOM, "Final Clinch River Site Land Use and Recreation Technical Report - Revision 2," Greenville, SC, Tennessee Valley Authority, October, 2014.

Reference 6.4-5. AECOM, "Final Clinch River Site Solid and Hazardous Materials/Waste Review Technical Report," Greenville, SC, Tennessee Valley Authority, July, 2013.

Table 6.4-1
Onsite Meteorological Data Collection[1]

Meteorological Tower	Data Collected	Beginning Date	Ending Date	Height (m)
Tower 1 (Mt)	WS, WD, DBT	04-11-1973	03-02-1978	25 and 60
	WS, WD, DBT	04-03-1974	03-02-1978	10
	DPT	05-15-1975	03-02-1978	10
Tower 2 (Ms)	WS, WD	02-16-1977	03-06-1978	10
	WS, WD	03-25-1982	11-04-1983	10
Tower 3 (Mp)	WS, WD, DBT	02-16-1977	03-06-1978	10, 60, 110
	DPT	02-16-1977	03-06-1978	10
	SR, RF, AP	02-16-1977	03-06-1978	1
	WS, WD, DBT	03-25-1982	11-04-1983	10, 60, 110
	DPT	03-25-1982	11-04-1983	10
	SR, RF	03-25-1982	11-04-1983	1
	WS, WD, DBT	**04-21-2011**	**07-09-2013[2]**	**10 and 60**
	DPT	**04-21-2011**	**07-09-2013[2]**	**10 and 60**
	SR, RF, AP	**04-21-2011**	**07-09-2013[2]**	**1**

1 Information in bold designated preapplication/preoperational meteorological monitoring program.
2 End date not listed in EDS Manual, which was issued while monitoring was still in progress.

Notes:
WS = Wind Speed
WD = Wind Direction
DBT = Dry Bulb Temperature
DPT = Dew Point Temperature
SR = Solar Radiation
RF = Rainfall
AP = Atmospheric Pressure

Source: (Reference 6.4-1)

Table 6.4-2
Data Recovery Rates for Combined Wind Speed and Direction

Year	Month	Data Recovery Percentage at 10m	Data Recovery Percentage at 60m	Data Recovery Percentage (Temperature Difference between 60-m and 10-m)
2011	May	100.0	100.0	99.9
	June	96.7	100.0	
	July	98.9	100.0	
	August	100.0	100.0	
	September	100.0	100.0	
	October	99.6	99.6	
	November	100.0	100.0	
	December	100.0	100.0	
2012	January	93.0	93.0	98.9
	February	100.0	100.0	
	March	99.7	99.7	
	April	99.9	99.9	
	May	100.0	100.0	
	June	99.4	99.4	
	July	94.2	99.9	
	August	99.9	99.9	
	September	100.0	100.0	
	October	100.0	99.7	
	November	99.6	98.8	
	December	100.0	99.5	
2013	January	100.0	99.7	99.8
	February	99.9	99.9	
	March	99.9	99.9	
	April	100.0	100.0	
	May	100.0	100.0	
	June	99.7	99.7	
	All Months	**99.1**	**99.4**	

Notes:
RG 1.23 requires at least 90% data recovery on an annual basis. All monthly wind data exceed 90% data recovery; all annual and 12 month periods exceed 90% data recovery

Table 6.4-3
Combined Wind Speed, Wind Direction, and Stability Class Data Recovery Rate at 10-Meters for June 1, 2011 through May 31, 2013

Total Possible Hours of Data During Period	17,544
Total Hours of Missing Wind Speed, Wind Direction or Stability Class	164
Available Valid Hours for Joint Frequency Distribution	17,380
Data Recovery Rate (%)	99.1

Table 6.4-4
Calibrations of Meteorological Sensors

Sensor	Calibration Performed
Wind Speed	In wind tunnel (NIST certified)
Wind Direction	In wind tunnel (NIST certified)
Air Temperature	Calibrated against certified platinum resistance thermometer
Dew Point Temperature	Calibrated in laboratory environmental chamber
Solar Radiation	Factory calibrated against manufacturer’s standard
Rain Gauge[1]	In the field calibration, calibrated against a known quantity of water

[1] Although calibrations were performed on the rain gauge, as discussed in Subsection 6.4.2.4, rain gauge data from the CRN Site was not used. Instead, concurrent rainfall data from the nearby Oak Ridge NWS Station was used.

Notes:
NIST = National Institute of Standards and Technology (formerly the National Bureau of Standards)

Source: (Reference 6.4-1)

Table 6.4-5
Meteorological System Accuracy Versus Specifications

Variable[1]	Units	Specification		Sensor Accuracy	System Accuracy	
		ANS-3.11	RG 1.23		Instantaneous	Time-Averaged
Wind Speed	mph					
8.9 mph		±0.45	±0.45	±0.36	±0.36	±0.06
30.0 mph		±1.50	±1.50	±0.37	±0.37	±0.06
100.0 mph		±5.00	±5.00	±0.38	±0.39	±0.06
Wind Direction	° azimuth	±5.0	±5.0	±3.0	±4.3	±2.1
Air Temperature	°F					
[Day] High solar rad		±0.900	±0.900	±0.078	+0.702	+0.657
[Day] Low solar rad		±0.900	±0.900	±0.078	-0.202	-0.157
[Night] No solar rad		±0.900	±0.900	±0.078	±0.202	±0.157
Vertical Temperature Difference		±0.180	±0.180	±0.105	±0.148	±0.046
Dewpoint	°F	±2.700	±2.700	±2.236	NA	±0.507
Rainfall						
0.10 in. [2]	inches	±0.010	±0.010	±0.007	±0.009	NA
Solar Radiation (SR)	ly/min					
0.28 ly/min		±0.014	Not specified	±0.006	NA	±0.021
0.45 ly/min [3]		±0.023		±0.015	NA	±0.022
1.50 ly/min		±0.075		±0.027	NA	±0.026

1 If a condition or value is listed, error values are specific for that condition/value. Otherwise, error values apply to the entire expected sampling range.
2 ANS-3.11-2005 and NRC RG 1.23 specify that accuracy be estimated for a specific volume (2.54 mm, 0.10 inch).
3 0.45 ly/min is the lowest value at which the ANS-3.11-2005 specification is satisfied.

Notes:
Values are converted to the same units and rounded to the same precision.
NA = Not Applicable

Source: (Reference 6.4-1)

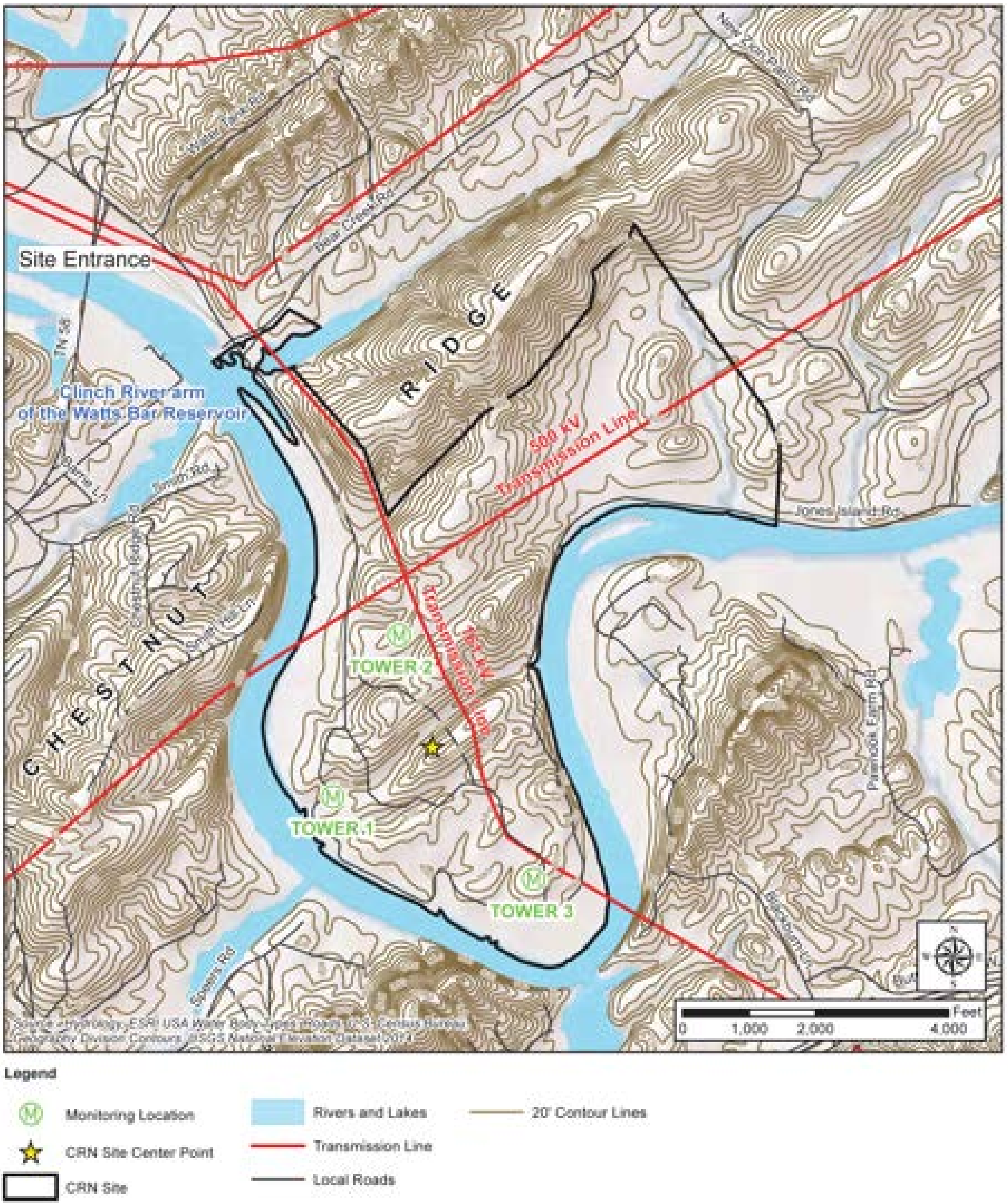


Figure 6.4-1. CRN Site Historical Meteorological Monitoring Locations

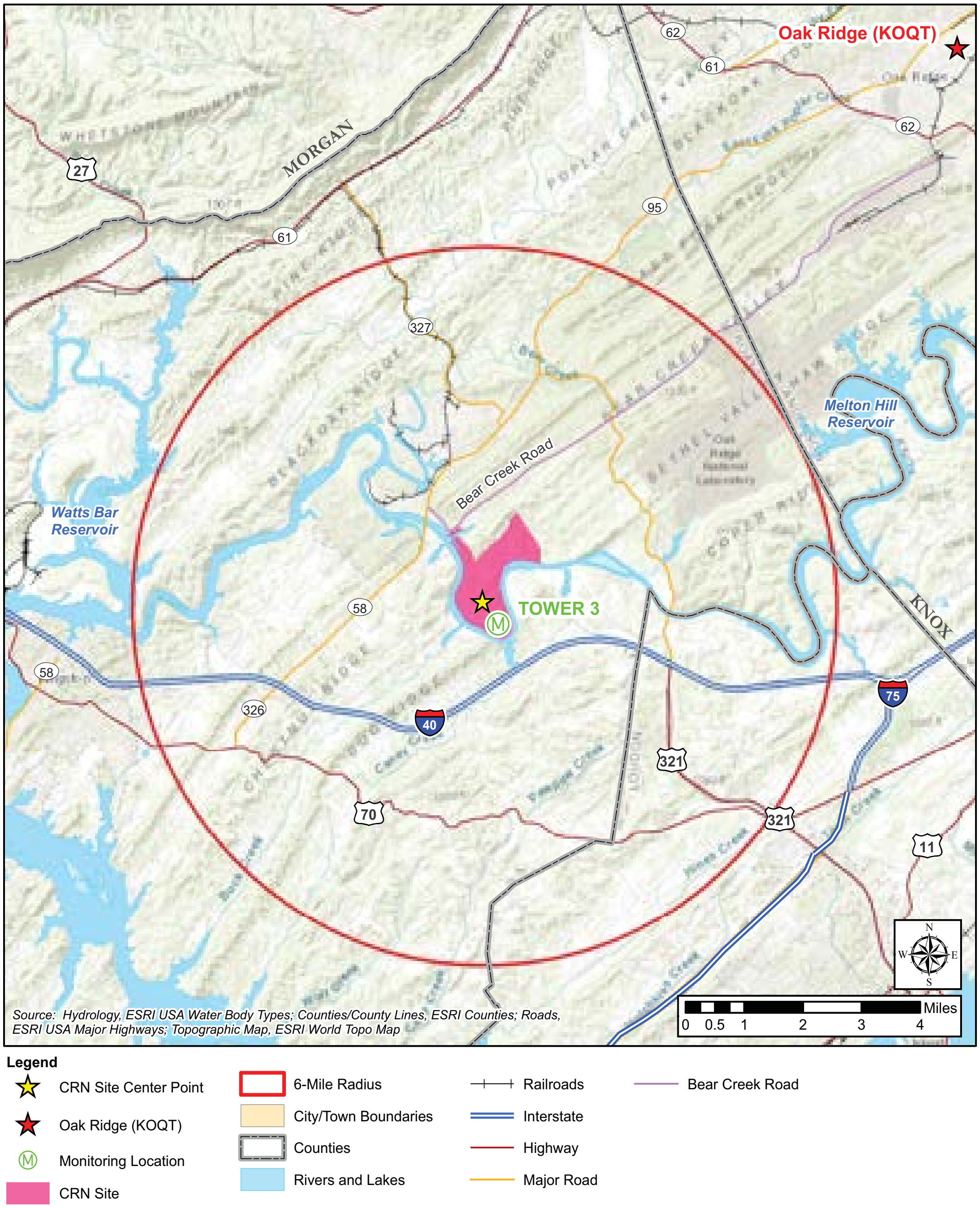


Figure 6.4-2. 6-Mile Vicinity Topographic Map

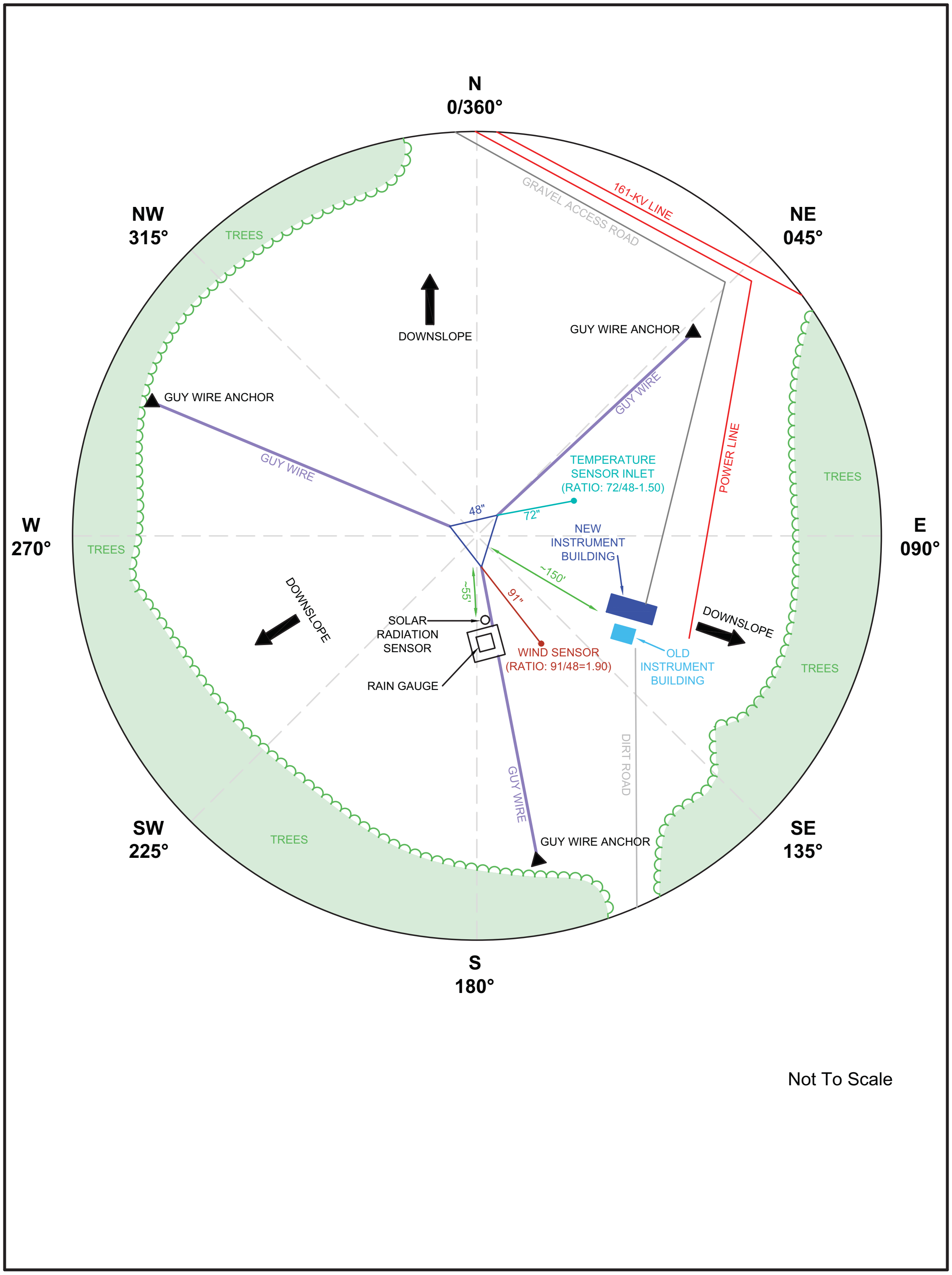


Figure 6.4-3. Meteorological Tower 3 EDS Site Layout

6.5 ECOLOGICAL MONITORING

This section addresses ecological monitoring of terrestrial ecology, land use, and aquatic ecology in the areas likely to be affected by site preparation, construction, and operation of two or more small modular reactors (SMRs). Figure 4.3-1 illustrates the layout of the Clinch River Nuclear (CRN) Site and improvements to be made in adjacent offsite areas, including delineation of areas to be permanently or temporarily cleared. Ecological monitoring programs are based on the anticipated environmental impacts from the new SMRs and expected permitting requirements. These programs focus on ecosystem components with the potential to be adversely affected by SMRs construction and/or operation. Tennessee Valley Authority (TVA) is responsible for all monitoring programs associated with TVA reservoirs, lands, transmission line rights-of-way, and power plants. TVA's ongoing and future ecological monitoring programs are designed to characterize baseline conditions and facilitate assessment of ecological effects through the various phases of the project, including site preparation, construction, and operation. The following subsections describe the ecological monitoring programs for terrestrial resources (Subsection 6.5.1) and aquatic resources (Subsection 6.5.2) at the CRN Site.

