CHAPTER 3 PLANT DESCRIPTION

Chapter 3 describes the new plant design based on the plant parameter envelope (PPE) and provides general information about the new plant on the Clinch River Nuclear (CRN) Site. This Chapter presents a description of two or more small modular reactors (SMRs) based upon pressurized water reactor technology; however, a specific design has not been selected. Therefore, a plant parameter envelope (PPE) has been developed for use in evaluating potential environmental impacts. The PPE is a composite of SMR- and owner-engineered parameters that bound the environmental impacts of construction and operation of the facility.

The parameters associated with the station appearance, water use, transmission facilities, and its relationship to the surrounding area are described in the following sections:

- External Appearance and Plant Layout (Section 3.1)
- Reactor Power Conversion System (Section 3.2)
- Plant Water Use (Section 3.3)
- Cooling System (Section 3.4)
- Radioactive Waste Management System (Section 3.5)
- Non-radioactive Waste System (Section 3.6)
- Power Transmission System (Section 3.7)
- Transportation of Radioactive Materials (Section 3.8)
- Construction Activities (Section 3.9)
- Workforce Characterization (Section 3.10)

3.1 EXTERNAL APPEARANCE AND PLANT LAYOUT

3.1.1 Site Description

The Clinch River Nuclear (CRN) Site consists of approximately 935 acres (ac) bounded on the east, south, and west by the Clinch River arm of the Watts Bar Reservoir and on the north by the U.S. Department of Energy's Oak Ridge Reservation and the Tennessee Valley Authority's Grassy Creek Habitat Protection Area (HPA). The CRN Site Utilization Plan and facility layout are depicted in Figures 3.1-1 and 3.1-2, respectively. The exclusion area boundary (EAB) is delineated by the boundaries of the Clinch River Property, which includes the CRN Site and the Grassy Creek HPA.

The facility layout was determined by reviewing a representative layout for each of the small modular reactor (SMR) designs under consideration, developing a composite layout, and identifying bounding areas for the power block (nuclear island), turbine building, switchyard, and cooling tower(s). Space is reserved for a future independent spent fuel storage installation. Five retention ponds and one additional small pond have been identified on the CRN Site. All six ponds were determined to be man-made. The five larger ponds were originally created as stormwater retention ponds for the Clinch River Breeder Reactor Project (CRBRP). The sixth pond was created for an unknown purpose. (Reference 3.1-1) The six ponds and onsite wetlands are shown in Figure 2.4.1-2.

The land proposed to be used for construction is indicated Figure 3.1-2. The majority of the construction would occur within the boundaries of the CRN Site. To support site construction and operations, some construction would also occur in offsite areas including the Barge/Traffic Area and the 69-kilovolt (kV) underground transmission line that is located within the 500-kV transmission line right-of-way (ROW) (Figure 3.1-2). Construction in the Barge/Traffic Area would include the addition of a northbound loop ramp at the intersection of Tennessee State Highway 58 and Bear Creek Road as well as improvements to Bear Creek Road as discussed in Subsection 4.4.2.3. The Barge/Traffic Area construction would also include refurbishment of a barge terminal near CRM 14.1. A 69-kV underground transmission line would be constructed from the CRN Site to the Bethel Valley substation along the ROW for an existing 500-kV transmission line as discussed in Section 3.7. Although the total temporarily cleared area indicated on Figure 3.1-2 is expected to bound the land to be used during construction, specific uses of areas for construction support would depend upon the specific design selected.

3.1.2 Power Plant Description

As described in Subsection 2.2.1.1, the CRN Site is located on the site of the previous CRBRP. At the time of the CRBRP's cancellation in 1983, preliminary site work was essentially complete, including the retention ponds, quality control test laboratory, construction shops, concrete batch plants, nuclear island excavation, and concrete foundation for a ringer crane (Reference 3.1-2; Reference 3.1-3). Upon project termination, the main site area was remediated, including partial backfilling the nuclear island excavation. The temporary structures were removed; however the retention ponds and associated drainage infrastructure were left intact. The finished elevation of the remediated nuclear island excavation area is approximately 821 feet (ft) above mean sea level (msl).