6.5.1 Terrestrial Ecology and Land Use

As described in Subsection 2.4.1, the CRN Site consists of approximately 935 acres (ac) of mainly undeveloped land on a peninsula formed by the Clinch River arm of Watts Bar Reservoir. As described in Subsection 4.1.1.1 and Table 4.1-1, land clearing for construction (140 ac) and operation (327 ac) of facilities would affect approximately half of the acreage on the CRN Site. Ecological communities in these areas comprise species that are characteristic of the ecoregion. Terrestrial ecological monitoring programs have documented baseline ecological conditions and support the assessment of potential effects on important species. Site conditions do not warrant land use monitoring.

6.5.1.1 Site Preparation Monitoring

Site preparation monitoring is needed to support applications for early site permits, construction permits, operating licenses, and combined licenses by providing field data to support descriptions of existing ecological communities (NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*). A program of field studies was designed and performed by TVA, in accordance with U.S. Nuclear Regulatory Commission Regulatory Guide (RG) 4.2, *Preparation of Environmental Reports for Nuclear Power Stations*, RG 4.7 *General Site Suitability Criteria for Nuclear Power Stations*, and RG 4.11, *Terrestrial Environmental Studies for Nuclear Power Stations,* to obtain the information needed to characterize the ecological communities at the CRN Site. The information from these field studies was used to develop the descriptions of the terrestrial environment, including wetlands, provided in Subsection 2.4.1, Terrestrial Ecology.

TVA performed field studies on the Clinch River Property on a seasonal basis such that seasonal variations could be characterized throughout at least one annual cycle. Terrestrial vegetation communities were surveyed in 2011 and 2013, wetlands were surveyed in 2011, and terrestrial animals were surveyed in 2011 and 2013. The study methods and results of these surveys are described in Subsection 2.4.1. The various activities included in the site preparation monitoring program for animals are summarized in Table 6.5-1. In addition, supplemental field studies were performed in 2014 and 2015 within 101-ac portion of the Barge/Traffic Area, where road and intersection construction are planned including at the entrance to the CRN Site, at the TN 58 ramps, as well as at the barge facility.

Plant and wildlife species as well as terrestrial habitats found on the CRN Site generally are common and representative of the region. As described in Subsection 2.4.1.5, the only federally listed terrestrial species observed on the CRN Site were three bat species. In addition, species with a state status that were observed on the CRN Site or the surveyed Barge/Traffic Area (101-ac) were a hawk and two herbaceous plants. Other species with federal or state status potentially could occur in the habitats present in these areas, but only these five were observed during the course of multiple surveys. Twelve small wetlands were identified on the CRN Site, but as described in Subsection 2.4.1.2, no other important terrestrial habitats are present on the CRN Site.

6.5.1.2 Construction, Preoperational, and Operational Monitoring

Potential impacts on terrestrial ecology from facility construction and operation are discussed in Subsections 4.3.1, 5.3.3.2, and 5.6.1. Based on the characteristics of the terrestrial ecological communities studied under the site preparation monitoring program and the locations and extent of areas to be cleared for construction, the need for ecological monitoring during construction is expected to be minimal. Habitats for the two state-listed plants potentially occurring on the CRN Site are not expected to occur within the footprint of the planned facilities. Because at least three species of bats that are federally listed have been found to forage on the CRN Site, the U.S. Fish and Wildlife Service (USFWS) may require additional bat surveys during the construction period to monitor possible changes in use of the CRN Site by these species. Under Section 7 of the Endangered Species Act (16 U.S. Code [USC] 1531 *et seq.*), if proposed activities may affect listed bats or other federally listed species (i.e., cause harm, harassment, or other forms of “take”), the USFWS would be informed in a biological assessment as part of ongoing Section 7 consultation. If the USFWS determines that reasonable and prudent measures are needed to minimize take of a species, monitoring may be required in conjunction with an incidental take permit, as specified in Section 2.3, of TVA’s Environmental Protection Plan (EPP) (Appendix B). Specific components of this monitoring, including monitoring onsite mortality, injury, or unusual behavior, reporting it to USFWS, and maintaining records, are defined in the incidental take permit. In addition, reporting of monitoring results to NRC is specified in Sections 2.3, 4.1, and 4.3, of the EPP (Appendix B).

As noted in Subsection 2.4.1.4, an osprey nest was observed on a tower supporting the 161-kV transmission line on the CRN Site and, in accordance with Executive Order 13186 – Responsibilities of Federal Agencies to Protect Migratory Birds, monitoring of this nest is proposed in order to assess responses of the ospreys to facility construction and operation. Bald eagles have been observed flying near the CRN Site and Barge/Traffic Area, but nests have not been observed in the vicinity. In accordance with the Bald and Golden Eagle Protection Act (16 USC 668-668c), if ecological monitoring during the preoperational/operational period indicates bald eagle nesting activity on or near the CRN Site or Barge/Traffic Area, the USFWS would be contacted for advice and recommendations for how to avoid eagle disturbance and whether an eagle permit is necessary, as specified in Section 2.2, of the EPP (Appendix B). Additional monitoring of terrestrial plant and animal communities during construction and preoperational phases is not warranted or proposed.

TVA would repeat field studies performed during the site preparation monitoring program for the period following construction in order to collect at least 1 year (yr) of preoperational and/or operational data for comparison to the baseline data. The ecological monitoring program in this phase may include seasonal species surveys of terrestrial communities. The activities included in a preoperational/operational monitoring program likely would be a subset of the site preparation terrestrial wildlife field studies summarized in Table 6.5-1. Sections 2.2, 2.3, 4.1, and 4.3 of the EPP describe the process for monitoring onsite mortality, injury, or unusual behavior associated with terrestrial resources, reporting it to NRC and other applicable regulatory agencies, and maintaining records (Appendix B).

6.5.2 Aquatic Ecology

As described in Subsection 2.4.2, the aquatic habitats with the potential to be affected by the proposed project include the Clinch River arm of the Watts Bar Reservoir, Melton Hill Reservoir, and the small streams and ponds on the CRN Site. Watts Bar Reservoir would be directly affected by water withdrawals and discharges. Melton Hill Reservoir may be affected indirectly through changes in water management to address downstream withdrawals for and thermal discharges from the proposed Clinch River SMR Project. Onsite ponds and streams may be directly affected if they are located within areas of the CRN Site required for development or operation of the SMRs. The ecological characteristics of these potentially affected water bodies are described in Subsection 2.4.2, Aquatic Ecology. The ecological communities in these water bodies consist of species that are characteristic of the region and not unique to the CRN Site. Aquatic ecological monitoring programs have documented baseline ecological conditions and support the assessment of potential effects on important aquatic species.

6.5.2.1 Site Preparation Monitoring

TVA characterized the aquatic communities in the vicinity of the Clinch River Property in 2011 (Reference 6.5-1). Investigations included analyses of fish eggs, larvae, juveniles, and adults; benthic macroinvertebrate and plankton communities; habitat characterization; and water quality. The study methods and results are described in Subsection 2.4.2.1.1. The studies serve to establish an ecological baseline for future trend analyses and support the assessment of potential impacts on aquatic ecology from construction and operation of the CR SMR Project, as discussed in Subsections 4.3.2, 5.3.1.2, 5.3.2.2, and 5.6.2.

As discussed in Subsection 2.4.2.1.1, TVA performed field studies in 2011 in the Clinch River arm of the Watts Bar Reservoir in the vicinity of the CRN Site. These studies characterized the fish community in winter, spring, summer, and fall. Ichthyoplankton (fish eggs and larvae) samples were collected in multiple events from February 2011 to January 2012 at transects upstream and downstream of the CRN Site. The benthic macroinvertebrate community was surveyed in spring, summer, and fall of 2011, and an additional mollusk survey also was performed that focused on characterizing the mussel community of the reservoir segment adjoining the CRN Site. The plankton community in this reservoir segment was surveyed monthly from March through December 2011.

Additionally, TVA systematically monitored ecological conditions in its system of reservoirs since 1990 as part of its Vital Signs Monitoring Program, and the ongoing Reservoir Ecological Health monitoring program continues to monitor the aquatic communities of the reservoirs. Four Reservoir Ecological Health monitoring locations have been established in Watts Bar Reservoir (forebay near the dam, mid-reservoir, Tennessee River inflow, and Clinch River inflow). The Clinch River inflow area of the Watts Bar Reservoir is upstream of the CRN Site. Three locations are monitored in Melton Hill Reservoir (forebay, mid-reservoir, and inflow). Both of these reservoirs are monitored on a 2-yr cycle in even-numbered years for physical, chemical, and biological parameters. The Reservoir Ecological Health monitoring program characterizes and assigns a rating to the fish community and benthic community at each location. (Reference 6.5-1) Sampling of fish and benthic invertebrates occurred once in late fall/early winter at each location. In addition, fish tissue samples from each location are analyzed every 4 yr to monitor for the presence of potentially toxic contaminants. Fish were last collected for this purpose from Watts Bar Reservoir in 2012, and the next collection is scheduled to occur in 2016.

As described in Subsection 2.4.2, ponds and streams, including ephemeral streams/wet-weather conveyances on the CRN Site were mapped and classified in 2011, 2013, and 2014. Field studies were performed in 2014 to map and classify streams within specific areas on or near the CRN Site where construction of supporting facilities is proposed. These include the offsite Barge/Traffic Area and barge facility. Perennial and intermittent streams on the CRN Site and in the Barge/Traffic Area were sampled in 2015 to identify aquatic species present.

The aquatic species found in waterbodies surveyed at the CRN Site generally are common in similar habitats in the region. The assessment of federally listed species in Subsection 2.4.2.3.1 determined that of the 13 aquatic, federally-listed, threatened or endangered species and one candidate species with documented occurrences in Roane County, eight are mussels that are considered extirpated or for which the occurrences are historical only, and one is a cave salamander for which habitat is not present on or adjacent to the CRN Site. The remaining four species include three freshwater mussels and one fish. Although these species historically have occurred or potentially could occur in the vicinity of the CRN Site, recent surveys did not detect any federally listed species in the Clinch River arm of the Watts Bar Reservoir. The assessment of state-listed species in Subsection 2.4.2.3.2 determined that, of the aquatic species with a state listing or other state protected status and recorded occurrences in Roane County, four species potentially could occur in streams on the CRN Site or in the adjacent reservoir. However, none of these species have been observed during previous monitoring surveys.

6.5.2.2 Construction Monitoring

Aquatic organisms can be affected by construction-related activities principally through degradation of water quality or sediment quality resulting from soil erosion and stormwater runoff. The potential sources of erosion and runoff are the extensive site clearing and excavation activities required for development of onsite facilities, including the intake and discharge structures and offsite facilities, such as the barge landing, intersection modifications, and underground transmission line. TVA has established best management practices (BMPs) that are used during construction to prevent potential soil erosion and transport to Watts Bar Reservoir and the small streams draining the areas to be developed on and off the CRN Site.

Construction activities within or adjacent to navigable waterways (waters of the United States) would require permits from the U.S. Army Corps of Engineers. As discussed in Subsection 6.3.2.1, stormwater discharges are regulated by the Tennessee Department of Environment and Conservation (TDEC) under the National Pollutant Discharge Elimination System (NPDES). A Stormwater Pollution Prevention Plan (SWPPP) with proposed BMPs (including measures to limit erosion and sedimentation) would be completed before obtaining authorization to discharge. Additionally, no sensitive habitats or rare aquatic species are known to be present in the aquatic habitats potentially affected by construction. Compliance with the SWPPP and the lack of sensitive receptors would ensure that potential effects on aquatic communities from construction would be minor, localized, and temporary. Therefore, additional formal monitoring during the construction phase beyond that conducted under TVA’s Reservoir Ecological Health monitoring program would not be warranted.

6.5.2.3 Preoperational and Operational Monitoring

Potential impacts to aquatic ecology from facility operation are discussed in Subsections 4.3.2, 5.3.1, 5.3.2, 5.3.3, 5.3.4.1, 5.6.1, and 5.6.2. NUREG-1555 notes that for aquatic ecology monitoring “any necessary preoperational monitoring will ordinarily be defined in the NPDES permit” and “any necessary operational monitoring will be covered under the relevant NPDES permit.” TVA does not currently have an NPDES permit for the CRN Site. TVA expects to finalize the operational monitoring plan during the NPDES permitting process. An NPDES permit for the SMR, as specified in Section 2.1 of the EPP, likely would include a requirement for toxicity monitoring on at least an annual basis. Sections 2.1, 2.3, 4.1, and 4.3 of the EPP describe the process for monitoring onsite mortality, injury, or unusual behavior associated with aquatic resources, reporting it to NRC and other applicable regulatory agencies, and maintaining records (Appendix B). The requirements for cooling water intakes under Clean

Water Act (CWA) Section 316(b), for the purpose of minimizing adverse impacts from entrainment and impingement of organisms, also are implemented through the NPDES permitting process. As a new facility, the CR SMR Project would have to meet CWA Section 316(b) Phase I requirements for its cooling water intake.

TVA plans to conduct aquatic ecology monitoring as determined by interactions with Federal and State agencies.

A facility designed and operated in compliance with State Water Quality Standards for temperature, is unlikely to be required by TDEC to conduct significant new biological monitoring in the vicinity of the CRN Site. In the event TVA pursues a variance from those criteria under CWA Section 316(a), additional preoperational and operational monitoring would be addressed as part of that permitting process. Surveys and monitoring would be designed to allow statistical analysis comparing the communities present in the Clinch River before construction and operation to those present after the CR SMR Project is online.

6.5.3 References

Reference 6.5-1. Tennessee Valley Authority, "Biological Monitoring to Characterize the Aquatic Community near the Site of the Proposed Clinch River Small Modular Reactor 2011," Tennessee Valley Authority Biological and Water Resources, Chattanooga, Tennessee, January, 2013.

Table 6.5-1
TVA Field Activities included in the Terrestrial Wildlife Site Preparation Monitoring Program

Survey Type	Survey Location	Survey Description, Sample Size	Survey Seasons[1]				Targeted Animal Groups
			W	S	Su	F	
Visual and aural surveys by boat	Shoreline of Clinch River adjacent to CRN Site	One survey/season; boat driven at slow pace, noting aural and visual detections.	X	X	X	X	Overwintering and nesting birds, turtles, mammals
Visual and aural encounter surveys (VES) by foot	Linear transects (N = 7) (500 m) distributed across CRN Site and Clinch River Property	Four surveys/season/transect, walked beginning to end on 4 consecutive days per season, noting aural and visual detections.	X	X	X	X	Any species observed, but focused on birds and mammals
Sherman traps	Placed along same transects used for VES	Seven traps/transect/season spaced ~100m from transect endpoints, ~35 m from each other, opened and then checked for 3 consecutive days.	X	X	X	X	Small mammals
Cover boards	Placed along same transects used for visual encounter surveys	Six boards/transect/season spaced 100 m apart from transect endpoints and ~50m from each other, checked for 3 consecutive days.	X	X	X	X	Amphibians and reptiles
Minnow traps	Aquatic water bodies (streams and ponds, N = 6)) across CRN Site and Clinch River Property	12 traps (2 traps per site)/season, partially submerged; traps set and then checked for 3 consecutive days.	X	X	X	X	Frogs, toads, salamanders
Anuran call surveys	Aquatic water bodies across CRN Site and Clinch River Property	Five surveys (1/site)/season, post- sunset following a rain event.	X	X	X	X	Frogs and toads
Bat acoustic surveys	Water crossings and forested corridors	Six acoustic detectors, deployed on day 1 of survey and set to collect data for 4 consecutive nights.	NS	X	X	X	Bats
Bat mist-net surveys	Eight stations near water, open edges, or open forest understory	Two nets per station, at least 30 m apart. Nets open 5 hr per night during July 11-21, 2011.	NS	NS	X	NS	Bats
Opportunistic sitings	Wherever present on CRN Site and Clinch River Property	Aural, visual, and sign (e.g., scat) indicating animal presence.	X	X	X	X	Any observed wildlife noted

[1] W = Winter (February to early March); S = Spring (April to May); Su = Summer (July to August); F = Fall (September to November); NS = Not Surveyed

6.6 CHEMICAL MONITORING

The following section describes the chemical monitoring programs at the Clinch River Nuclear (CRN) Site for surface water and groundwater quality, including:

- Preapplication/Site preparation monitoring that supports, in part, the baseline water quality descriptions in Chapter 2
- Construction/preoperational monitoring intended to identify potential impacts of preconstruction, construction, and preoperational activities and provide a basis for identifying and assessing environmental impacts from the operation of two or more small modular reactors (SMRs)
- Operational discharge monitoring intended for evaluation of environmental impacts from the operation of two or more SMRs

Discussions related to historic, current, and future water use, and potential discharges and pollutant sources are found in Subsections 2.3.2 and 2.3.3 and Sections 3.3, 3.6, 5.2, and 5.5. Baseline environmental water quality is described in Subsection 2.3.3 and anticipated wastewater generation is described in Sections 3.6 and 5.5.

6.6.1 Site Preparation Monitoring

The purpose of the site preparation monitoring program is to provide data to support the assessment of potential impacts that result from the construction and operation of two or more SMRs. The program includes both ongoing surface water and groundwater monitoring conducted to collect baseline water quality data in support of the Early Site Permit application (ESPA) for the Clinch River (CR) SMR Project.