The designs under consideration for deployment at the CRN Site are SMRs based upon pressurized water reactor technology; however, a specific design has not been selected. Therefore, a plant parameter envelope (PPE) has been developed for use in evaluating potential environmental impacts. The PPE is a composite of SMR and owner engineered parameters that bound the environmental impacts of construction and operation of the facility. The PPE is used to define a “surrogate plant” that can bound two or more technologies. This surrogate plant is used as an input for the analyses needed to support the development of the early site permit application (ESPA). In order for an applicant to move forward with a combined license application, an SMR technology must be selected. The selection of one of the SMR technologies used in the construction of the PPE or a future SMR technology that is demonstrated to be bounded by the PPE maximizes the benefits of the ESP. This process provides reasonable assurance that siting issues would remain resolved when an SMR technology is selected and the ESP is incorporated into a combined license. Table 1 of the PPE is provided in Table 3.1-1, Site Characteristics, and Table 3.1-2, Site Related Design Parameters. Other PPE tables are provided in Sections 3.5 and 3.6.

The height of structures in the power block area depends upon the SMR technology selected; however, as indicated in Table 3.1-2, Item 1.1.1, the bounding structure height (excluding the cooling tower(s) and facility stack(s)) is 160 ft above grade. In general, buildings are constructed using standard building materials such as concrete, metal with metal siding, or wood with metal, vinyl, or other acceptable siding. The design and construction of building structures would take into consideration the surroundings to minimize aesthetic impacts. A rendering of the facility based on the PPE provided in Tables 3.1-1 and 3.1-2 is provided in Figure 3.1-3.

The circulating water system includes one or more mechanical draft cooling towers with make-up water drawn from the Clinch River arm of the Watts Bar Reservoir. The intake and discharge structures are described in Section 3.4. As described in Section 3.7, a new switchyard and an upgrade to an existing switchyard are required to support the facility, and the existing on-site transmission lines would be modified as required to incorporate the new generation capacity into the electric grid.

After the completion of construction, areas used to support construction activities which are not re-used to support facility operations would be re-graded and landscaped. Areas cleared for temporary construction facilities would be re-vegetated, and topographical features created during construction would be re-contoured to match the surrounding areas.

3.1.3 References

Reference 3.1-1. 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 5," Tennessee Valley Authority, December 22, 2015.

Reference 3.1-2. U.S. Department of Energy, "Clinch River Breeder Reactor Plant Project Site Redress Plan," March, 1984.

Reference 3.1-3. Breeder Reactor Corporation, "Final Report The Clinch River Breeder Reactor Plant Project," January, 1985.

Table 3.1-1
CRN Site Characteristics

PPE Section[1]	Definition	Parameter Type	PPE Value	ER Section
9. Unit Vent/Airborne Effluent Release Point				
9.1 Atmospheric Dispersion (X/Q) (Accident)				
9.1.1 0-2 hr @ EAB	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases in the limiting two hour interval.	Site	5.58E-04 s/m^3	7.1
9.1.2 0-8 hr @ low population zone (LPZ)	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases in the first eight hours.	Site	4.27E-05s/m^3	7.1
9.1.3 8-24 hr @ LPZ	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases between hours 8 and 24 after the accident.	Site	3.80E-05 s/m^3	7.1
9.1.4 1-4 day @ LPZ	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases between the first day and the fourth day after the accident	Site	2.94E-05 s/m^3	7.1
9.1.5 4-30 day @ LPZ	The atmospheric dispersion coefficients used in the design safety analysis to estimate dose consequences of accident airborne releases between day four until the end of the first 30 days after the accident.	Site	2.04E-05 s/m^3	7.1
9.3 Calculated Dose Consequences				
9.3.1 Normal	The design radiological dose consequences due to airborne releases from normal operation of the plant.	Site	10 CFR 20, 10 CFR 50 Appendix I	5.4[2], 7.2[2]
9.3.2 Post-Accident	The design radiological dose consequences due to airborne releases from postulated accidents.	Site	10 CFR 52.17 (a)(1) (ix), 10 CFR 100.20	5.4[2], 7.2[2]

[1] The numbering of the PPE listing is not meant to be sequential, and was compiled from and is consistent with the list developed by industry and refined for this ESPA.
[2] Information utilized in the development of the impacts described in the section, but not referenced specifically in the text.