6.6.1.1 Surface Water Monitoring

6.6.1.1.1 River and Reservoir Compliance Monitoring Program

As part of the operation and management of the Tennessee River, Tennessee Valley Authority (TVA) monitors surface water quality and sediment data in the TVA reservoirs, including the Watts Bar Reservoir, as part of a reservoir system monitoring program. TVA monitors ecological conditions at 69 sites on 31 reservoirs. Each site is monitored biennially unless a substantial change in the ecological health score occurs during a 2-year (yr) cycle. If that occurs, the site is monitored the next year to ascertain whether the change was a trend or an anomaly. Roughly half the sites are sampled each year on an alternating basis. The program includes five ecological indicators (chlorophyll-a, dissolved oxygen (DO), sediment quality, benthic macroinvertebrates, and fish assemblage), which are monitored at up to four locations in each reservoir. To complete the ecological health scoring process, the 20 to 100 percent scoring range is divided into categories representing good, fair, and poor ecological health conditions relative to what is expected given the hydrogeomorphology of the reservoir. (Reference 6.6-1)

As part of this program, TVA has collected samples at four locations on Watts Bar Reservoir, usually on a 2-yr cycle: the forebay area of deep water near the dam at Tennessee River Mile (TRM) 531.0 (prior to 2000) and TRM 532.5 (after 2000), the middle part of the reservoir at TRM 560.8, the inflow area at the extreme upper end of the reservoir at TRM 600, and the inflow area in the Clinch River arm of the Watts Bar Reservoir at Clinch River Mile (CRM) 19 (Reference 6.6-2). The sampling focused on ecological health, but included general water quality parameters (i.e., DO, chlorophyll, and chemical analysis of sediment) as indicators of ecological health. (Reference 6.6-3)

6.6.1.1.2 Site Preparation Monitoring Program

To support the evaluation of the suitability of the CRN Site, TVA monitored the surface water on and in the immediate vicinity of the CRN Site. This program consisted of characterization of surface water in the Clinch River arm of the Watts Bar Reservoir, as well as characterization of stormwater runoff. In addition, water quality sampling, including sediment sampling, was performed between CRM 10.0 and 22.0. The resulting data provide information to determine existing conditions for surface water. (Reference 6.6-4)

The sampling locations for surface water monitoring in the immediate vicinity of the CRN Site are shown in Figure 2.3.3-1. Descriptions of these locations are as follows:

- CRS1 is a stormwater pond, identified as P01 in Figure 2.4.1-2, which drains the area northwest of the reactor footprint. It is located on the site near CRM 15.5, close to the proposed locations of the holding pond and the discharge. Several culverts drain into the pond area. Surface water samples were collected at one of the culverts as stormwater flows into the pond. (Reference 6.6-4)
- CRS2 is a stormwater pond, identified as P02 in Figure 2.4.1-2, located off River Road. It is located on the site, near CRM 16.2. There are three inflows associated with this stormwater pond. Surface water samples were collected at inflow location on the northern side of the pond. (Reference 6.6-4)
- CRS3 is a stormwater pond, identified as P06 in Figure 2.4.1-2, located on the southern tip of the peninsula. It is located on the site, near CRM 16.5. Surface water samples were collected where the pond discharge circumvents the discharge culvert. If river water was backed up to that location in the stormwater pond, then samples were collected from the inlet into the pond. (Reference 6.6-4)
- CRS6 is a stormwater pond, identified as P04 in Figure 2.4.1-2, located east of the reactor footprint, near the stream identified as S01. It is located on the site, near CRM 17.8. Surface water samples were collected from the weir if the pond was discharging; otherwise, they were collected from pond inflow. (Reference 6.6-4)
- CRS8 is the upstream river location on the Watts Bar Reservoir, located near CRM 18.3 (Reference 6.6-4).

- CRS9 is a downstream river location near the confluence of Grassy Creek, near CRM 14.5 (Reference 6.6-4).
- CRS10 is located at the mouth of Grassy Creek, at the outlet of the culvert, near CRM 14.5 (Reference 6.6-4).
- CRS11 is located on the downstream side of a culvert under Bear Creek Road, near CRM 14.3. Surface water samples were collected at the downstream side of the culvert under the road. Depending on the reservoir level, the surface water sample was collected at the safest accessible location between the outlet of the culvert and the point where the flow enters the reservoir pool. (Reference 6.6-4)
- CRS 12 is the downstream river location at the Tennessee State Highway 58 (Gallaher) Bridge near CRM 14.0, at approximately mid-stream (Reference 6.6-4).

Samples were collected in July 2013, March 2014, and May 2014 at locations CRS1, CRS2, CRS3, CRS6, CRS8, and CRS9. Samples were collected in November 2014 at all locations. Samples were collected in February 2015, April 2015, and June 2015 at locations CRS8, CRS10, CRS11, and CRS12. (Reference 6.6-4)

Access for sampling at sites CRS1, CRS2, CRS3, and CRS6 was by vehicle, while access for sampling at sites CRS8, CRS9, and CRS12 was by boat (Reference 6.6-5). For CRS10 and CRS11, the reservoir level determined the sampling method. For samples collected in November and May, access was by vehicle, since the water was too low to reach by the sites by boat. For the June samples the water was high enough to allow access by boat.

Surface water samples were grab samples collected during or within 24 hours (hr) following a rain event that was greater than 0.1 inches (in.) and occurred at least 72 hr following the previous measurable (> 0.1 in.) rain event. Where practicable, stormwater sampling and Watts Bar Reservoir sampling were performed on the same days. Onsite stormwater is routed to impoundments which hold runoff but do not normally discharge. Discharges from these basins are not expected barring an unusually large rainfall event. Therefore, stormwater (surface water) samples were collected from within the ponds. Reservoir (surface water) samples were collected at the point of concentrated flow. (Reference 6.6-4)

The surface water analytes and bottle types are listed in Table 6.6-1. Surface water sample results are provided in Tables 2.3.3-2 through 2.3.3-6.

The field procedures used for surface water sampling are provided in the following paragraphs.

Analytical sample collections and field analyses follow the applicable procedures from the U.S. Environmental Protection Agency (EPA) Region IV Field Branches Quality Systems and Technical Procedures (http://www.epa.gov/region4/sesd/fbqstp/). A field blank was collected for each parameter which is represented by a grab sample. (Reference 6.6-5)

The general field procedures used to satisfy surface water monitoring requirements included:

- Performing and documenting standardization of pH meter(s) immediately prior to monitoring
- Measuring and recording pH and temperature
- Collecting grab samples
- Placing all samples on ice and preparing for transport to the laboratory
- Documenting the following storm event information as part of the storm event monitoring:
  - Date
  - Duration (in minutes) and total rainfall during sampled storm event (in inches)
  - Number of hours between the beginning of sampled storm event and the previous event of 0.1 in. or greater
  - Flow rate during storm event sampling if discharging
  - Estimated total runoff discharged for storm event for each discharge
  - Description of the method(s) used for flow measurements and volume estimates for each discharge if applicable (Reference 6.6-5)

Field observations noted and recorded during each storm event sampling included:

- Floating materials or foam
- Oil sheen
- Appearance and odor of pond and/or discharge stream
- Possible sources of contamination
- Date and exact time of observation
- Name of person making observation (Reference 6.6-5)

Field analyses included measurement of pH and temperature (Reference 6.6-5).

6.6.1.1.3 Biological Monitoring Program

As part of the biological monitoring to characterize the aquatic community near the CRN Site TVA collected and analyzed surface water and sediment samples at selected locations on the Clinch River arm of the Watts Bar Reservoir between CRM 15.5 and 22.0. These data were collected in 2011 to characterize baseline conditions of the aquatic habitats and communities in the reservoir immediately upstream and downstream of the CRN Site. This program focused on ecological health, but included collection of surface water quality and sediment chemistry data as indicators of ecological health. Surface water samples were collected at four mid-channel locations, including three upstream locations (CRM 18.5, CRM 19.7, and CRM 22.0) and one downstream location (CRM 15.5). The surface water samples were collected monthly from March to December 2011. The surface water quality parameters measured are listed in Table

6.6-2. The surface water sample analytes are listed in Table 6.6-3, In June 2011, sediment samples were collected at three of the locations (CRM 15.5, CRM 18.5, and CRM 22.0). The sediment sample types and analytes are listed in Table 6.6-4. The results from the biological monitoring program are provided in Tables 2.3.3-4 through 2.3.3-8, and are described in Subsections 2.3.3 and 2.4.2. (Reference 6.6-6)

6.6.1.2 Groundwater Monitoring

The site preparation groundwater monitoring program, including descriptions of monitoring locations and sampling results, is described in Subsections 2.3.1.2, 2.3.2.2, and 2.3.3.2. Groundwater sampling was conducted on a quarterly basis to satisfy requirements for the site preparation monitoring program. Groundwater sample events were performed in December 2013/January 2014, April 2014, August 2014, and November 2014. Groundwater sampling results are provided in Tables 2.3.3-9 and 2.3.3-10. In fall of 2013, 37 monitoring wells were installed, consisting of 15 clusters of two to three wells each. Each cluster consists of an upper and lower well, and some clusters contain an additional deep well. The 21 monitoring wells listed in Table 2.3.1-3 were initially chosen as the groundwater monitoring wells. These wells are contained within nine of the 15 clusters that are distributed around the area of the construction footprint. Table 2.3.1-3 also provides a summary of installation details. The monitoring well locations are shown in Figure 2.3.1-18. (Reference 6.6-7)

Groundwater sampling for the first quarter occurred from December 2013 to January 2014. Well CRS-OW420U did not have enough water to purge properly or perform field analysis. Laboratory samples were collected, but may be biased from high turbidity and the underdeveloped well conditions. Well CRS-OW429L also did not produce enough water to purge properly and also did not recharge after purging. This well was not sampled for field or laboratory analysis. Wells CRS-OW428D, CRS-OW428L, CRS-OW420U, CRS-OW419L, and CRS-OW401L exhibited high turbidity readings. (Reference 6.6-7)

Second quarter groundwater sampling occurred in April 2014. Wells CRS-OW420U and CRS-OW429L did not have enough water to purge properly or perform field analysis. Some laboratory samples were collected, but may be biased from high turbidity and the underdeveloped well conditions. Wells CRS-OW401U, CRS-OW401L, CRS-OW416U, CRS-OW420U, CRS-OW428L, CRS-OW428D, and CRS-OW429L exhibited high turbidity readings. (Reference 6.6-7)

Third quarter groundwater sampling occurred in August 2014. Similar to previous events, well CRS OW420U was only able to be sampled for laboratory parameters. CRS-OW429L was removed from the sampling plan due to previous performance. Wells CRS-OW401L, CRS-OW401D, CRS-OW416U, CRS-OW420U, CRS-OW421U, CRS-OW421D, and CRS-OW428D exhibited high turbidity readings. (Reference 6.6-7)

Fourth quarter groundwater sampling occurred in November 2014. Wells CRS-OW420U and CRS-429L were both removed from the sampling plan due to previous poor sampling conditions. Wells CRSOW421U, CRS-OW419L, CRS-OW416U, CRS-OW401L, and CRS-OW401U exhibited high turbidity readings. (Reference 6.6-7)

Groundwater samples were collected using a submersible bladder pump placed below the water level in the selected monitoring well, above the screen interval. For wells which exhibited low yields, disposable Teflon bailers were used to collect sample volumes. Field parameters (i.e., temperature, specific conductance, pH, DO, oxidation-reduction potential, and turbidity) were monitored during well purging using a flow-through cell and calibrated instruments. Each monitoring well was considered properly evacuated when field parameters remained stable after purging a minimum of three well volumes or after purging standing water in the well. Following sample collection in a temporary field container, water from each monitoring well was transferred to new, pre-labeled sample containers with appropriate preservatives (where applicable). Sample containers were then sealed, necessary data were recorded on a chain-of-custody form, and samples were placed in iced coolers for transport. All groundwater sampling was conducted in accordance with TVA's Technical Instructional document for Groundwater Sampling EMA-TI-05.80.42. (Reference 6.6-7)

The list of parameters analyzed to characterize CRN Site groundwater is provided in Table 6.6-5.

Various reference values were used to compare the groundwater quality data, including Maximum Contaminant Levels set by the Tennessee Department of Environment and Conservation (TDEC) and EPA regional screening levels (Reference 6.6-7).

6.6.2 Construction and Preoperational Monitoring

6.6.2.1 Surface Water Monitoring

Surface water monitoring requirements for the construction phase would be developed as part of the permit application for a National Pollutant Discharge Elimination System (NPDES) general stormwater construction permit issued by the TDEC. Prior to initiation of construction, a completed and signed Notice of Intent (NOI) for Construction Activity - Stormwater Discharges would be required to be submitted to TDEC. A site-specific Stormwater Pollution Prevention Plan (SWPPP) would be developed and submitted with the NOI. The SWPPP would be developed, implemented, and updated according to Part 3 of the Construction General Permit.

Shoreline excavation would be required for construction of the intake structure, along a length of shoreline approximately 50 ft wide. The diffuser pipe for the discharge would be partially buried, which would also require underwater excavation. The Lower Clinch River sediments are listed as impaired for mercury, polychlorinated biphenyls (PCBs), and chlordane. Also, legacy contamination, including radionuclides, from U.S. Department of Energy (DOE) activities is present in the portion of the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site. TVA is party to an Interagency Agreement, along with the U.S. Army Corps of Engineers, DOE, TDEC, and Environmental Protection Agency, to coordinate review of permitting and other use authorization activities which could result in the disturbance, re-suspension, removal, and/or disposal of contaminated sediments in the reservoir. The agreement, signed in 1991, defines how each agency would coordinate with the others to review proposed activities to determine their potential to disturb contaminated sediments. (Reference 6.6-9) As stipulated by this agreement, it is expected that TDEC would require monitoring of sediment in the area(s) where dredging is proposed. In addition, acceptable best management practices would have to be implemented to ensure that dredging activity does not further degrade surface water quality. Any sediment removed may also contain manmade radionuclides. Coordination of the disposition of the sediment with DOE is also expected.

6.6.2.2 Groundwater Monitoring

Quarterly monitoring well sampling would be re-initiated for two years preceding the construction start date. Eight quarterly samples of concurrent data would provide a solid baseline dataset. Table 6.6-6 lists monitoring wells that could be included in this sampling. During the interim between completion of the water level monitoring in October 2015 and the re-initiation of groundwater sampling two years prior to start of construction, the monitoring wells would be inspected quarterly for damage, the locks maintained, and access maintained.

6.6.3 Operational Monitoring

6.6.3.1 Surface Water Monitoring

There is no operating facility and no existing NPDES permit at the CRN Site, so there is no existing operational surface water monitoring program. The ongoing preoperational surface water monitoring establishes surface water quality based NPDES permit limitations. Discharge of cooling water and other effluents during operations are subject to monitoring to ensure compliance with the NPDES permit, as specified in Section 2.1 of TVA’s Environmental Protection Plan (EPP) (Appendix B). These surface water monitoring requirements assure compliance with applicable TDEC Water Quality Standards. Sections 2.3, 4.1, and 4.3 of the EPP describe the process for monitoring onsite mortality, injury, or unusual behavior that may result from surface water quality issues, reporting it to NRC and other applicable regulatory agencies, and maintaining records (Appendix B). Operational surface water monitoring beyond that required for NPDES permit compliance is not anticipated.

6.6.3.2 Groundwater Monitoring

The location of groundwater monitoring wells to be monitored during SMR operation are unknown at this time, but would be provided following selection of a reactor design as part of the combined license application (COLA). The monitoring wells to be included would be a subset of the existing wells from the preoperational groundwater monitoring program. The manner in which the results of the operational groundwater chemical monitoring program would be compared to modeling predictions and the established baseline to identify and address adverse impacts would be established following selection of a reactor design, and would be evaluated as part of the COLA.

6.6.4 References

Reference 6.6-1. Tennessee Valley Authority, "Programmatic Environmental Impact Statement, Reservoir Operations Study," May, 2004.

Reference 6.6-2. Tennessee Valley Authority, "Final Environmental Impact Statement Watts Bar Reservoir Land Management Plan Loudon, Meigs, Rhea, and Roane Counties, Tennessee," February, 2009.

Reference 6.6-3. Tennessee Valley Authority, Watts Bar Reservoir Ecological Health Rating - 1994-2012, Website: http://www.tva.com/environment/ecohealth/wattsbar.htm, 2015.

Reference 6.6-4. Tennessee Valley Authority, "Clinch River Surface Water Quality Report - Revision 2," July 10, 2015.

Reference 6.6-5. Tennessee Valley Authority, "Surface Water Sampling Plan," Rev. 10, October 21, 2014.

Reference 6.6-6. Tennessee Valley Authority, "Biological Monitoring to Characterize the Aquatic Community near the Site of the Proposed Clinch River Small Modular Reactor 2011," Tennessee Valley Authority Biological and Water Resources, Chattanooga, Tennessee, January, 2013.

Reference 6.6-7. Tennessee Valley Authority, "Groundwater Quality Monitoring Report," Rev. 1, April 20, 2015.

Reference 6.6-8. Tennessee Valley Authority, "Workplan to Characterize Groundwater Quality on the Clinch River Small Modular Reactor Site," December 10, 2013.

Reference 6.6-9. Tennessee Valley Authority, "Interagency Agreement (Memoranda of Agreement [MOA]) Watts Bar Reservoir Permit Coordination," February 1991.

Table 6.6-1
Surface Water Analytical Parameters and Bottle Types

Parameters	Holding Time	Sample Type	Bottle type
Temperature	15 minutes	Field Analysis and Grab Sample	Field Quart – 1L poly
pH	15 minutes	Field Analysis and Grab Sample	
Oil & Grease	28 days	Grab	1L wide mouth glass, spiked (HCL)
Total Cyanide	14 days	Grab	250 ml amber poly spiked (NaOH to pH>12)
Total Phenols (EPA Method 420.2)	28 days	Grab	250 ml amber glass spiked (H_2SO_4)
Biochemical Oxygen Demand	48 hours	Grab	1L poly
Total Suspended Solids	7 days	Grab	TSS – 500 ml poly
Color	48 hours	Grab	Color – 250 ml poly
Bromide	28 days	Grab	125 ml poly
Surfactants (MBAS)	48 hours	Grab	1L poly
Total Organic Carbon	28 days	Grab	250 ml amber glass w/septa, spiked (HCL)
Sulfide	7 days	Grab	500 ml poly spiked (ZnAc+NaOH)
Ammonia Nitrogen	28 days	Grab	250 ml poly spiked (H_2SO_4 +NaThio)
Nitrate/Nitrite (as N)	28 days	Grab	Nutrients/COD - 250 ml poly spiked (H_2SO_4)
Total Organic Nitrogen (as N)	28 days	Grab	
TKN, Total Phosphorous (as P)	28 days	Grab	
Chemical Oxygen Demand (COD)	28 days	Grab	
Fluoride (by IC)	28 days	Grab	125 ml poly
Sulfate (by IC)	28 days	Grab	
Aluminum, Magnesium, Calcium, Iron, Copper, Zinc, Barium, Boron, Cobalt, Manganese, Molybdenum, Tin, Titanium, Antimony, Arsenic, Beryllium, Cadmium, Chromium, Lead, Mercury, Nickel, Selenium, Silver, Thallium	6 months	Grab	500 ml poly spiked (HNO_3)
Hardness	6 months	Grab	
Acids/Base/Neutral Compounds	7 days	Grab	1 L amber
Gross Alpha, Gross Beta, Radium, Radium226	6 months	Grab	1-gallon cubitainer
PCB listed in Part C of EPA Form 2C	7 days	Grab	1 L glass

Source: (Reference 6.6-5)

Table 6.6-2
Surface Water Quality Parameters, Reporting Limits, and Methods of Analysis

Parameter	Reporting Limit	Units	Method Analysis
Alkalinity	20	mg/L	2320B
Ammonia Nitrogen	0.1	mg/L	350.1
Chlorophyll-a	1	µg/L	ASTM D3731
Dissolved Solids	10	mg/L	2540C
Hardness, Total (mg/L as CaCO3)	30	mg/L	130.1
Kjeldahl Nitrogen	0.1	mg/L	351.2
Nitrate-Nitrite	0.1	mg/L	353.2
Phosphate, Ortho	0.025	mg/L	4500P-E
Phosphorus, Total	0.003	mg/L	365.1
Suspended Solids	1	mg/L	2540D
Total Organic Carbon	1	mg/L	9060A
Turbidity	0.1	NTU	SM2130B
Temperature	0.1	C	Hydrolab®
pH	0.1	Stand. Units	Hydrolab®
Conductivity	0.1	µS/cm	Hydrolab®
Dissolved Oxygen	0.1	mg/L	Hydrolab®

Source: (Reference 6.6-6)

Table 6.6-3
Total and Dissolved Metals Analyses in Surface Water, Reporting Limits, and Methods

Metals, Total and Dissolved	Reporting Limit (µg/l)	Method of Analysis
Aluminum	100	200.7
Arsenic	1	200.8
Cadmium	0.5	200.8
Calcium	500	200.7
Chromium	1	200.8
Copper	1	200.8
Iron	100	200.7
Lead	1	200.8
Magnesium	1	200.8
Manganese	10	200.7
Nickel	1	200.8
Selenium	1	200.8
Zinc	10	200.8

Source: (Reference 6.6-6)

Table 6.6-4
Chemical Measurements in Sediments, Detection Limits, and Methods

Analysis	Method Detection Limit	Units	Method of Analysis
Metals			
Aluminum, Total	5	mg/kg	EPA 6010B
Arsenic, Total	0.5	mg/kg	EPA 7060A
Cadmium, Total	0.5	mg/kg	EPA 6010B
Calcium, Total	10	mg/kg	EPA 6010B
Chromium, Total	5	mg/kg	EPA 6010B
Copper, Total	1	mg/kg	EPA 6010B
Iron, Total	1	mg/kg	EPA 6010B
Lead, Total	5	mg/kg	EPA 6010B
Magnesium, Total	1	mg/kg	EPA 6010B
Manganese, Total	0.5	mg/kg	EPA 6010B
Mercury, Total	0.1	mg/kg	EPA 7471A
Nickel, Total	5	mg/kg	EPA 6010B
Zinc, Total	1	mg/kg	EPA 6010B
Organochlorine Pesticides and PCB's			
Aldrin	10	µg/kg	EPA 8081A
alpha-BHC	10	µg/kg	EPA 8081A
beta-BHC	10	µg/kg	EPA 8081A
gamma-BHC (Lindane)	10	µg/kg	EPA 8081A
delta-BHC	10	µg/kg	EPA 8081A
Chlordane	10	µg/kg	EPA 8081A
Dieldrin	10	µg/kg	EPA 8081A
4,4'-DDD	10	µg/kg	EPA 8081A
4,4'-DDE	10	µg/kg	EPA 8081A
4,4'-DDT	10	µg/kg	EPA 8081A
Endosulfan alpha	10	µg/kg	EPA 8081A
Endosulfan beta	10	µg/kg	EPA 8081A
Endosulfan sulfate	10	µg/kg	EPA 8081A
Endrin	10	µg/kg	EPA 8081A
Endrin aldehyde	10	µg/kg	EPA 8081A
Heptachlor	10	µg/kg	EPA 8081A
Heptachlor epoxide	10	µg/kg	EPA 8081A
Methoxychlor	10	µg/kg	EPA 8081A
Aroclor 1016	25	µg/kg	EPA 8082
Aroclor 1221	25	µg/kg	EPA 8082
Aroclor 1232	25	µg/kg	EPA 8082
Aroclor 1242	25	µg/kg	EPA 8082
Aroclor 1248	25	µg/kg	EPA 8082
Aroclor 1254	25	µg/kg	EPA 8082
Aroclor 1260	25	µg/kg	EPA 8082
Toxaphene	500	µg/kg	EPA 8081A

Source: (Reference 6.6-6)

Table 6.6-5 (Sheet 1 of 4)
Groundwater Analytical Parameters

Field Analysis	Temperature pH Dissolved Oxygen Conductivity Oxidation Reduction Potential Turbidity
Lab Analysis – Major Ions	Calcium Sodium Potassium Chloride Alkalinity (HCO3)
Lab Analysis - Group A	Biochemical Oxygen Demand Chemical Oxygen Demand Total Organic Carbon Total Suspended Solids Ammonia (as N)
Lab Analysis - Group B	Bromide Total Residual Chlorine Color Surfactants Fluoride Nitrate-Nitrite (as N) Oil and Grease Phosphorus (as P), Total Radioactivity - (1) Alpha, Total Radioactivity - (2) Beta, Total Radioactivity - (3) Radium, Total Radioactivity - (4) Radium 226, Total Titanium, Total Sulfate (as SO4) Sulfide (as S) Aluminum, Total Barium, Total Boron, Total Cobalt, Total Iron, Total Magnesium, Total Molybdenum, Total Manganese, Total Tin, Total

Table 6.6-5 (Sheet 2 of 4)
Groundwater Analytical Parameters

Lab Analysis – Section 1	Antimony, Total Arsenic, Total Beryllium, Total Cadmium, Total Chromium, Total Copper, Total Lead, Total Mercury, Total Nickel, Total Selenium, Total Silver, Total Thallium, Total Zinc, Total Cyanide, Total Phenols, Total
Gas Chromatogram/Mass Spectrometer (GC/MS) Fraction[1] - Volatile Organic Compounds (VOCs)	Acrolein Acrylonitirle Benzene Bromoform Carbon Tetrachloride Chlorobenzene Chlorodibromomethane Chloroethane 2-Chloroethylvinyl Ether Chloroform Dichlorobomomethane 1,1-Dichloroethane 1,2-Dichloroethane 1,2-Dichloropropane 1,3-Dichloropropylene Ethylbenzene Methyl Bromide Methyl Chloride Methylene Chloroethane 1,1,2,2-Tetrachloroethane Tetrachloroethylene Toluene 1,2-Trans-Dichloroethylene 1,1,1-Trichloroethane 1,1,2-Trichloroethane Trichloroethylene Vinyl Chloride

Table 6.6-5 (Sheet 3 of 4)
Groundwater Analytical Parameters

GC/MS Fraction[1] - Acid Compounds	2-Chlorophenol 2,4-Dichlorophenol 2,4 Dimethylphenol 4,6-Dinitro-O-Cresol 2,4-Dinitro-phenol 2-Nitrophenol 4-Nitrophenol P-Chloro-M-Cresol Pentachlorophenol Phenol 2,4,6-Trichlorophenol
GC/MS Fraction[1] - Base/Neutral Compounds	Acenaphthene Acenaphtylene Anthracene Benzidine Benzo (a) Anthracene Benzo (a) Pyrene 3,5-Benzofluoranthene Benzo (ghi) Perylene Benzo (k) Fluoranthene Bis (2-Chloroethoxy) Methane Bis (2-Chloroethyl) Ether Bis (2-Chloroisopropyl) Ether Bis (2-Ethylhexyl) Phthalate 4-Bromophenyl Phenyl Ether Butyl Benzyl Phthalate 2-Chloronaphthalene 4-Chlorophenyl Phenyl Ether Chrysene Dibenzo (a,h) Anthracene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4 Dichlorobenzene 3,3-Dichlorobenzidine Diethyl Phthalate Dimethyl Phthalate Di-N-Butyl Phthalate 2,4-Dinitrotoluene 2,6-Dinitrotoluene Di-N-Octyl Phthalate 1,2-Diphenylhydrazine (as Azobenzen) Fluoranthene Fluorene Hexachlorobenzene Hexachlorobutadiene Hexachlorocyclopentadiene Hexachloroethane Ideno (1,2,3-cd) Pyrene

Table 6.6-5 (Sheet 4 of 4)
Groundwater Analytical Parameters

GC/MS Fraction[1] - Base/Neutral Compounds (continued)	Isophorone Naphthalene Nitrobenzene N-Nitro-sodimethylamine N-Nitrosodi-N-Propylamine N-Nitro-sodiphenylamine Phenanthrene Pyrene 1,2,4-Trichlorobenzene
GC/MS Fraction[1] – Pesticides	Aldrin Gamma-BHC Alpha-BHC Delta-BHC Beta-BHC Chlordane 4,4' DDT 4,4' DDE 4,4'-DDD Dieldrin Alpha-Endosulfan Beta-Endosulfan Endosulfan Sulfate Endrin Endrin Aldehyde Heptachlor Heptachlor Epoxide PCB-1242 PCB-1254 PCB-1221 PCB-1232 PCB-1248 PCB-1260 PCB-1016 Toxaphene
Other VOCs	Hexane
Isotopes	Tritium Strontium 90 Technetium 99

[1] Fractions defined in 40 CFR Part 136

Source: (Reference 6.6-8)

Table 6.6-6
Monitoring Wells Included in Sampling

CRS-OW401U	CRS-OW419L
CRS-OW401L	CRS-OW420L
CRS-OW401D	CRS-OW421U
CRS-OW415U	CRS-OW421L
CRS-OW415L	CRS-OW421D
CRS-OW416U	CRS-OW428U
CRS-OW416L	CRS-OW428L
CRS-OW418U	CRS-OW428D
CRS-OW418L	CRS-OW429U
CRS-OW419U	

6.7 SUMMARY OF MONITORING PROGRAMS

This section summarizes the environmental monitoring programs described in the preceding sections of Chapter 6. The summary is divided into three sections:

- Site preparation and construction monitoring
- Preoperational monitoring
- Operational monitoring

Table 6.7-1 lists the environmental monitoring programs within each section by resource and program.

6.7.1 Site Preparation and Construction Monitoring

The site preparation and construction thermal, radiological, hydrological, meteorological, ecological, and chemical monitoring performed and/or planned for the Clinch River (CR) Small Modular Reactor (SMR) Project are summarized below and in Table 6.7-1:

- Site preparation and construction thermal monitoring and modeling programs are detailed in Subsections 6.1.1 and 6.1.2, and include:
  - Data collection to establish baseline conditions and to provide calibration data for modeling the potential SMR thermal impacts throughout the Watts Bar Reservoir
  - Evaluation of thermal impacts in regions near the Clinch River Nuclear (CRN) Site using an unsteady, three-dimensional computational fluid dynamics model for the portion of the Clinch River arm of Watts Bar Reservoir near the CRN Site
  - Evaluation of thermal impacts in regions beyond the CRN Site using CE-QUAL-W2, that assesses the laterally-averaged, unsteady buildup of thermal effluent in the Clinch River arm of the Watts Bar Reservoir as well as the potential reservoir-wide effects of operation of the SMRs
  - Construction discharges subject to monitoring to ensure compliance with a National Pollutant Discharge Elimination System (NPDES) permit, including hydrological monitoring of the temperature of the discharge
- No radiological monitoring program (Section 6.2) is required during the site preparation and construction phase of the initial SMR. Operational monitoring associated with the initial SMR will be implemented during the construction of additional SMRs.
- Hydrological site preparation and construction monitoring programs are detailed in Subsections 6.3.1 and 6.3.2, respectively. These programs include:
  - Hydrographic surveys of the Clinch River arm of the Watts Bar reservoir in the vicinity of the CRN Site which were conducted.

- Groundwater characterization activities which included drilling 82 boreholes, installing 44 wells, monitoring groundwater level, performing packer tests in boreholes, performing slug tests in monitoring wells, performing an aquifer pumping test, and collecting groundwater geochemical samples were conducted.
- Construction discharges are subject to monitoring to ensure compliance with a NPDES permit, including hydrological monitoring of the effects of the discharge.
- Groundwater monitoring will be conducted to assess and control the impacts from construction at the CRN Site by monitoring groundwater. Groundwater monitoring during construction will likely involve measuring water levels to monitor potential draw down caused by construction activities, sampling for the presence of new contaminants, and sampling for increased concentrations of known contaminants relative to site preparation monitoring results.

- The site preparation and construction meteorological monitoring programs are detailed in Subsection 6.4.2. Two years of baseline meteorological data were collected for the CRN Site and surrounding area from April 2011 through July 2013.
- Terrestrial ecology and land use monitoring programs are described in Subsection 6.5.1. These programs include:
  - Site preparation field studies were conducted on the Clinch River Property on a seasonal basis such that seasonal variations could be characterized throughout at least one annual cycle. The following field studies were conducted during the following periods:
    - Terrestrial vegetation community surveys in 2011 and 2013
    - Wetland surveys in 2011
    - Terrestrial animal surveys in 2011 and 2013
    - Supplemental field studies performed in 2014 and 2015 at specific areas on or near the CRN Site where construction of supporting facilities is proposed
  - Additional monitoring of terrestrial plant and animal communities during construction and preoperational phases is not warranted.

- Aquatic ecology monitoring programs are described in Subsection 6.5.2. These programs include:
  - Aquatic site preparation field studies were performed in 2011 in the Clinch River arm of the Watts Bar Reservoir at locations immediately upstream of, adjacent to, and downstream of the CRN Site.
  - Ecological conditions in the Tennessee Valley Authority (TVA) system of reservoirs have been monitored since 1990 as part of ongoing ecological health and compliance monitoring programs.

  - Ponds, perennial and intermittent streams, and ephemeral streams/wet-weather conveyances on the CRN Site were mapped and classified in 2011, 2013, and 2014. Water bodies on the Barge/Traffic Area were mapped and classified in 2014. Species present in perennial and intermittent streams in both areas were sampled in 2015.
  - Additional formal monitoring of aquatic species during the construction phase beyond that conducted under TVA's ongoing ecological health and compliance monitoring programs is not warranted or proposed as discussed in Subsection 6.5.2.2.

- Details of the site preparation and construction chemical monitoring are provided in Subsections 6.6.1 and 6.6.2. These programs include:
  - Characterization of surface water in the Clinch River arm of the Watts Bar Reservoir, as well as characterization of stormwater runoff, was performed from July 2013 through June 2015.
  - Groundwater sampling was conducted on a quarterly basis, from December 2013 to January 2014 through November 2014, to satisfy site preparation monitoring program requirements.
  - Surface water monitoring requirements for the construction phase will be developed as part of the permit application for a NPDES permit.
  - Groundwater monitoring will be re-initiated for two years preceding the construction start date.

6.7.2 Preoperational Monitoring

The purpose of preoperational monitoring, generally conducted in the one or two years prior to the start up a nuclear power plant, is to establish baseline conditions. However, with staggered construction of multiple reactors, preoperational monitoring and construction monitoring can overlap and data collected can meet dual purposes. The information provided below and in Table 6.7-1 provides the preoperational monitoring planned for the CR SMR project:

- Thermal monitoring is addressed in Subsection 6.1.2. Because the site preparation monitoring already conducted provides adequate baseline data, no additional preoperational monitoring is planned during construction.
- As discussed in Section 6.2, a Radiological Environmental Monitoring Program (REMP) is initiated two years before scheduled fuel load. It includes monitoring of the environment by sampling air, water, sediment, fish and food products, as well as measuring radiation directly.
- Surface water monitoring requirements for preoperational activities will be developed as part of the permit application for an NPDES permit issued by the Tennessee Department of Environment and Conservation (TDEC).

- The preoperational meteorological monitoring program, as described in Section 6.4, has already been conducted and is the same as the site preparation and construction monitoring program. Two years of baseline meteorological data were collected for the CRN Site and surrounding area from April 2011 through July 2013.
- At least 1 year (yr) of preoperational and/or operational seasonal species surveys of terrestrial communities will be collected for comparison to the baseline data.
- At least 1 yr of preoperational and/or operational aquatic community studies will be performed to collect data for comparison to the baseline data.
- Preoperational surface water monitoring requirements will be developed as part of the permit application for a NPDES general stormwater construction permit issued by TDEC.
- Quarterly groundwater monitoring well sampling will be re-initiated for two years preceding the construction start date. Eight quarterly samples of concurrent data will provide a solid baseline dataset.

6.7.3 Operational Monitoring

Specific operational monitoring requirements and programs for the CR SMR Project have not yet been defined. The operational monitoring programs for thermal, hydrological, and chemical effects are developed when the final SMR design is selected. The operational radiological monitoring is defined by the REMP, and begins during the preoperational phase. A new meteorological monitoring program (including construction of a new meteorological tower at the location of the tower from which the 2011 through 2013 data were collected) will be established for operational monitoring. The operational phase meteorological monitoring program is similar to the preoperational meteorological program. No specific ecological monitoring is proposed for the operational phase.