Table 3.1-2 (Sheet 1 of 5)
CRN Site Related Design Parameters

PPE Section[1]	Definition	Parameter Type	PPE Value	ER Section
1. Structure				
1.1 Building Characteristics				
1.1.1 Height (w/o Stack and Cooling Towers)	The height from finished grade to the top of the tallest power block structure, excluding cooling towers (excludes stairway towers, elevator, etc.).	Rx	160 ft	2.5.2, 3.1, 4.4, 5.8
3. Normal Plant Heat Sink				
3.1 Condenser				
3.1.2 Condenser / Heat Exchanger Duty	Design value for the waste heat rejected to the circulating water system across the condensers.	Eng	5593 MBTU/hr for site	3.4
3.2 Non-Safety Related Service Water Systems				
3.2.3 Miscellaneous Plant Water Uses Intake	The maximum, and normal, water intake of the plant neglecting cooling tower makeup, potable/sanitary water users, and liquid radwaste treatment.	Eng	Maximum: 5100 gpm Normal: 1345 gpm See Figure 3.3-1	3.4
3.2.4 Miscellaneous Plant Water Uses Discharge	The maximum, and normal, water discharge of the plant neglecting cooling tower makeup, potable/sanitary water users, and liquid radwaste treatment.	Eng	Maximum: 4200 gpm Normal: 445 gpm See Figure 3.3-1	3.4
3.3 Mechanical Draft Cooling Towers				
3.3.1 Acreage	The land required for cooling towers, including support facilities such as equipment sheds, basins, canals, or shoreline buffer areas.	Eng	SMR Project DWG 25847-000-c2-0010-00002, Site layout (See Figure 3.1-1)	3.4, 5.3
3.3.3 Blowdown Constituents and Concentrations	The maximum expected concentrations for anticipated constituents in the cooling water systems blowdown to the receiving water body.	Eng	Table 3.6-1 (values for site)	3.6
3.3.4 Blowdown Flow Rate	The normal (and maximum) flow rate of the blowdown stream from the cooling water systems to the receiving water body for closed system designs.	Eng	Maximum: (2 COC) 12,800 gpm, Expected: (4 COC) 4270 gpm See Figure 3.3-1	3.4
3.3.5 Blowdown Temperature	The maximum expected blowdown temperature at the point of discharge to the receiving water body.	Eng	90 F	3.4
3.3.6 Cycles of Concentration	The ratio of total dissolved solids in the cooling water blowdown streams to the total dissolved solids in the make- up water streams.	Eng	Maximum: 4, Minimum: 2	3.4, 5.3

Table 3.1-2 (Sheet 2 of 5)
CRN Site Related Design Parameters

PPE Section[1]	Definition	Parameter Type	PPE Value	ER Section
3.3.7 Evaporation Rate	The expected (and maximum) rate at which water is lost by evaporation from the cooling water systems.	Eng	12,800 gpm (Expected and Maximum) - values for site	3.4
3.3.8 Height	The vertical height above finished grade of mechanical draft cooling towers associated with the cooling water systems.	Eng	65 ft	3.4, 5.3, 5.8
3.3.9 Makeup Flow Rate	The expected (and maximum) rate of removal of water from a natural source to replace water losses from closed cooling water system.	Eng	17,078 gpm (expected), 25,608 gpm (maximum)	3.4
3.3.10 Noise	The maximum expected sound level produced by operation of cooling towers, measured at 1000 ft from the noise source.	Eng	<70 dba	5.3, 5.8, 9.3
3.3.11 Cooling Tower Temperature Range	The temperature difference between the cooling water entering and leaving the towers.	Eng	18 F	3.4
3.3.12 Cooling Water Flow Rate	The total cooling water flow rate through the condenser/heat exchangers.	Eng	755,000 gpm	3.4, 5.3
3.3.14 Maximum Consumption of Raw Water	The expected maximum short-term consumptive use of water by the cooling water systems (evaporation and drift losses).	Eng	12,808 gal	3.4
3.3.16 Stored Water Volume	The quantity of water stored in cooling water system impoundments, basins, tanks and/or ponds.	Eng	5 million gal	3.4
3.3.17 Drift	Rate of water lost from the tower as liquid droplets entrained in the vapor exhaust air stream.	Eng	8 gpm	3.4
5. Potable Water/Sanitary Waste System				
5.1 Discharge to Site Water Bodies				
5.1.1 Flow Rate (Potable/Sanitary Normal)	The expected (normal) effluent flow rate from the potable/sanitary water system to the receiving water body.	Rx	50 gpm	3.4, 3.6, 5.5
5.1.2 Flow Rate (Potable/Sanitary Maximum)	The maximum effluent flow rate from the potable/sanitary water system to the receiving water body.	Rx	100 gpm	3.4, 3.6, 5.5
9.5 Source Term				
9.5.1 Gaseous (Normal)	The expected annual activity, by radionuclide, contained in routine plant airborne effluent streams, excluding tritium.	Rx	Table 3.5-3	3.5
10. Liquid Radwaste System				
10.2 Release Point				
10.2.1 Flow Rate	The discharge (including minimum dilution flow, if any) flow rate of liquid potentially radioactive effluent streams from plant systems to the receiving water body.	Eng	900 gpm - expected normal and maximum -	3.4