Table 6.7-1 (Sheet 1 of 4)
Summary of Monitoring Programs

Resource	Program	Scope/Content	Applicable Section/Subsection for Additional Details
Site Preparation and Construction Monitoring			
Water	Thermal Monitoring	Thermal monitoring of the rivers and reservoirs in the vicinity of the CRN Site was conducted from October 2013 through December 2014. Also, temperatures in Watts Bar Reservoir and Melton Hill Reservoir have been monitored since 2000 as routine operation data collection. Construction discharges are subject to monitoring to ensure compliance with the NPDES permit including monitoring of the temperature of the discharge.	6.1.1
Human Health	Radiological Monitoring	No site preparation radiological monitoring has been performed. No monitoring required during site preparation and construction.	6.2.1
Water	Hydrological Monitoring	Hydrographic surveys of the Watts Bar Reservoir were performed in June 2013. Construction discharges are subject to monitoring to ensure compliance with the NPDES permit, including hydrologic monitoring of the effects of the discharge. Groundwater monitoring included installation of 37 observation wells in 2013, and sampling of those wells in 2013 and 2014. Groundwater monitoring during construction includes measuring water levels to monitor potential draw down caused by construction activities, sampling for the presence of new contaminants, and sampling for increased concentrations of known contaminants relative to site preparation monitoring results.	6.3.1.1 6.3.2.1 6.3.1.2 6.3.2.2
Meteorology	Meteorological Monitoring	For the CR SMR Project's site preparation meteorological monitoring program, the meteorological data collection system at Tower 3 was refurbished in 2011 to meet U.S. Nuclear Regulatory Commission Regulatory Guide 1.23, *Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants*. Table 6.4-1 presents the list of data collected at the meteorological tower, and the measurements are explained in Subsection 6.4.2. The meteorological monitoring program was initiated in April 2011 and data was collected through July 2013.	6.4.2

Table 6.7-1 (Sheet 2 of 4)
Summary of Monitoring Programs

Resource	Program	Scope/Content	Applicable Section/Subsection for Additional Details
Terrestrial	Ecological Monitoring	TVA performed site preparation field studies on the Clinch River Property and the CRN Site on a seasonal basis. Terrestrial vegetation communities were surveyed in 2011 and 2013, wetlands were surveyed in 2011, and terrestrial animals were surveyed in 2011 and 2013, and supplemental field studies were performed in 2014 and 2015 at specific areas on or near the CRN Site where construction of supporting facilities is proposed, as described in Subsection 2.4.1. Additional monitoring of terrestrial plant and animal communities during site preparation and construction phases is not warranted.	6.5.1.1
Aquatic	Ecological Monitoring	TVA performed site preparation field studies in 2011 and 2012 in the Clinch River arm of Watts Bar Reservoir at locations immediately upstream and downstream of the CRN Site. These studies characterized the baseline conditions of the aquatic habitats and communities in winter, spring, summer, and fall. Ponds and streams on the CRN Site were mapped and classified in 2011, 2013, and 2014. Species present in the perennial and intermittent streams were sampled in 2015. Additional monitoring during the construction phase beyond that conducted under TVA's ongoing ecological health and compliance monitoring programs is not warranted.	6.5.2.1 6.5.2.2
Water	Chemical Monitoring	Baseline water quality studies for surface water were conducted in 2013, 2014, and 2015. Baseline groundwater quality studies were conducted in 2013 and 2014. Surface water monitoring requirements are developed as part of the permit application for a NPDES permit issued by the TDEC. Quarterly groundwater monitoring well sampling is re-initiated for two years preceding the construction start date.	6.6.1 6.6.2

Table 6.7-1 (Sheet 3 of 4)
Summary of Monitoring Programs

Resource	Program	Scope/Content	Applicable Section/Subsection for Additional Details
Preoperational Monitoring			
Water	Thermal Monitoring	Because the site preparation monitoring already conducted provides adequate baseline data, no additional thermal monitoring is planned during the preoperational phase.	6.1.2
Human Health	Radiological Monitoring	The REMP includes monitoring of the environment by sampling air, water, sediment, fish, invertebrates and food products, as well as measuring radiation directly. The REMP is initiated two years before scheduled fuel load.	6.2
Water	Hydrological Monitoring	Surface water monitoring requirements for preoperational activities are developed as part of the permit application for a NPDES permit issued by TDEC.	6.3.2
Meteorology	Meteorological Monitoring	Refurbished meteorological Tower 3 was used to collect the meteorological monitoring data for the preoperational phase of the SMR project.	6.4.1
Terrestrial	Ecological Monitoring	Field studies performed during the site preparation monitoring program, which includes seasonal species surveys of terrestrial communities, are repeated for the period following construction, in order to collect at least 1 yr of preoperational and/or operational data for comparison to the baseline data. The activities included in a preoperational/operational monitoring program are a subset of the site preparation field studies.	6.5.1.2
Aquatic	Ecological Monitoring	Field studies performed during the site preparation monitoring program of aquatic communities are repeated for the period prior to startup of the initial SMR in order to collect at least 1 yr of preoperational and/or operational data (including aquatic monitoring) for comparison to the baseline data. The activities included in a preoperational/operational aquatic monitoring program are a subset of the site preparation field studies.	6.5.2.3

Table 6.7-1 (Sheet 4 of 4)
Summary of Monitoring Programs

Resource	Program	Scope/Content	Applicable Section/Subsection for Additional Details
Operational Monitoring			
Water	Chemical Monitoring	Preoperational surface water monitoring requirements are developed as part of the permit application for a NPDES general stormwater construction permit issued by TDEC.	6.6.2
Water	Thermal Monitoring	Thermal monitoring during the operational phase is developed, once the final SMR design is selected. Operational monitoring is in accordance with the NPDES permit, which is finalized prior to the start of operation.	6.1.3
Human Health	Radiological Monitoring	Radiological monitoring for the operational period is defined in the REMP.	6.2
Water	Hydrological Monitoring	Hydrological monitoring to assess impacts to water quality resulting from operation of the SMRs is developed once the final SMR design is selected.	6.3.3
Meteorology	Meteorological Monitoring	As part of the operational phase of the CR SMR Project, a new meteorological tower is expected to be constructed at the location of the old meteorological tower from which the 2011 through 2013 data were collected, and the new meteorological monitoring program is established for operational monitoring. It is expected to meet the same TVA and regulatory requirements satisfied by the preoperational meteorological program.	6.4.3
Ecology	Ecological Monitoring	No specific ecological monitoring is proposed.	6.5.1.2
Water	Chemical Monitoring	Preoperational surface water monitoring is used to establish surface water quality to demonstrate compliance with the NPDES permit limitations and surface water monitoring requirements to assure compliance with TDEC Water Quality Standards. The groundwater monitoring program is established once the final SMR design is selected.	6.6.3

CHAPTER 7 ENVIRONMENTAL IMPACTS OF POSTULATED ACCIDENTS INVOLVING RADIOACTIVE MATERIALS

This chapter assesses the environmental impacts of postulated accidents involving radioactive materials at the Clinch River Nuclear (CRN) Site. The chapter is divided into four sections that address design basis accidents, severe accidents, severe accident mitigation design alternatives, and transportation accidents.

- Design Basis Accidents (Section 7.1)
- Severe Accidents (Section 7.2)
- Severe Accident Mitigation Design Alternatives (Section 7.3)
- Transportation Accidents (Section 7.4)

7.1 DESIGN BASIS ACCIDENTS

7.1.1 Accident Selection

The evaluation of nuclear power plant safety includes analysis of the facility's response to a spectrum of postulated disturbances in process variables and postulated equipment failures.

However, it is neither practical nor necessary to analyze all historically-postulated design basis accidents (DBAs) associated with small modular reactor (SMR) types under consideration for the Clinch River Nuclear (CRN) Site in the early site permit application (ESPA), as discussed below.

As noted in NEI 10-01, *Industry Guideline for Developing a Plant Parameter Envelope (PPE) in Support of an Early Site Permit*, 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. Different reactor designs have different release pathways, and each pathway has different release rates and different radionuclide removal mechanisms. Given these differences, it is impractical to develop a bounding analysis for use in a PPE-based ESPA, and accordingly, for the purposes of evaluating offsite post-accident doses, the vendor analysis with the highest resultant post-accident dose was selected for use in the CRN Site-specific dose analysis presented here. (Reference 7.1-1)

At this time, the site layout and building configuration for each of the proposed reactor designs for the CRN Site has yet to be determined, making it impractical to model near-field atmospheric dispersion around buildings in order to determine doses in the main control room and other areas where habitability is required post-accident. Thus, these types of detailed accident analyses are more appropriately performed during the combined license application (COLA) stage when a technology is selected and the orientation of the plant on the site is known.

Pressurized water reactor (PWR) designs, as documented in ESPAs to date, have shown that offsite doses due to a postulated loss-of-coolant accident (LOCA) are expected to more closely approach Title 10 of the Code of Federal Regulations (10 CFR) 52.17 limits than other DBAs that may have a greater probability of occurrence but a lesser magnitude of activity release, as evidenced by the following:

- Clinton Site ESPA, Environmental Report (ER) Table 7.1-2 (Reference 7.1-2)
- Grand Gulf Site ESPA, ER Table 7.1-1 (Reference 7.1-3)
- North Anna Site ESPA, ER Table 7.1-2 (Reference 7.1-4)
- Vogtle Site ESPA, ER Table 7.1-12 (Reference 7.1-5)
- PSEG Site ESPA, ER Tables 7.1-39, 7.1-47 and 7.1-56 (Reference 7.1-6)
- Victoria County Station Site ESPA, ER Table 7.1-5 (Reference 7.1-7)

Based on initial design feedback, TVA has reasonably high confidence that the consequences of a LOCA will be shown to be proportionally less than those for large PWR designs, and that no new events of greater consequence will be identified. Each of the four small modular PWR designs under consideration for the CRN Site is expected to include advanced design features that would further minimize accident consequences. In particular, based on initial design feedback, Tennessee Valley Authority (TVA) anticipates that the consequences of a LOCA will be less than those for large PWR designs and that no events of greater consequence will be identified.

Thus, analysis of postulated DBAs other than a LOCA is not necessary for the 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. The COLA will verify that the accident doses provided in this ESPA are bounded or will provide an evaluation of accident radiological consequences.

7.1.2 Source Term

The bounding design basis accident (LOCA) source term is provided in Table 7.1-1.

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 with the highest resulting doses at the exclusion area boundary (EAB) and the low population zone (LPZ) boundary from the four SMR designs under consideration. Key input parameters associated with the accident source term in the PPE have been evaluated to assess their reasonableness for and representativeness of SMR designs.

The PPE LOCA source term is based on a design that uses standard light water reactor fuel, which is representative of the SMR designs under consideration, and assumes a core power level for a single unit at 800 megawatt thermal (MWt). The methodology and analytical techniques used for development of the source term are similar to those used for large light water reactors, and TVA anticipates that comparable methodologies and techniques will be used in the development of the SMR accident source terms to be presented in the SMR design control documents.

To assess reasonableness, a comparison of the PPE LOCA source term to that of the AP1000 design (as provided in the Vogtle 3 and 4 ESPA) was performed, scaling the source term presented in the Vogtle ESPA by a factor of 0.235 (800 MWt/3400 MWt) to account for the smaller core thermal power of the SMR designs being considered for the CRN Site. The activity release associated with the worst 2-hour time period of the scaled-down AP1000 is approximately 25 percent greater than that of the surrogate plant (as provided in the PPE). This difference is reasonable given that SMR designs contain additional safety features that will result in increased safety margins general improvements over the AP1000 design. The activity release for the 30-day duration of the LOCA is approximately equivalent to that of the surrogate plant and is also considered reasonable.

The source terms developed for the surrogate plant are representative of the potential SMR designs considering core power and average burnup. The surrogate plant assumes a core power that is bounding but representative of the remaining SMR designs being considered. The maximum average burnup assumed for the surrogate plant is 51 gigawatt days per metric tons of uranium (GWD/MTU), while the maximum average burnup for the remaining SMR designs is less than 41 GWD/MTU. Although it is recognized that core power and burnup do 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 SMR designs.

7.1.3 Evaluation Methodology and Conclusions

Doses for a LOCA are evaluated at the EAB and LPZ boundary. The evaluation uses the following parameters, as shown in Table 7.1-2:

- Short-term 50th percentile accident atmospheric dispersion factors (*X*/Qs) for the CRN Site
- Bounding vendor-provided LOCA doses
- *X*/Q values associated with the bounding vendor-provided LOCA doses

Doses are calculated based on the amount of activity released to the environment, the dispersion of activity during transport to the receptor (*X*/Q), the breathing rate at the receptor, and the applicable dose conversion factors. The only parameters that are site-specific are the *X*/Qs. Hence, it is reasonable to adjust the vendor LOCA doses for site-specific *X*/Q values, provided in Table 2.7.5-13

For a given time step, the vendor dose is multiplied by the ratio of the site-specific *X*/Q to the vendor *X*/Q, as shown in the following equation:

$$Dose_{Site} = Dose_{Vendor}\left[\frac{(X/Q)_{Site}}{(X/Q)_{Vendor}}\right]$$

The resulting accident doses are expressed as total effective dose equivalent (TEDE) consistent with 10 CFR 52.17. As shown in Table 7.1-2, all site LOCA doses meet the 25 rem TEDE limit specified in 10 CFR 52.17.

7.1.4 References

Reference 7.1-1. Nuclear Energy Institute, "Industry Guideline for Developing a Plant Parameter Envelope in Support of an Early Site Permit," May, 2012.

Reference 7.1-2. Exelon Nuclear, Early Site Permit Application for the Clinton ESP Site, Revision 4 (Chapter 7), Website: http://pbadupws.nrc.gov/docs/ML0611/ML061100280.pdf, April 4, 2006.

Reference 7.1-3. Entergy, Grand Gulf Early Site Permit Application, Revision 2 (Chapter 7), Website: http://pbadupws.nrc.gov/docs/ML0527/ML052790350.pdf, October 3, 2005.

Reference 7.1-4. Dominion Nuclear North Anna, LLC, North Anna Early Site Permit Application, Revision 9 (Chapter 3), Website: http://pbadupws.nrc.gov/docs/ML0625/ML062580114.pdf, September 12, 2006.

Reference 7.1-5. Southern Nuclear Operating Company, Inc., Vogtle Early Site Permit Application, Revision 5 (Chapter 7), Website: http://pbadupws.nrc.gov/docs/ML0915/ML091540840.pdf, December 23, 2008.

Reference 7.1-6. PSEG Power, LLC, Application for Early Site Permit for the PSEG Site, Revision 3 (Chapter 7), Website: http://pbadupws.nrc.gov/docs/ML1409/ML14093A939.pdf, March 31, 2014.

Reference 7.1-7. Exelon Generation, Application for Early Site Permit for Victoria County Station, Revision 1 (Chapter 7), Website: http://pbadupws.nrc.gov/docs/ML1213/ML12131A101.pdf, May 30, 2012.

Table 7.1-1 (Sheet 1 of 2)
LOCA Bounding Design Basis Accident
Atmospheric Radioactive Release (in Ci)

Nuclide	Worst 2 hour	0-8 hour	8-24 hour	1-4 days	4-30 days
Kr-85m	3.51E+02	9.28E+02	4.60E+02	2.10E+01	0.00E+00
Kr-85	3.01E+01	1.05E+02	2.50E+02	5.64E+02	4.84E+03
Kr-87	2.66E+02	4.84E+02	1.22E+01	1.00E-02	0.00E+00
Kr-88	7.48E+02	1.74E+03	4.05E+02	4.20E+00	0.00E+00
Xe-131m	1.92E+01	6.69E+01	1.55E+02	3.13E+02	1.27E+03
Xe-133m	1.17E+00	3.98E+00	8.14E+00	1.07E+01	6.72E+00
Xe-133	3.82E+03	1.32E+04	2.95E+04	5.25E+04	1.04E+05
Xe-135m	2.08E+00	8.91E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	8.53E+02	2.57E+03	2.70E+03	5.62E+02	2.30E+00
Xe-138	5.81E+00	2.92E+01	0.00E+00	0.00E+00	0.00E+00
I-130	2.12E+00	4.19E+00	1.55E-01	8.10E-03	2.00E-04
I-131	1.34E+02	2.76E+02	1.52E+01	5.80E+00	1.75E+01
I-132	9.61E+01	1.69E+02	1.11E+00	1.00E-07	0.00E+00
I-133	2.59E+02	5.20E+02	2.28E+01	2.54E+00	2.50E-01
I-134	4.98E+01	9.21E+01	2.10E-02	0.00E+00	0.00E+00
I-135	2.06E+02	3.94E+02	1.02E+01	1.50E-01	0.00E+00
Cs-134	2.35E+01	4.71E+01	2.06E+00	1.11E-02	9.60E-02
Cs-136	6.70E+00	1.20E+01	4.60E-01	3.09E-03	9.00E-03
Cs-137	1.80E+01	3.63E+01	1.59E+00	9.07E-03	7.50E-02
Cs-138	1.14E+01	2.75E+01	1.00E-08	0.00E+00	0.00E+00
Rb-86	2.06E-01	4.15E-01	1.81E-02	9.07E-05	4.80E-04
Te-127m	2.74E-01	5.48E-01	2.62E-02	1.40E-04	1.11E-03
Te-127	1.34E+00	2.52E+00	7.40E-02	0.00E+00	0.00E+00
Te-129m	9.09E-01	1.82E+00	8.65E-02	4.00E-04	3.00E-03
Te-129	1.14E+00	1.80E+00	1.70E-03	0.00E+00	0.00E+00
Te-131m	3.32E+00	6.51E+00	2.67E-01	5.00E-04	2.00E-04
Te-132	2.59E+01	5.14E+01	2.32E+00	8.00E-03	9.00E-03
Sb-127	1.59E+00	3.17E+00	1.44E-01	6.00E-04	7.00E-04
Sb-129	3.38E+00	5.99E+00	9.99E-02	0.00E+00	0.00E+00
Sr-89	7.79E+00	1.56E+01	7.42E-01	4.00E-03	2.80E-02
Sr-90	9.52E-01	1.91E+00	9.12E-02	5.00E-04	4.30E-03
Sr-91	8.01E+00	1.51E+01	4.46E-01	0.00E+00	0.00E+00
Sr-92	5.48E+00	9.27E+00	8.32E-02	0.00E+00	0.00E+00
Ba-139	4.14E+00	6.61E+00	1.17E-02	0.00E+00	0.00E+00

**Table 7.1-1 (Sheet 2 of 2)
LOCA Bounding Design Basis Accident
Atmospheric Radioactive Release (in Ci)**

Nuclide	Worst 2 hour	0-8 hour	8-24 hour	1-4 days	4-30 days
Ba-140	1.33E+01	2.66E+01	1.25E+00	6.00E-03	2.60E-02
Ru-103	1.40E+00	2.81E+00	1.34E-01	7.00E-04	4.80E-03
Ru-105	6.27E-01	1.12E+00	1.93E-02	0.00E+00	0.00E+00
Ru-106	4.75E-01	9.52E-01	4.55E-02	2.50E-04	2.08E-03
Rh-105	8.37E-01	1.65E+00	6.92E-02	2.00E-04	0.00E+00
Mo-99	1.71E+00	3.38E+00	1.51E-01	5.00E-04	4.00E-04
Tc-99m	1.16E+00	2.12E+00	4.78E-02	0.00E+00	0.00E+00
Ce-141	3.19E-01	6.38E-01	3.03E-02	1.60E-04	1.02E-03
Ce-143	2.81E-01	5.53E-01	2.30E-02	5.00E-05	2.00E-05
Ce-144	2.65E-01	5.31E-01	2.54E-02	1.40E-04	1.15E-03
Pu-238	5.94E-04	1.19E-03	5.68E-05	3.00E-07	2.70E-06
Pu-239	7.10E-05	1.42E-04	6.79E-06	4.00E-08	3.20E-07
Pu-240	1.08E-04	2.16E-04	1.03E-05	6.00E-08	4.80E-07
Pu-241	2.64E-04	5.30E-04	2.53E-05	1.40E-07	1.19E-06
Np-239	3.16E+00	6.26E+00	2.76E-01	8.00E-04	6.00E-04
Y-90	9.55E-03	1.89E-02	8.43E-04	2.00E-06	3.00E-06
Y-91	1.01E-01	2.02E-01	9.62E-03	5.00E-05	3.80E-04
Y-92	6.37E-02	1.11E-01	1.47E-03	0.00E+00	0.00E+00
Y-93	9.72E-02	1.84E-01	5.60E-03	0.00E+00	0.00E+00
Nb-95	1.34E-01	2.69E-01	1.28E-02	7.00E-05	4.40E-04
Zr-95	1.32E-01	2.65E-01	1.26E-02	7.00E-05	5.00E-04
zr-97	1.17E-01	2.25E-01	8.22E-03	1.00E-05	0.00E+00
La-140	1.32E-01	2.61E-01	1.11E-02	3.00E-05	1.00E-05
La-142	4.13E-02	6.62E-02	1.66E-04	0.00E+00	0.00E+00
Nd-147	4.89E-02	9.77E-02	4.60E-03	2.00E-05	8.00E-05
Pr-143	1.17E-01	2.34E-01	1.11E-02	5.00E-05	2.40E-04
Am-241	1.56E-05	3.12E-05	1.49E-06	8.00E-09	7.00E-08
Cm-242	3.16E-03	6.33E-03	3.02E-04	1.70E-06	1.32E-05
Cm-244	1.84E-04	3.69E-04	1.76E-05	1.00E-07	8.30E-07
Total	6.64E+03	2.00E+04	3.31E+04	5.39E+04	1.10E+05

Table 7.1-2
CRN Site LOCA Doses

Location	Time (hr)	*X/Q* (sec/m³)		*X/Q* Ratio (Site/Vendor)	Dose (rem TEDE)	
		Site (50th %)	Vendor		Vendor	Site
EAB	0-2	5.58E-04	1.0E-03	0.56	4.4	2.4[1]
LPZ	0-8	4.27E-05	5.0E-04	0.085	4.4	0.38
	8-24	3.80E-05	3.0E-04	0.13	0.20	0.025
	24-96	2.94E-05	1.5E-04	0.20	0.05	0.0098
	96-720	2.04E-05	8.0E-05	0.26	0.06	0.015
				LPZ Total	4.8	0.43[1,2]

1 Versus the 25 rem TEDE limit specific in 10 CFR 52.17.
2 Column total dose not equal sum of individual values due to rounding.