Table 3.1-2 (Sheet 3 of 5)
CRN Site Related Design Parameters

PPE Section[1]	Definition	Parameter Type	PPE Value	ER Section
10.3 Source Term				
10.3.1 Liquid	The annual activity, by radionuclide, contained in routine plant liquid effluent streams, excluding tritium.	Rx	Table 3.5-1 ([value per site)	3.5
11. Solid Radwaste System				
11.2 Solid Radwaste				
11.2.1 Activity	The annual activity, by radionuclide, contained in solid radioactive wastes generated during routine plant operations.	Rx	Table 3.5-5 (site value)	3.5
11.2.3 Volume	The expected volume of solid radioactive wastes generated during routine plant operations.	Rx	5000 cubic ft/yr (site value)	3.5, 3.8, 5.7, 7.4
13. Auxiliary Boiler System		Eng		
13.1 Exhaust Elevation	The height above finished plant grade at which the flue gas effluents are released to the environment.	Eng	Plant Grade	3.6
13.2 Flue Gas Effluents	The expected combustion products and anticipated quantities released to the environment due to operation of the auxiliary boilers.	Eng	Table 3.6-2	3.6
14. Standby Power System				
14.1 Diesel				
14.1.2 Diesel Exhaust Elevation	The elevation above finished grade of the release point for standby diesel exhaust releases.	Eng	25 ft	3.6
14.1.3 Diesel Flue Gas Effluents	The expected combustion products and anticipated quantities released to the environment due to operation of the emergency standby diesel generators.	Eng	Table 3.6-3 (value per site)	3.6
14.2 Gas Turbine				
14.2.2 Gas-Turbine Exhaust Elevation	The elevation above finished grade of the release point for standby gas turbine exhaust releases.	Eng	50 ft	3.6
14.2.3 Gas-Turbine Flue Gas Effluents	The expected combustion products and anticipated quantities released to the environment due to operation of the emergency standby gas-turbine generators.	Eng	Table 3.6-4	3.6

Table 3.1-2 (Sheet 4 of 5)
CRN Site Related Design Parameters

PPE Section[1]	Definition	Parameter Type	PPE Value	ER Section
15. Plant Layout Considerations				
15.1 Access Routes				
15.1.1 Heavy Haul Routes	The land usage required for permanent heavy haul routes to support normal operations and refueling.	Eng	5 ac	3.9
15.2 Acreage to Support Plant Operations	The land area required to provide space for plant facilities.	Eng	SMR Project DWG 25847-000-c2-0010-00002, Site Layout (See Figure 3.1-1)	3.7
16. Plant Operations Considerations				
16.1 Megawatts Thermal	The thermal power generated by one unit (may be the total of several modules). Specify both core thermal power and RCP thermal power (if there are RCPs in the design).	Rx	800 MWt (core) 805 MWt (core + RCP), 2420 MWt total for site	5.7, 7.4
16.2 Plant Design Life	The operational life for which the plant is designed.	Rx	60 years	3.2
16.3 Plant Population				
16.3.1 Operation	The estimated number of total permanent staff to support operations of the plant.	Eng	500 (value per site)	3.10,5.8, 9.3
16.3.2 Refueling / Major Maintenance	The estimated additional number of temporary staff required to conduct refueling and major maintenance activities.	Eng	1000	5.8, 9.3
16.4 Station Capacity Factor	The percentage of time that a plant is capable of providing power to the grid.	Eng	Maximum 98% Minimum: 90%	5.7, 7.4
16.6 Megawatts Electrical (at 100% power with 85F circulating water)	Best estimate of MWe generator output.	Eng	800 MWe (value for site)	3.2, 5.7, 5.9, 7.4, 9.4, 10.1
17. Construction				
17.2 Acreage				
17.2.1 Laydown Areas	The land area required to provide space for construction support facilities. Provide a list of what buildings and/or areas and the associated acreage for each.	Eng	SMR Project DWGs 25847-000-CL-0010-00001, 25847-000-CL-0010-00002 25847-000-CL-0010-00003 Site Utilization Plan (See Figure 3.1-1 and Figure 3.1-2)	3.7