7.2 SEVERE ACCIDENTS

This section evaluates the potential environmental impacts of severe accidents at the Clinch River Nuclear (CRN) Site. Four small modular reactor (SMR) designs are included in the plant parameter envelope (PPE): BWXT mPower, Holtec, NuScale, and Westinghouse. The environmental impacts from postulated severe accidents were calculated using site-specific data to demonstrate acceptability.

The current United States nuclear fleet has an exceptional safety record. Each of the four SMR designs included in the PPE includes design features that result in additional enhancements to safety.

Severe accidents are defined as accidents with substantial damage to the reactor core and degradation of containment systems. Subpart B of Title 10 of the Code of Federal Regulations Part 52 requires applications for standard design certification to include information from the probabilistic risk assessment (PRA) of the design. No application for standard design certification has been submitted to the U.S. Nuclear Regulatory Commission (NRC) for the four designs included in the PPE, and the final design and PRA information was not available for these designs at the time of preparation of this early site permit application.

The Tennessee Valley Authority (TVA) requested that each of the four SMR vendors provide information from the PRA for its design to allow the assessment of potential severe accident consequences. While information regarding severe accident release categories, source terms, and release frequencies was provided to TVA from some SMR vendors, information was not received from all vendors. Therefore, TVA made a reasonable, bounding estimate of the severe accident consequences for the PPE by evaluating the SMR design that represents the largest SMR considered for the CRN Site.

This section uses preliminary PRA information for severe accidents for the largest SMR design, along with site-specific characteristics, to estimate the impacts of severe accidents. The purpose of this analysis is to identify the environmental impacts from potential severe accidents.

7.2.1 Methodology

The MACCS2 computer code was developed to model the environmental consequences of the severe accidents (Reference 7.2-1). MACCS2 was developed specifically for the NRC to evaluate severe accidents at nuclear power plants. The NRC has approved MACCS2 analyses of environmental consequences from a new pressurized water reactor (PWR) design with passive safety features. The ratio of the thermal power rating of the previously analyzed PWR to the largest SMR considered for the CRN Site was used to estimate the source terms required for analysis of the impacts of severe accidents. Use of the largest SMR for the severe accident analysis is considered to provide representative accident consequences. The relative frequencies, source term chemical groups, and source term release fractions for the severe accident scenarios were calculated as part of the PRA for the SMR design with the maximum thermal output and are shown in Tables 7.2-1, 7.2-2, and 7.2-3, respectively. This data was used together with the MACCS2 ATMOS module input files and an estimated core damage frequency (CDF) to approximate the consequences of severe accidents for the SMR.

The SMR design used for this analysis differs from the surrogate SMR defined by the PPE. The PPE defines a maximum thermal power rating for the CRN Site based on the range of SMR designs under consideration. The individual reactor considered for this analysis uses the maximum thermal power rating for a single reactor unit [800 megawatt thermal (MWt)] from one of the potential SMR vendors; thus maximizing the severe accident consequences for an accident involving a single unit.

The CDF is a measure of the likelihood of severe accidents associated with reactor core damage. CDF is estimated using PRA modeling, which evaluates how changes to the reactor or auxiliary systems can change the severity of the accident. The vendor of the SMR considered in this analysis estimates the total CDF for the design to be approximately 4.65E-08 per reactor year (Ryr), which is lower than the CDF of 2.41E-07 for a modern full scale reactor (Reference 7.2-2). Table 7.2-1 presents the relative frequency of each release category.

The SMR used in this analysis utilizes six severe accident sequences (release categories) as follows:

- Intact Containment (IC): Containment integrity is maintained throughout the accident. The release of radioactivity to the environment is due to nominal design leakage.
- Containment Bypass (BP): Radioactivity is released from the reactor coolant system to the environment via the secondary system or other interfacing system bypass. Containment failure occurs prior to the onset of core damage. This accident class contributes to the large, early release frequency.
- Containment Isolation Failure (CI): Radioactivity is released through a failure of the valves that close the penetrations between containment and the environment. Containment failure occurs prior to the onset of core damage. This accident class contributes to the large, early release frequency.
- Early Containment Failure (CFE): Radioactivity release occurs through a containment failure caused by some dynamic severe accident phenomenon after the onset of core damage but prior to core relocation. Such phenomena could include hydrogen detonation, hydrogen diffusion flame, steam explosions, or vessel failures. This accident class contributes to the large, early release frequency.
- Intermediate Containment Failure (CFI): Radioactivity release occurs through a containment failure caused by some dynamic severe accident phenomenon after core relocation but before 24 hours (hr) have passed since initiation of the accident. Such phenomena could include hydrogen detonation and hydrogen deflagration. This accident class contributes to large releases but does not occur early in the accident life cycle.

- Late Containment Failure (CFL): Radioactivity release occurs through a containment failure caused by some dynamic severe accident phenomenon more than 24 hr after initiation of the accident. Such phenomena could include the failure of containment heat removal. This accident class contributes to large releases but does not occur early in the accident life cycle.

7.2.2 TVA Methodology

The MACCS2 computer code (Version 3.10.0, with the WinMACCS graphical user interface), was used to evaluate the environmental consequences of the severe accidents (Reference 7.2-3). The exposure pathways modeled include external exposure from the passing plume, external exposure from material deposited on the ground, inhalation of material in the passing plume or re-suspended from the ground, and ingestion of contaminated food and surface water. The MACCS2 code primarily addresses dose from the air pathway, but also calculates dose from surface runoff and deposition on surface water. The code also evaluates the extent of contamination. The analysis used site-specific meteorology and population data and also included the ingestion pathway over the entire life cycle of the accident.

To assess human health impacts, TVA determined the collective dose, risk of early fatalities, and the risk of latent cancer fatalities from a severe accident for the population within a 50-mile (mi) radius. Economic costs were also determined, including the costs associated with short-term relocation of people, decontamination of property and equipment, and interdiction of food supplies.

MACCS2 requires five input files: ATMOS, EARLY, CHRONC, METEOROLOGICAL, and SITE. ATMOS provides data to calculate the amount of material released to the atmosphere that is dispersed and deposited. The calculation uses a Gaussian plume model. Important reactor and site-specific inputs in this file include the core inventory, release fractions, and geometry of the reactor and associated buildings. These input data are the same as those in the MACCS2 input files used by the vendor of the SMR. EARLY provides inputs to calculations regarding exposure in the time period immediately following the release. Important site-specific information includes emergency response information such as evacuation time. CHRONC provides data for calculating long-term impacts and economic costs and includes region-specific data on agriculture and economic factors. These files access a meteorological file and a site characteristics file. METEOROLOGICAL provides actual site-specific meteorological monitoring data (hourly data that includes wind speed and direction, stability class, and rainfall) for one year (mid-2012 to mid-2013). SITE provides site-specific population data, land usage, watershed index, and economic data for the region.

The MACCS2 calculations and accident frequency information are used to determine risk. The sum of the accident frequencies, the CDF, includes only internally initiated events. Risk is the product of frequency of an accident multiplied by the consequences of the accident. The consequence can be radiation dose, fatalities, economic cost or farmland that needs to be decontaminated. Dose-risk is the product of the collective dose times the accident frequency.

Because the severe accident analysis addressed a suite of accidents (release categories), the individual risks are summed to provide a total risk (person-sievert [Sv] per Ryr). The same process was applied to estimating the risk of fatalities (fatalities per Ryr), the economic cost-risk (dollars per Ryr), and the risk of farmland decontamination (hectares per Ryr).

Chapter 5 of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 0, assesses the impacts of postulated accidents at nuclear power plants on the environment. NUREG-1437 was revised in 2013. Appendix E of NUREG-1437, Rev. 1, provides an update on postulated accident risk. Rev. 1 considers how more recent information on postulated accidents would affect the conclusions of Rev. 0 and provides comparative data where appropriate. However, Rev. 1 does not provide new information necessary for the evaluation of postulated accidents for all dose pathways, and was not used for this evaluation.

7.2.3 Consequences to Population Groups

This subsection evaluates impacts of severe accidents from air, surface water, and groundwater pathways. The MACCS2 code was used to evaluate the doses from the air pathway and from water ingestion with site-specific data. MACCS2 does not model other surface water and groundwater dose pathways. These are analyzed qualitatively based on a comparison of doses from the atmospheric pathway for CRN Site to those of the existing fleet of United States nuclear reactors.

7.2.3.1 Air Pathways

The potential severe accidents for the SMR considered in this analysis were grouped into six accident classes (release categories) based on the similarity of their characteristics. The number and description of release categories is reactor design-specific. Radionuclides that may be released are organized into groups having similar chemical characteristics as shown in Table 7.2-2. Each release category was assigned a set of characteristics representative of the chemical elements for that category as shown in Table 7.2-3. Each release category was analyzed with MACCS2 to calculate population dose, number of early and latent fatalities, economic cost, and the amount of farmland requiring decontamination. The analysis assumed that 99.5 percent of the population within the 2-mi emergency planning zone (EPZ) of the CRN Site would be evacuated following declaration of a general emergency.

For each release category, risk was calculated by multiplying each consequence (population dose, fatalities, cost, and area of contaminated land) by the total CDF and the relative frequency for the release category. The sum of the long-term dose risk to the 50-mi population from atmospheric releases was calculated by MACCS2 for the 2-mi EPZ to be 7.71E-05 person-Sv/Ryr (Table 7.2-4). As shown in Tables 7.2-5 and 7.2-6, this 50-mi population risk is much lower than the risk estimated for (1) the five plants evaluated in NUREG-1150, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*, (2) the other current operating reactors in the United States, (3) the recently licensed AP1000 reactors at the V.C. Summer and Vogtle sites, and (4) the NRC Safety Goals (51 CFR 30028).

For an additional comparison, as reported in Section 5.4, the calculated collective total body dose based on the PPE source term from normal operations at the CRN Site due to radioactive effluents (liquid and gaseous) is 6.8E+01 person-rem/Ryr (6.8E-01 person-Sv/Ryr) (from Table 5.4-16). As previously described, dose risk is the total population dose rate (in person-Sv/Ryr) multiplied by the frequency, and normal operation has a frequency of one. Therefore, the calculated population dose risk for normal operation is also 6.8E-01person-Sv/Ryr. Comparison of this value to the severe accident dose risk of 7.71E-05 person-Sv/Ryr indicates that the calculated dose risk from severe accidents is far less than the calculated dose risk from normal operation.

The economic costs (in dollars per reactor year) are also provided in Table 7.2-4. The total cost calculation considered consequences, such as evacuation costs, value of crops contaminated and condemned, value of milk contaminated and condemned, cost of property decontamination, and indirect costs resulting from loss of property use and incomes as a result of the accident. The calculated economic risk of a severe accident for the largest potential SMR at the CRN Site is 29.3 dollars/Ryr. The area of farmland requiring decontamination was calculated by MACCS2 for the 2-mi EPZ to be 1.69E-04 hectares/Ryr. These impacts are smaller than the impacts that were estimated for most other new reactor license applications. Again, these impact risks are lower than those presented in the Final Environmental Impact Statements for recently approved reactor license applications such as Vogtle (NUREG-1872, *Final Environmental Impact Statement for an Early Site Permit (ESP) at the Vogtle ESP Electric Generating Plant Site*) and V.C. Summer (NUREG-1939, *Final Environmental Impact Statement for Combined Licenses for Virgil C. Summer Nuclear Station, Units 2 and 3*) and found to be acceptable.

7.2.3.2 Surface Water Pathways

People can be exposed to radiation when airborne radioactivity is deposited onto surface water. The exposure pathways can include drinking the water, aquatic food, swimming, and shoreline pathways. Surface water bodies within the 50 mi of the CRN Site include the Tennessee River, Clinch River, Norris Lake, and other smaller bodies of water.

The NRC examined the aquatic food, swimming, and shoreline pathways in NUREG-0769, *Final Environmental Impact Statement Related to the Operation of Enrico Fermi Atomic Power Plant, Unit No. 2,* and demonstrated that the dose from the aquatic food pathway was more than ten times the dose from the combined swimming and shoreline doses. The examination concluded that the uninterdicted aquatic food pathway was the principal pathway of exposure and the swimming and shoreline pathways were not significant.

The NRC also evaluated doses from the aquatic food pathway for nuclear power plants discharging to various bodies of water in NUREG-1437, Rev. 0. NUREG-1437, Subsection 5.3.3.3.3 concluded that the risk associated with the aquatic food pathway is small relative to the atmospheric pathway for most sites, including small and large river sites. The CRN Site is a good approximation of the generic small river site examined in the NUREG-0440, *Liquid Pathway Generic Study: Impacts of Accidental Radioactive Releases to the Hydrosphere from*

Floating and Land-based Nuclear Power Plants, (the source of the NUREG-1437 analysis). Appendix E of NUREG-1437, Rev. 1, provides no updated information on the evaluation of the aquatic food pathway.

MACCS2 calculated the dose from drinking water pathway for surface water sources. The sum of the severe accident dose risk to the 50-mi population from drinking water was calculated by MACCS2 for the 2-mi EPZ to be 1.19E-06 person-Sv/Ryr) (Table 7.2-4). This value is the sum of the drinking water risk from each of the six release categories. As Table 7.2-4 shows, the total drinking water dose risk is very small in comparison to the total dose risk for the atmospheric pathways. This dose risk is also lower than the dose risk from the drinking water pathway presented in the final environmental impact statements for recently approved reactor license applications such as Vogtle (NUREG-1872) and V.C. Summer (NUREG-1939) and found to be acceptable.

7.2.3.3 Groundwater Pathways

People also could receive a dose from groundwater pathways. Radioactivity released during an accident can enter groundwater that serves as a source of drinking water or move through an aquifer that eventually discharges to surface water. The MACCS2 code does not calculate the dose from groundwater pathways. NUREG-1437, Rev. 0, evaluated the groundwater pathway dose, based on the analysis in NUREG-0440. NUREG-0440 analyzed a core meltdown that contaminated groundwater and subsequently contaminated surface water. NUREG-0440 did not analyze direct groundwater drinking at small river sites because of the limited number of potable groundwater wells. Therefore, Subsection 5.3.3.4.1 of NUREG-1437, Rev. 0, concludes that the dose from the groundwater pathway for small river sites is considered to be “minor or nonexistent.” As stated previously, the CRN Site is a good approximation of the generic small river site examined in NUREG-0440. Appendix E of NUREG-1437, Rev. 1, provides no updated information on the evaluation of the groundwater pathway.

7.2.4 Health Risks

Based on the total calculated dose risk from the SMR at the CRN Site considered in this analysis, the risk of early fatalities to the 50-mi population was calculated to be 2.00E-11 fatalities/Ryr and the risk of latent cancer fatalities to the 50-mi population was calculated by MACCS2 for the 2-mi EPZ to be 4.09E-06 fatalities/Ryr. These fatality risks are lower than the fatality risks presented in the Final Environmental Impact Statements (FEIS) for recently approved reactor license applications. In NUREG-1872 fatality risks are reported as1.9E-10 early fatalities/Ryr and 1.9E-05 latent fatalities/Ryr. In NUREG-1939 fatality risks are reported as 2.4E-08 early fatalities/Ryr and 6.4E-05 latent fatalities/Ryr, respectively. While these risks are site-specific and dependent on local meteorology and regional populations, CRN Site risks are considered comparable to other facilities.

In addition, the MACCS2 computer code estimated the average individual fatality risks to be 1.27E-13 per Ryr from early fatalities within about one mi of CRN Site and 9.12E-12 per year from latent cancer fatalities within 10 mi. These risks are well below the safety goals for the average individual early fatality and latent cancer fatality risks set by the NRC in the Safety Goal Policy Statement (51 FR 30028) - less than 0.1 percent of risk resulting from other accidents. As indicated in draft NUREG-2168, *Environmental Impact Statement for an Early Site Permit (ESP) at the PSEG Site, Final Report*, the individual risk of a prompt fatality from all other accidents to which members of the United States population are generally exposed is about 4.1E-04 per year, and the sum of cancer fatality risks resulting from all other causes for an individual is taken to be the cancer fatality rate in the United States, which is about 1 in 500 or 2E-03 per year. The risks estimated for the CRN Site are much less than one-tenth of one percent of these everyday public risks.

7.2.5 Conclusions

These estimates of the environmental impacts of severe accidents are considered to be bounding for each of the four SMR designs; the power levels of the other SMR designs are lower than the power level of the SMR considered in this analysis. Also, as provided in Tables 7.2-5 and 7.2-6, the 50-mi population dose risks and the population fatality risks are less than those calculated for other operating reactors or new reactors currently under construction and the individual fatality risks are several orders of magnitude below the NRC Safety Goals.

Based on the discussions in the subsections above, these environmental impacts are concluded to be SMALL.

7.2.6 References

Reference 7.2-1. Sandia National Laboratories, "Code Manual for MACCS2," 1998.

Reference 7.2-2. U.S. Nuclear Regulatory Commission, Westinghouse AP1000 Design Control Document Rev. 19 (Chapter 19, Section 19.59), Website: http://pbadupws.nrc.gov/docs/ML1117/ML11171A411.pdf, June 21, 2011.

Reference 7.2-3. McFadden, K., Bixler, N. E., Eubanks, Lee, and Haaker, R., "WinMACCS, Calculating Health and Economic Consequences from Radioactive Material Accidents," 2007.