Table 3.1-2 (Sheet 5 of 5)
CRN Site Related Design Parameters

PPE Section[1]	Definition	Parameter Type	PPE Value	ER Section
17.3 Construction				
17.3.1 Noise	The maximum expected sound level due to construction activities, measured at 50 ft from the noise source.	Eng	101 dB at 50 ft	3.9
17.4 Plant Population				
17.4.1 Construction	Maximum number of people on-site during construction.	Eng	2200 (value per site)	3.10
18. Miscellaneous Items				
18.0.1 Fuel Characteristics	What is the form of the reactor fuel and the burnup (GWd/MTU)?	Rx	UO_2, 51 GWD/MTU	5.7, 7.4
18.0.2 Fuel assemblies	Provide the active length of the reactor fuel. Provide the number of fuel assemblies per core and the weight (in MTU) of each assembly.	Rx	Number of Fuel Assemblies: 96 Weight of Each Assembly: 0.304 MTU	3.8, 5.7, 7.4
18.0.4 Refueling	Provide the refueling frequency, average number of assemblies per refueling, fuel pool capacity (in years), and cooling time in pool.	Rx	Frequency 2 years, Assemblies per Refueling: 96, Capacity 6 years ,	3.8, 5.7, 5.8
18.0.5 Irradiation fuel transportation	Provide the weight of irradiated fuel per spent fuel shipping cask (MTU).	Rx	21.2 MTU	5.7
18.1 Maximum Fuel Enrichment	Concentration (weight percent fraction) of U-235 in the fuel uranium.	Rx	<5% U-235	3.2, 5.7, 7.4
18.2 Maximum Average Assembly Burnup	Maximum assembly average burn-up at end of assembly life.	Rx	51 GWD/MTU	3.2, 5.7, 7.4
18.3 Peak fuel rod exposure at end of life	Peak fuel rod exposure at end of life.	Rx	62 GWD/MTU	3.2
18.7 Clad Material	Fuel rod clad material.	Rx	Zirc Alloy (Zircaloy)	5.7

[1] The numbering of the PPE listing is not meant to be sequential, and was compiled from and is consistent with the list developed by industry and refined for this ESPA.

Notes:
RX = Reactor Parameter Eng = Owner Engineered Parameter COC = Cycles of Concentration