Table 7.2-1
Bounding CRN Site SMR Release Category Relative Frequencies

Release Category	Description	Relative Frequency (%)
IC	Intact Containment	91.9
BP	Containment Bypass	4.37
CFE	Early Containment Failure	3.11
CI	Containment Not Isolated	0.55
CFI	Intermediate Containment Failure	0.08
CFL	Late Containment Failure	0.000001
	Total	100

Table 7.2-2
Representative CRN Site SMR Chemical Group Assignment

Group	Nuclides
1	Kr-85, Kr-85m, Kr-87, Kr-88, Xe-133, Xe-135
2	I-131, I-132, I-133, I-134, I-135
3	Rb-86, Cs-134, Cs-136, Cs-137
4	Sb-127, Sb-129, Te-127, Te-127m, Te-129, Te-129m, Te-131m, Te-132
5	Sr-89, Sr-90, Sr-91, Sr-92
6	Mo-99, Tc-99m, Ru-103, Ru-105, Ru-106, Rh-105
7	Y-90, Y-91, Y-92, Y-93, Zr-95, Zr-97, Nb-95, La-140, La-141, La-142, Pr-143, Am-241, Cm-242, Cm-244
8	Ce-141, Ce-143, Ce-144, Np-239, Pu-238, Pu-239, Pu240, Pu-241
9	Ba-139, Ba-140

Table 7.2-3
Representative CRN Site SMR Source Term Release Fractions

Release Category	Plume No.	Group No. 1	Group No. 2	Group No. 3	Group No. 4	Group No. 5	Group No. 6	Group No. 7	Group No. 8	Group No. 9
Intermediate Containment Failure (CFI)	1	5.40E-01	3.19E-03	3.18E-03	4.18E-04	2.11E-02	9.11E-03	3.53E-03	2.64E-05	1.62E-02
	2	2.58E-01	1.35E-04	1.35E-04	1.67E-05	6.50E-04	1.68E-04	4.53E-03	1.68E-05	3.40E-04
	3	8.40E-02	0.00E+00	0.00E+00	4.47E-06	0.00E+00	0.00E+00	6.00E-03	2.17E-05	0.00E+00
	4	3.83E-02	0.00E+00	0.00E+00	1.57E-06	0.00E+00	0.00E+00	5.22E-03	1.89E-05	0.00E+00
Early Containment Failure (CFE)	1	4.16E-01	5.53E-02	5.37E-02	1.23E-03	3.14E-03	1.16E-02	5.57E-05	9.54E-07	4.63E-03
	2	4.05E-01	1.26E-03	1.21E-03	1.61E-04	3.43E-04	2.58E-03	9.66E-06	4.56E-08	6.45E-04
	3	1.08E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	4	3.43E-02	0.00E+00	0.00E+00	6.04E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Intact Containment (IC)	1	9.83E-04	1.20E-05	1.15E-05	8.04E-07	1.07E-05	1.31E-05	1.35E-06	5.85E-09	1.20E-05
	2	4.93E-04	0.00E+00	0.00E+00	4.83E-09	0.00E+00	0.00E+00	6.00E-09	3.20E-11	0.00E+00
	3	3.94E-04	0.00E+00	0.00E+00	1.21E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	4	7.72E-04	0.00E+00	0.00E+00	6.04E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Containment Bypass (BP)	1	1.00E+00	1.69-01	1.62E-01	6.27E-03	3.57E-03	4.48E-02	1.30E-04	3.19E-06	8.93E-03
	2	0.00E+00	4.64E-02	3.38E-02	3.12E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-06
	3	0.00E+00	2.31E-01	6.60E-02	5.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	4	0.00E+00	2.80E-03	9.96E-03	1.57E-03	0.00E+00	0.00E+00	0.00E+00	1.00E-06	0.00E+00
Containment Isolation Failure (CI)	1	5.73E-01	4.56E-02	2.10E-02	1.64E-03	2.03E-02	4.04E-02	2.39E-04	2.97E-06	3.16E-02
	2	1.13E-01	0.00E+00	0.00E+00	1.15E-05	0.00E+00	0.00E+00	1.00E-07	0.00E+00	0.00E+00
	3	5.66E-02	0.00E+00	0.00E+00	8.10E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	4	2.74E-02	0.00E+00	0.00E+00	1.27E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Late Containment Failure (CFL)	1	3.36E-04	1.20E-05	1.15E-05	1.00E-06	1.57E-05	1.68E-05	9.96E-07	7.41E-09	1.61E-05
	2	1.19E-03	5.00E-08	3.23E-08	1.75E-08	1.04E-06	2.90E-07	1.07E-05	4.05E-08	6.60E-07
	3	9.79E-01	2.13E-05	1.16E-05	2.47E-05	2.39E-03	1.26E-03	9.75E-02	3.68E-04	2.25E-03
	4	0.00E+00	0.00E+00	2.56E-07	1.20E-05	4.42E-04	1.55E-04	4.39E-02	1.66E-04	3.46E-04

Table 7.2-4
Environmental Impacts with a 50-Mile Radius for Severe Accidents at CRN Site

Release Category	Population Dose Risk (person-Sv per Ryr)		Risk of Fatalities (fatalities per Ryr)		Economic Cost (dollars per Ryr)	Farmland Decontamination (hectares per Ryr)
	Water Ingestion	Total	Early	Latent		
Containment Bypass (BP)	1.01E-06	6.12E-05	1.77E-11	3.19E-06	2.42E+01	1.35E-04
Early Containment Failure (CFE)	1.55E-07	1.26E-05	0.00E+00	6.57E-07	4.50E+00	3.08E-05
Containment Isolation Failure (CI)	2.18E-08	2.54E-06	2.28E-12	1.97E-07	5.73E-01	3.86E-06
Intact Containment (IC)	1.94E-09	4.79E-07	0.00E+00	2.21E-08	2.53E-02	3.40E-10
Intermediate Containment Failure (CFI)	2.07E-09	3.84E-07	4.06E-15	2.18E-08	4.09E-02	2.81E-07
Late Containment Failure (CFL)	4.50E-13	1.52E-09	0.00E+00	8.25E-11	6.05E-04	3.90E-09
Total	1.19E-06	7.71E-05	2.00E-11	4.09E-06	2.93E+01	1.69E-04

Table 7.2-5
Comparison of Environmental Risks for the PPE with Risks for Current-Generation Reactors at Five Sites Evaluated in NUREG−1150

Reactor Facility	Core Damage Frequency (/Ryr)	50-mi Population Dose Risk (Person-Sv/Ryr)	Fatalities (/Ry)		Average Individual Fatality Risk (/Ryr)	
			Early	Latent	Early	Latent Cancer
Grand Gulf[1]	4.0E-06	5E-01	8E-09	9E-04	3E-11	3E-10
Peach Bottom[1]	4.5E-06	7E+00	2E-08	5E-03	5E-11	4E-10
Sequoyah[1]	5.7E-05	1E+01	3E-05	1E-02	1E-08	1E-08
Surry[1]	4.0E-05	5E+00	2E-06	5E-03	2E-08	2E-09
Zion[1]	3.4E-04	5E+01	4E-05	2E-02	9E-09	1E-08
PPE at the CRN Site[2]	4.7E-08	8E-05	2E-11	4E-06	1E-13	9E-12
NRC Safety Goals[3]	NA	NA	NA	NA	4E-07	2E-06

1 Risks were calculated using the MACCS code and presented in NUREG-1150.
2 Risks were calculated with MACCS2 code using CRN Site site-specific input.
3 Provided by the NRC in the Safety Goal Policy Statement (51 FR 30028).

Note:
NA = Not Applicable

Table 7.2-6
Comparison of Environmental Risks from Severe Accidents for PPE with Risks for Current Nuclear Power Plants Undergoing Operating License Renewal Review

	Core Damage Frequency (per year)	50-mi Population Dose Risk (person-Sv/Ryr)
Current Reactor Maximum[1]	2.4E-04	6.9E-01
Current Reactor Mean[1]	3.1E-05	1.5E-01
Current Reactor Median[1]	2.5E-05	1.3E-01
Current Reactor Minimum[1]	1.9E-06	3.4E-01
AP1000 Reactor at Summer site[2]	2.4E-07	1.0E-03
AP1000 Reactor at Vogtle site[3]	2.4E-07	2.8E-04
PPE at the CRN Site[4]	4.7E-08	7.7E-05

1 Based on MACCS calculations for over 70 current plants at over 40 sites (NUREG-2168).
2 NUREG-1939 (FEIS for V.C. Summer COL)
3 NUREG-1872 (FEIS for Vogtle ESP)
4 Calculated with MACCS code using CRN Site-specific input.

7.3 SEVERE ACCIDENT MITIGATION ALTERNATIVES

This section is not required for an Early Site Permit Application.

7.4 TRANSPORTATION ACCIDENTS

This section describes the environmental impacts of postulated transportation accidents involving the shipment of radioactive materials including unirradiated fuel, irradiated (spent) fuel and radioactive waste to and from the Clinch River Nuclear (CRN) Site and alternative sites discussed in detail in Section 9.3. The evaluations in this section assume that all fuel and radioactive waste shipments are by truck.

Because a small modular reactor (SMR) technology has not been selected, a plant parameter envelope (PPE) has been developed for use in evaluating potential environmental impacts. The PPE is described in Sections 3.1 and 3.2. The SMR technologies being considered for the CRN Site, which are based on a pressurized water reactor (PWR) design, are: BWXT mPower, Holtec, NuScale, and Westinghouse. The PPE is based on the values of fuel-related parameters for the four SMR technologies.

The NRC evaluated the environmental effects of fuel and waste transportation for light water reactors (LWRs) in WASH-1238, “Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Plants,” and NUREG-75/038, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, Supplement 1, and found the impacts to be SMALL (Reference 7.4-1). These documents provide the basis for Table S-4 in Title 10 of the Code of Federal Regulations (10 CFR) 51.52, which summarizes the environmental impacts of fuel and waste transportation to and from one reference LWR. The impacts are provided for normal transport conditions and accidents in transport assuming a 1100 megawatt electric (MWe) LWR with a capacity factor of 0.8, referred to as the “reference reactor.”

As stated in 10 CFR 51.52:

> “Under § 51.50, every environmental report prepared for the construction permit stage or early site permit stage or combined license stage of a light-water-cooled nuclear power reactor, and submitted after February 4, 1975, shall contain a statement concerning transportation of fuel and radioactive wastes to and from the reactor. That statement shall indicate that the reactor and this transportation either meet all of the conditions in paragraph (a) of this section or all of the conditions of paragraph (b) of this section.”

10 CFR 51.52(a)(1) through (5) delineate specific conditions the license applicant’s proposed reactor(s) must meet to use Table S-4 as part of its Environmental Report (ER):

1) The reactor has a core thermal power level not exceeding 3800 megawatt thermal (MWt).
2) Fuel is in the form of sintered uranium oxide pellets having a uranium-235 enrichment not exceeding 4 percent by weight; and the pellets are encapsulated in zircaloy rods.

3) The average level of irradiation of the fuel from the reactor does not exceed 33,000 megawatt days per metric tons uranium (MWD/MTU), and no irradiated fuel assembly is shipped until at least 90 days after it is discharged from the reactor.

4) With the exception of irradiated fuel, all radioactive waste shipped from the reactor is packaged and in solid form.

5) Unirradiated fuel is shipped to the reactor by truck; irradiated (spent) fuel is shipped from the reactor by truck, rail, or barge, and radioactive waste other than irradiated fuel is shipped from the reactor by truck or rail.

For reactors not meeting all of the conditions in 10 CFR 51.52 paragraph (a), paragraph (b) requires a further analysis of the transportation effects.

The PPE differs from conditions 2 and 3 of 10 CFR 51.52(a). As provided in Table 3.1-2, Item 18.1, the fuel enrichment for the PPE could be as high as 5 percent by weight of uranium-235. Also, as provided in Table 3.1-2, Item 18.0.1, the maximum average discharge batch irradiation (burnup) of the irradiated fuel could be as high as 51 gigawatt days per metric tons uranium (GWD/MTU) (51,000 MWD/MTU). Therefore, 10 CFR 51.52 (b) requires "... a full description and detailed analysis of the environmental effects of transportation of fuel and wastes to and from the reactor, including values for the environmental impact under normal conditions of transport and for the environmental risk from accidents in transport. The statement shall indicate that the values determined by the analysis represent the contribution of such effects to the environmental costs of licensing the reactor."

A comparison of fuel and radioactive waste parameters in Table 3.1-2 to the reference reactor parameters in Table S-4, including a discussion of the acceptability of the parameters that differ from Table S-4, is provided in Subsection 5.7.2.1. As discussed in Subsection 3.2.1, the per reactor unit thermal output of the SMR technologies being considered varies from approximately 160 MWt to 805 MWt, with a site total of 1920 MWt to 2420 MWt. Table 3.1-2, Item 16.6 provides the generating output of the SMRs at the CRN Site as 800 MWe.

The reference reactor for Table S-4 is an 1100-MWe LWR with a capacity factor of 80 percent (1100 MWe times 80 percent equals 880 MWe). Table 3.1-2, Item 16.6 shows the generating output of the SMRs at the CRN Site as 800 MWe, and Item 16.4 shows a station capacity factor of 90 percent (800 MWe times 90 percent equals 720 MWe). In each subsection below, the expected number of shipments is multiplied by the ratio, 1.22, to estimate the number of shipments normalized to the reference reactor used in Table S-4.

7.4.1 Radiological Impacts

Accident risks are the product of accident frequency and the consequence of the accident. According to NUREG-1815, *Environmental Impact Statement for an Early Site Permit (ESP) at the Exelon ESP Site*, Appendix G, accident frequencies today are likely to be lower than those used in the WASH-1238 analysis, because traffic accident, injury, and fatality rates have fallen over the past 30 years (yr).

7.4.1.1 Transportation of Unirradiated Fuel

The following assumptions are made in this analysis of the transportation of unirradiated fuel:

- Unirradiated fuel would be transported to the CRN Site via truck in robust packages designed to protect the fuel from damage from dropping or puncture.
- The WASH-1238 analysis of postulated accidents during the transportation of unirradiated fuel found accident impacts to be negligible.
- As noted in NUREG-1815, accident frequencies are likely to be lower in the future than those used in the analysis in WASH-1238 because traffic accident, injury, and fatality rates have fallen since the initial analyses were performed.
- Advanced fuel behaves like fuel evaluated in the analyses provided in WASH-1238.
- Per NUREG-1815, there is no significant difference in the consequences of accidents severe enough to result in a release of unirradiated fuel particles to the environment between advanced LWRs and previous-generation LWRs because the fuel form, cladding, and packaging are similar to those analyzed in WASH-1238.
- The fuel form, cladding, and packaging for the SMR designs considered in the PPE would be similar to the fuel form, cladding, and packaging for advanced LWRs.

Based on this information, the dose impact from nuclides released from postulated accidents involving new fuel is assumed to be negligible when compared to dose from postulated irradiated fuel and radiation waste transportation accidents. Therefore, quantitative analysis of dose from new fuel accidents was not performed.

The radiological impacts from incident free transportation of unirradiated fuel were estimated using the WebTRAGIS 6.0 and RADTRAN 6.5 computer codes (Reference 7.4-3; Reference 7.4-4). The evaluation model assumes that unirradiated fuel is shipped from a fuel fabrication facility located in Richland, Washington, to the CRN Site. The distance from Richland, Washington, to the CRN Site was determined to be 2451 miles (mi; 3944 kilometers [km]) by the WebTRAGIS computer code for a commercial road route. The fuel fabrication facility in Richland is the farthest fabrication facility in the United States from the CRN Site that is currently in operation; therefore, to maximize the transportation distance and potential impacts, it was used as a representative fuel fabrication facility for the purposes of the evaluation. The dose impacts from incident free transportation of unirradiated fuel are summarized in Subsection 5.7.2.2.

7.4.1.2 Transportation of Irradiated Fuel

In accordance with 10 CFR 51.52(a), a full description and detailed analysis of transportation impacts is not required when licensing an LWR (i.e., impacts are assumed to be bound by table S-4) if the reactor meets the following criteria:

- The reactor has a core thermal power level not exceeding 3800 MWt.

- Fuel is in the form of sintered Uranium Dioxide (UO_2) pellets having a uranium-235 enrichment not exceeding 4 percent by weight; and pellets are encapsulated in zircaloy-clad fuel rods.
- The average level of irradiation of the fuel from the reactor does not exceed 33 GWD/MTU, and no irradiated fuel assembly is shipped until at least 90 days after it is discharged from the reactor.
- With the exception of irradiated fuel, all radioactive waste shipped from the reactor is packaged and in solid form.
- Unirradiated fuel is shipped to the reactor by truck; irradiated (spent) fuel is shipped from the reactor by truck, railroad, or barge; and radioactive waste other than irradiated fuel is shipped from the reactor by truck or railroad.

While the SMR design to be deployed at the CRN Site has not been selected, the CRN Site would generate power of up to 800 MWe or 2420 MWt (Table 3.1-2, Item 16.1), well below the power criterion above. Fuel for the reactors would be enriched up to 5 weight percent uranium-235 (Table 3.1-2, Item 18.1), and the expected irradiation level is about 51 GWD/MTU (Table 3.1-2, Item 18.0.1), both exceeding the associated 10 CFR 51.52(a) condition. Therefore, a detailed analysis of transportation impacts was performed.

The radiological impacts from incident free transportation of irradiated fuel and transportation accidents were estimated using the WebTRAGIS and RADTRAN and the accident, injury and fatality rates provided in Table 7.4-1. The irradiated fuel transportation evaluation model assumes that irradiated fuel is shipped by truck to the geological spent fuel repository previously proposed for construction at Yucca Mountain, Nevada. Although the Yucca Mountain repository may no longer be considered a probable shipment location, the impacts of the transportation of spent fuel to Yucca Mountain provide a reasonable estimate of the transportation risks to a monitored retrievable storage facility because of the distances involved. The distance from the CRN Site to the potential repository is 2292 mi (3689 km) as determined by the WebTRAGIS computer code for a highway route controlled quantity (HRCQ) route. Because of the distance from the CRN Site to Yucca Mountain, the impacts of shipments to a regional spent fuel storage facility are considered to be bounded by the transportation analysis for Yucca Mountain. The dose impacts from incident free transportation of irradiated fuel are summarized in Subsection 5.7.2.2.

The initial irradiated fuel activity is decayed five years to account for the minimum decay period prior to shipment to the repository. The NRC has used the five-year decay period in its evaluated the environmental effects of extending fuel burnup in NUREG/CR-6703, *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU*. The source term in curies per MTU used for the analysis (i.e., with 5 yr decay) is provided in Table 7.4-2. This source term is based on the radionuclide inventory for irradiated AP1000 reactor fuel provided in NUREG-1939, *Final Environmental Impact Statement (EIS) for Combined License for Virgil C.*

Summer Nuclear Station, Units 2 and 3, Table 6-10, Radioactive Inventories Used in Transportation-Accident Risk Calculations for the Westinghouse AP1000.