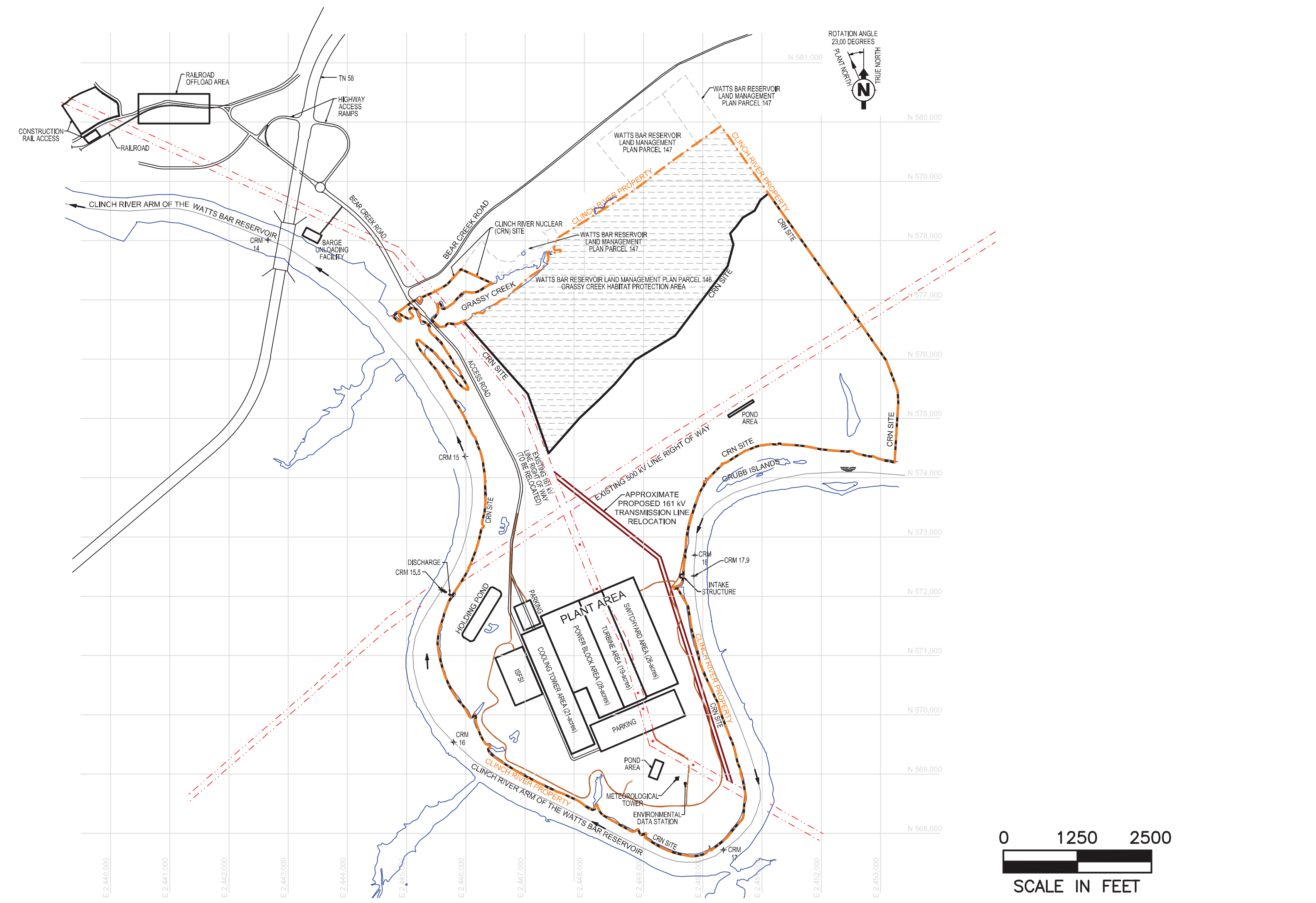

Figure 3.1-1. CRN Site Utilization Plan

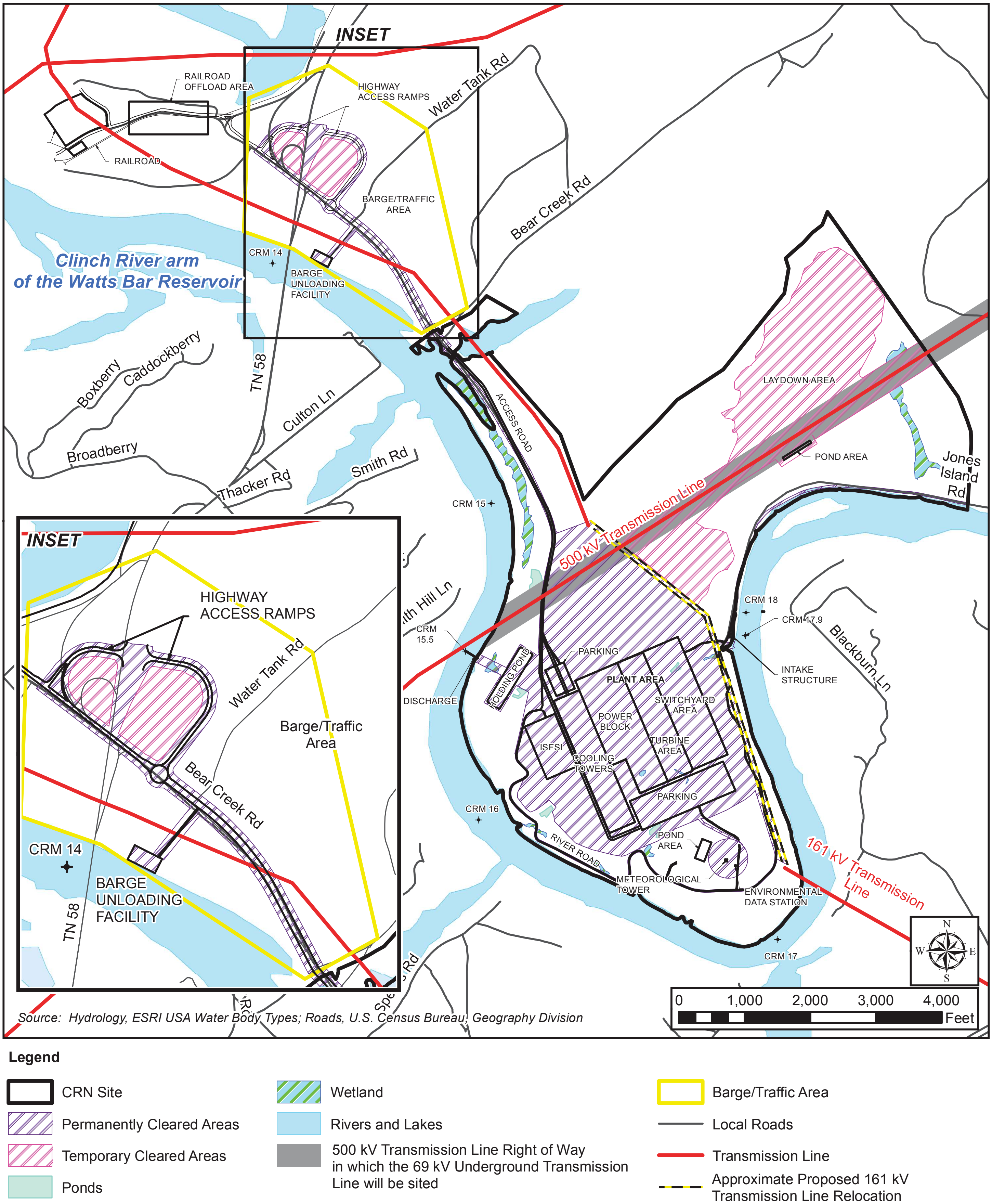

Figure 3.1-2 CRN Site Cleared Areas

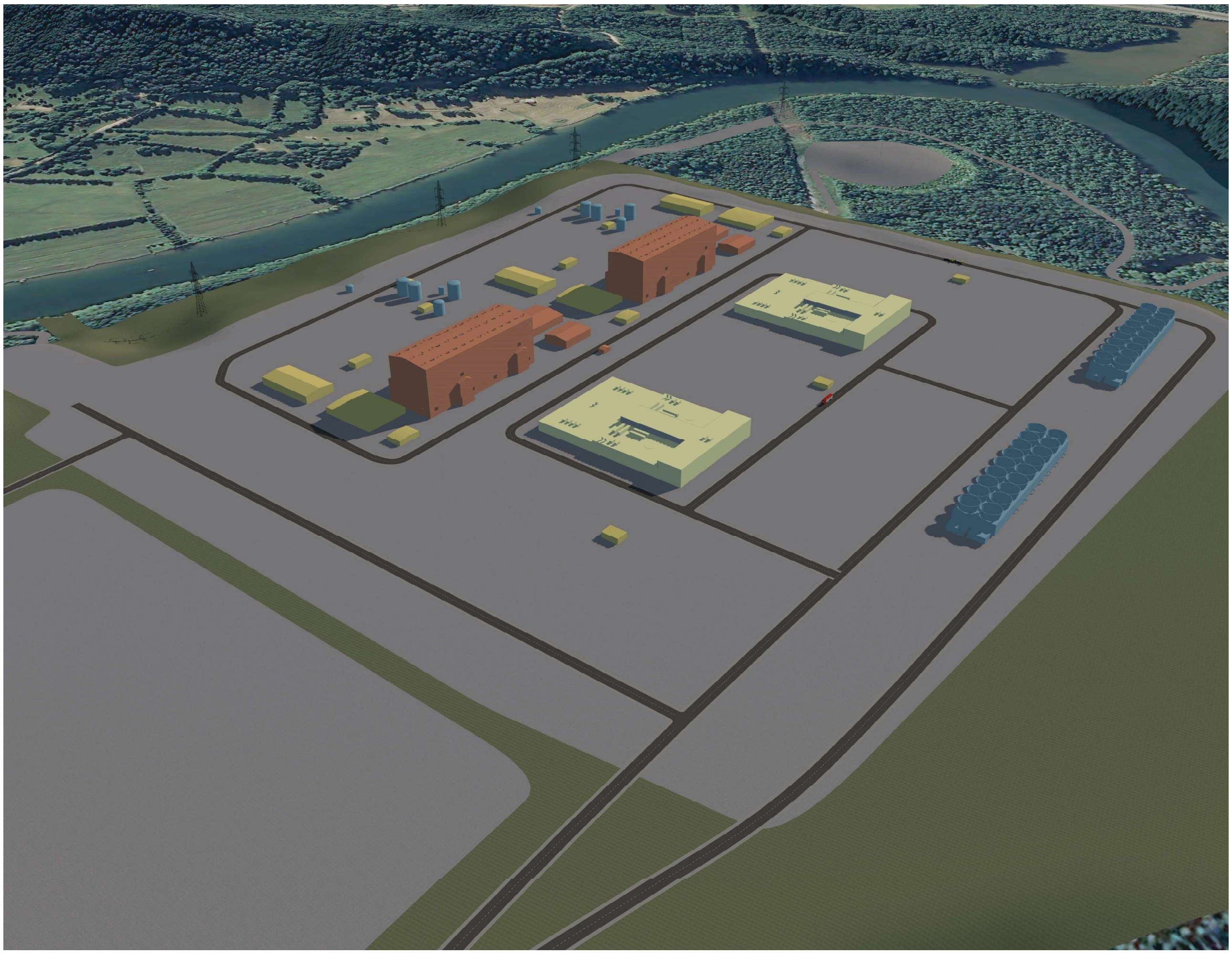

Figure 3.1-3. Architectural Rendering of the Clinch River SMR Surrogate Plant (Two Units) Superimposed on a Site Aerial (View to the Southeast)

3.2 REACTOR POWER CONVERSION SYSTEM

For the Clinch River Nuclear (CRN) Site, the selection of the vendor for a small modular reactor (SMR), and thus the reactor power conversion system, has not been made. Because an 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 Section 3.1. The SMR technologies being considered for the CRN Site, which are based on a pressurized water reactor (PWR) design, are:

- BWXT mPower (up to 4 units)
- NuScale (up to 12 units)
- Holtec SMR-160 (up to 4 units)
- Westinghouse (up to 3 units)

As provided in Table 3.1-2, Item 16.6, the facility has a maximum total electrical output of 800 megawatt electric (MWe), depending upon the design and number of units deployed.

In general, steam generated by the nuclear steam supply system of each unit flows through the steam turbine, creating rotational mechanical work, which in turn rotates the electric generator to produce electricity.