The AP1000 and the SMR designs considered in the PPE are PWRs with sintered uranium dioxide fuel pellets in Zircaloy cladding. In the absence of a selected design, a surrogate source term (in curies per MTU) is provided in Table 7.4-2. This source term is based on the radionuclide inventory for irradiated AP1000 reactor fuel from NUREG-1939. This inventory was selected as representative based on its similarity in design, i.e., both AP1000 and SMR designs considered in the PPE are PWRs with sintered uranium dioxide fuel pellets in zircaloy cladding. The enrichment for the CRN Site fuel may be as high as 5 percent U-235 by weight, slightly higher than the maximum enrichment of 4.45 U-235 percent by weight for the AP1000 (NUREG-1939). As provided in Table 3.1-2, Item 18.0.1, the maximum assembly average burnup at end of assembly life is 51 GWD/MTU for the CRN Site PPE, approximately the same as the average 50.5 GWD/MTU burnup for the AP1000 fuel (NUREG 1939).

The source term inventory provided in Table 7.4-2 includes cobalt-60, which is used to represent fuel rod surface contamination by corrosion-related unidentified deposits (CRUD). NUREG/CR-6672, *Reexamination of Spent Fuel Shipment Risk Estimates*, concluded that cobalt-60 is the dominant contributor to the dose from fuel rod surface contamination. The accident severity categories, severity fractions, and release fractions for gas, volatiles, particulates, and CRUD used in the RADTRAN analyses are presented in Table 7.4-3. Table 7.4-3 was obtained from Table 8, “Severity and release fractions for uncanistered truck-transported PWR spent fuel,” in the RADTRAN 6/RadCat 6 User Guide, Rev. 1. This table was adapted from the U.S. Department of Energy (DOE), “Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.”

As provided in Table 3.1-2, Item 18.0.2, each fuel assembly is assumed to contain 0.304 MTU, and each shipment of irradiated fuel is assumed to contain 4 fuel assemblies or 1.22 MTU, assuming a standard GA4 cask as provided in NUREG 2125, Appendix B. As discussed in Subsection 5.7.2.1.11 of the ER and provided in Table 5.7-7, an average of 46 shipments of irradiated fuel per year for a total of 56.1 MTU is expected. Normalized to the reference reactor used to estimate the parameters in 10 CFR Part 51, Table S-4, 56.1 MTU per year is divided by 0.5 MTU per shipment and 0.82 for the ratio of net power of the CRN Site SMRs to the reference reactor. Therefore, the accident doses calculated by RADTRAN were multiplied by 137 normalized shipments per year to obtain a dose risk value. Using this calculation, the population dose risk from transportation accidents involving irradiated fuel is 2.44E-04 person-rem per year, as summarized in Table 7.4-4. This total dose risk is lower than the reference reactor and estimates for new reactors provided in recent EISs published by the NRC, such as NUREG-2176, *Environmental Impact Statement for Combined Licenses (COL) for Turkey Point Nuclear Plant Units 6 and 7*.

7.4.1.3 Transportation of Radioactive Waste

This subsection discusses the environmental effects of transporting radioactive waste other than spent fuel from the CRN Site. The environmental conditions listed in 10 CFR 51.52 that apply to shipments of radioactive waste are as follows:

- Radioactive waste (except spent fuel) would be packaged and in solid form.
- Radioactive waste (except spent fuel) would be shipped from the reactor by truck or railroad.
- The weight limitation of 73,000 pounds (lb) per truck and 100 tons per cask per railcar would be met.
- Traffic density would be less than the one truck shipment per day or three railcars per month condition.

Radioactive waste other than spent fuel from the CRN Site would be shipped in compliance with federal or state weight restrictions. The sum of the daily shipments of unirradiated fuel, spent fuel, and radioactive waste for the CRN Site PPE is less than the one-truck-shipment-per-day condition given in 10 CFR 51.52, Table S–4.

As provided in Table 3.1-2, Item 11.2.3, the annual volume of radioactive waste generated and shipped from the CRN Site would be 5000 cubic feet per year (ft^3/yr). Table 5.7-7 shows the expected number of radioactive waste shipments from the CRN Site is 61 shipments per year. Multiplying by the ratio of 1.22, discussed above, the estimated number of shipments per year is 75, normalized to the reference reactor used to estimate the parameters in 10 CFR Part 51, Table S-4. Table 3.5-5 provides the projected annual radioisotope inventory of the principal radionuclides in solid radioactive waste produced at the CRN Site. Radionuclides in the list with a radiological half-life greater than 2 days were included in the source term for the RADTRAN calculations.

Tennessee Valley Authority (TVA) plans to ship radioactive waste to the Waste Control Specialists disposal facility in Andrews County, Texas. The distance from the CRN Site to the Andrews repository is 1214 mi (1954 km) as determined by the WebTRAGIS computer code for a HRCQ route. The radiological impacts from incident free transportation of radioactive waste and transportation accidents were estimated using the WebTRAGIS and RADTRAN 6.5 computer codes.

The state-specific safety parameter values that were used to estimate the frequencies of accidents involving the trucks carrying radioactive waste were obtained from the same sources discussed in Subsection 7.4.1.2.

The accident severity categories, conditional probabilities, and release fractions for particulates, CRUD, gas, and volatiles used in the analysis of radioactive waste transportation are the same as those used for the irradiated fuel analysis (Table 7.4-3). The accident data in Table 7.4-3 provides a generally representative description of transportation accidents for other radioactive waste shipments that meet U.S. Department of Transportation requirements.

The resulting total dose risk from transportation accidents involving radioactive waste is 3.13E-08 person-rem per reactor year assuming 75 shipments per year normalized to the reference reactor. This result is provided in Table 7.4-4. This population dose risk impact from accidents is small, much lower than the dose to the exposed population along the transportation route provided in Table S-4.

7.4.2 Non-Radiological Impacts

Non-radiological impacts associated with the postulated accidents are calculated for:

- Injuries and fatalities during transportation of unirradiated fuel
- Injuries and fatalities during transportation of irradiated fuel
- Injuries and fatalities during transportation of radioactive waste

The non-radiological impacts from postulated accidents during transportation were evaluated using the WebTRAGIS code to define appropriate routing and the RADTRAN 6 code to calculate the non-radiological impacts (e.g., injuries and fatalities).

The non-radiological impacts were based on round-trip distances because the return of the empty truck is included in the evaluation. Therefore, the frequency (fatalities per reactor-year and injuries per reactor-year) was multiplied by two.

7.4.2.1 Transportation of Unirradiated Fuel

The evaluation model assumes that unirradiated fuel is shipped by truck from Richland, Washington, to the CRN Site. The distance from Richland, Washington, to the CRN Site was determined to be 2451 mi. (3944 km) by the WebTRAGIS computer code for a HRCQ route. The fabrication facility in Richland is the farthest fabrication facility in the United States from the CRN Site that is currently in operation; therefore, it was used as a representative fuel fabrication facility for the purposes of the evaluation.

As discussed in Subsection 5.7.2.1.11 and Table 5.7-6, the total number of lifetime shipments of unirradiated fuel for the CRN Site is 492, and the average is 12.3 shipments per year. Multiplying by the ratio of 1.22, discussed above, the estimated number of shipments per year is 15 (600 total shipments), normalized to the reference reactor used to estimate the parameters in 10 CFR Part 51, Table S-4.

The non-radiological fatality rates and injury rates normalized to the transportation rates for the reference reactor are provided in Tables 7.4-5 and 7.4-6. Subsection 7.4.2.4 discusses the significance of these rates.

7.4.2.2 Transportation of Irradiated Fuel

The routing and accident parameters used to analyze non-radiological impacts of transporting irradiated fuel were the same as those used to analyze the radiological impacts of transporting irradiated fuel described in Subsection 7.4.1.2. As noted above and provided in Table 5.7-7, the number of shipments of irradiated fuel from the CRN Site normalized to the reference reactor would be 137 shipments of irradiated fuel per year.

The non-radiological fatality rates and injury rates normalized to the transportation rates for the reference reactor are provided in Tables 7.4-5 and 7.4-6. Subsection 7.4.2.4 discusses the significance of these rates.

7.4.2.3 Transportation of Radioactive Waste

The routing and accident parameters used to analyze non-radiological impacts of transporting radioactive waste were the same as those used to analyze the radiological impacts of transporting radioactive waste described in Subsection 7.4.1.3.

As shown in Table 3.1-2, Item 11.2.3, the annual volume of radioactive waste generated and shipped from the CRN Site would be 5000 ft^3/yr. Table 5.7-7 shows the number of radioactive waste shipments from the CRN Site to be 61 shipments per year. As noted above and in Table 5.7-7, the number of shipments of radioactive waste (other than spent fuel) normalized to the reference reactor is 75 shipments per year.

The non-radiological fatality rates and injury rates normalized to the transportation rates for the reference reactor are provided in Tables 7.4-5 and 7.4-6. Subsection 7.4.2.4 discusses the significance of these rates.

7.4.2.4 Comparison to 10 CFR 51.52 Table S-4

For an equal comparison to the reference reactor in 10 CFR 51.52 Table S-4, the normalized number of shipments provided in the subsections above were used to determine the non-radiological environmental impacts due to transportation accidents. Tables 7.4-5 and 7.4-6 indicate the fatal and non-fatal injury consequences, respectively, for unirradiated fuel, irradiated fuel, and radioactive waste shipments based on the normalized numbers of shipments. Table 7.4-7 is a comparison of the CRN Site to the summary of “Accidents in Transport” in 10 CFR 51.52 Summary Table S-4. The estimated number of fatal injuries is 2.24E-02 per reactor year for the CRN Site, slightly more than two fatal injuries in 100 reactor years or more than twice the number of fatal injuries assumed for the reference reactor in Table S-4. The estimated number of non-fatal injuries is 3.50E-01 per reactor year (3.5 in 10 reactor years) for the CRN Site, more than three times the value of 1 non-fatal injury in 10 reactor years for the reference reactor in Table S-4. The estimated numbers of fatal injuries and non-fatal injuries for the CRN Site are higher than the values for the reference reactor because the one-way shipping distances for unirradiated fuel, irradiated fuel, and radioactive waste shipments are more than twice the distances assumed in the analyses for Table S-4 (WASH-1238). Considering these differences in the analyses, the impacts are comparable. Therefore, as the Table S-4 values are considered SMALL, the estimated numbers of fatal injuries and non-fatal injuries for the CRN Site are also SMALL.

7.4.3 Summary and Conclusion

A detailed accident analysis of the environmental impacts for the transportation of unirradiated fuel, irradiated fuel, and radioactive waste transported to and from the CRN Site was performed in accordance with 10 CFR 51.52(b).

The results of the radiological accident analysis are summarized in Table 7.4-4, and the results of the non-radiological accident analysis are summarized in Tables 7.4-5 and 7.4-6. The values determined by these analyses represent the environmental impacts of licensing SMRs at the CRN Site.

As discussed in Subsections 7.4.1.2 and 7.4.1.3, because the number of normalized shipments of irradiated fuel and radioactive waste provided in Table 5.7-7 are not significantly different from number of shipments from the reference reactor, the impacts from radiological accidents from the CRN Site are consistent with the “Small” impacts designation provided in Table S-4. The calculated dose risks provided in Table 7.4-4 are also SMALL. As discussed in Subsection 7.4.2.4, the non-radiological accident environmental impacts related to transportation of unirradiated fuel, irradiated fuel, and radioactive waste are also consistent with the Table S-4 fatality and nonfatal injury rates.

Therefore, the overall corresponding impacts from accidents associated with the transportation of fuel and waste to and from the CR SMR Project are SMALL.

7.4.4 References

Reference 7.4-1. U.S. Atomic Energy Commission, "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants (WASH-1238)," December, 1972.

Reference 7.4-2. Weiner, Ruth F., Hinojosa, Daniel, Heames, Terence, and Farnum, Cathy O., "RADTRAN 6/RadCat6 User Guide Rev 1," 2015.

Reference 7.4-3. UT-Battelle, LLC, Transportation Routing Analysis Geographic Information System (TRAGIS), Version 6.0. U.S. Department of Energy Contract No. DE-AC05-00OR22725. Website: https://webtragis.ornl.gov/tragis/app/map/view, 2017.

Reference 7.4-4. Sandia National Laboratories, "RADTRAN 6 Technical Manual," SAND2013-0780, January 2014.

Table 7.4-1
CRN Site Model
Accident, Fatality and Injury Rates

State	Accident Rate (Accident/km)	Fatality Rate (Fatality/km)	Fatality Rate (Fatality/ Accident)	Injury Rate (Injury/km)	Injury Rate (Injury/Accident)
AR	2.20E-07	9.73E-09	4.43E-02	1.18E-07	5.35E-01
AZ	2.16E-07	1.48E-08	6.82E-02	1.40E-07	6.49E-01
CA	2.62E-07	1.10E-07	4.20E-02	1.44E-07	5.50E-01
CO	7.31E-07	1.79E-08	2.45E-02	3.78E-07	5.17E-01
IA	1.84E-07	1.48E-08	8.03E-02	1.03E-07	5.62E-01
ID	4.84E-07	5.97E-09	1.23E-02	3.68E-07	7.61E-01
IL	3.64E-07	1.30E-08	3.58E-02	1.80E-07	4.94E-01
KS	4.66E-07	8.16E-09	1.75E-02	3.05E-07	6.54E-01
KY	5.08E-07	2.01E-08	3.95E-02	2.65E-07	5.22E-01
MO	7.61E-07	1.95E-08	2.56E-02	3.77E-07	4.95E-01
NE	5.23E-07	2.15E-08	4.11E-02	2.36E-07	4.52E-01
NM	1.85E-07	1.85E-08	1.00E-01	1.38E-07	7.46E-01
NV	3.69E-07	1.04E-08	2.81E-02	1.78E-07	4.81E-01
OK	4.40E-07	2.09E-08	4.75E-02	3.47E-07	7.89E-01
OR	3.54E-07	3.20E-08	9.04E-02	1.63E-07	4.61E-01
TN	2.02E-07	1.57E-08	7.78E-02	1.10E-07	5.47E-01
TX	9.84E-07	2.04E-08	2.07E-02	6.55E-07	6.66E-01
UT	4.76E-07	1.87E-08	3.93E-02	3.04E-07	6.38E-01
WA	4.35E-07	2.83E-09	6.50E-03	2.16E-07	4.97E-01
WY	1.11E-06	1.70E-08	1.53E-02	3.88E-07	3.51E-01

Table 7.4-2
CRN Site Model
Irradiated Fuel Source Term

Nuclide	Activity (Ci/MTU)
Am-211	7.27E+02
Am-242m	1.31E+01
Am-234	3.34E+01
Ce-144	8.87E+03
Pr-144 (D)[1]	-
Pr-144m (D)[1]	-
Cm-242	2.83E+01
Cm-243	3.07E+01
Cm-244	7.75E+03
Cm-245	1.21E+00
Co-60 (CRUD)	4.09E+00
Cs-134	4.80E+04
Cs-137	9.31E+04
Ba-137m (D)[1]	-
Eu-154	9.13E+03
Eu-155	4.62E+03
I-129	4.65E-02
Kr-85	8.9E+03
Pm-147	1.76E+04
Pu-238	6.07E+03
Pu-239	2.55E+02
Pu-240	5.43E+02
Pu-241	6.96E_04
Pu-242	1.82E+00
Ru-106	1.55E+04
Rh-106(D)[1]	-
Sb-125	3.83E+03
Sr-90	6.19E+04
Y-90	6.19E+04

1 The nuclides labeled with a (D) are daughter products and are included with the parent in the RADCAT/RADTRAN program.

Source: NUREG-1939, Table 6-10

Table 7.4-3
CRN Site Model
Severity and Release Fractions for Uncanistered Truck-Transported Fuel

Severity Category	Severity Fraction	Gas Release Fraction	Volatiles Release Fraction	Particulates Release Fraction	CRUD Release Fraction
0	0.99993	0	0	0	0
1	6.06E-05	9.0E-02	1.5E-06	3.36E-06	1.00E-03
2	5.86E-06	9.0E-02	1.5E-06	3.36E-06	1.00E-03
3	4.95E-07	9.0E-02	1.5E-06	3.36E-06	1.00E-03
4	7.49E-08	9.0E-02	1.5E-06	3.36E-06	1.00E-03
5	3.00E-10	9.0E-02	6.75E-07	1.54E-06	1.00E-03

Table 7.4-4
CRN Site Model
Radiological Accident Analysis Results
(per CRN Site operating year)

Environmental Impact	Unirradiated Fuel	Irradiated Fuel	Radioactive Waste	Total
Annual Dose for CRN Site	Not Calculated	2.44E-04 Person-rem/yr	3.13E-08 Person-rem/yr	2.44E-04 Person-rem/yr

Table 7.4-5
CRN Site Model
Non-Radiological Accident Analysis Results for
Normalized Number of Shipments: Fatalities

	Fatalities per Shipment	Normalized Shipments Per Year	Fatalities per Year[1]	Fatalities per 100 Years
New Fuel	6.08E-05	15	1.82E-03	1.82E-01
Spent Fuel	5.73E-05	137	1.57E-02	1.57E+00
Radioactive Waste	3.24E-05	75	4.86E-03	4.86E-01
Total	-	227	2.24E-02	2.24E+00

[1] The fatalities per year are calculated assuming a round trip for the truck. Therefore the normalized number of shipments was doubled when calculating total route fatalities.

Table 7.4-6
CRN Site Model
Non-Radiological Accident Analysis Results for Normalized Number of Shipments: Injuries

	Injuries per Shipment	Normalized Shipments Per Year	Injuries per Year[1]	Injuries per 10 Years
New Fuel	1.18E-03	15	3.54E-02	3.54E-01
Spent Fuel	7.55E-04	137	2.07E-01	2.07E+00
Radioactive Waste	7.21E-04	75	1.08E-01	1.08E+00
Total	-	227	3.50E-01	3.50E+00

[1] The fatalities per year are calculated assuming a round trip for the truck. Therefore the normalized number of shipments was doubled when calculating total route injuries.

Table 7.4-7
CRN Site Model Comparison to
10 CFR 51.52 Summary Table S-4: "Accidents in Transport"
Bounding Technology Summary

Types of Effects	Environmental Risk	CRN Site Model
	10 CFR 51.52 Table S-4 Reference Reactor	CRN Site SMRs
Radiological effects of transportation of unirradiated fuel, irradiated fuel, and radioactive waste Person-rem per reactor-year	Small	2.44E-04
Non-radiological effects of transportation of unirradiated fuel, irradiated fuel, and radioactive waste	1 fatal injury in 100 reactor years 1 nonfatal injury in 10 reactor years	2.24E+00 (fatalities per 100 years) 3.50E+00 (injuries per 10 years)

CHAPTER 8 NEED FOR POWER

Title 10 of the Code of Federal Regulations 51.50(b)(2) does not require a need for power discussion be included in an early site permit application. The need for power discussion is to be included in the combined license application.