3.2.1 Reactor Description

Because the number of units vary based upon the SMR technology selected, the arrangement of the units on the CRN Site is to be provided at combined license application (COLA) for the selected technology. The basic layout of the power block, turbine island, switchyard, and cooling tower areas is provided in Figure 3.1-1. The assumed facility design life, as provided in Table 3.1-2, Item 16.2, is 60 years.

The per reactor unit thermal output of the SMR technologies being considered varies from approximately 160 megawatt thermal (MWt) to 800 MWt, with a site total of 1920 MWt to 2420 MWt. The reactor and associated power conversion equipment allows generation of a gross electrical output of approximately 50 MWe to 240 MWe per unit and 600 MWe to 800 MWe total gross output for the facility. Because the auxiliary loads vary between the SMR technologies, the net electrical output is not currently available and is provided for the SMR technology selected at COLA.

Although fuel design is specific to the reactor design selected, all of the SMR technologies being considered for the CRN Site use uranium as their fissile material. As provided in Table 3.1-2, Items 18.1, 18.2, and 18.3, the maximum enrichment would be less than 5 percent uranium-235, the maximum average assembly burnup would be 51,000 megawatt-days per metric ton of uranium (MWD/MTU), and the peak fuel rod exposure would be 62,000 MWD/MTU.

3.2.2 Engineered Safety Features

A range of engineered safety feature (ESF) systems are included in the SMR designs being considered. These include both active and passive types of ESF systems. In general, active safety systems rely on powered components, such as valve openings, to supply safety injection water and provide core and containment cooling. In the event of the loss of preferred normal and preferred alternate alternating current power, the active systems would be powered by redundant power sources, such as a diesel generator or a gas turbine. Alternatively, passive safety systems rely almost exclusively on natural forces, such as differences in density, gravity, or stored energy, to supply safety injection water and to provide core and containment cooling. Specific details about the ESF system for the SMR technology selected are addressed at COLA.

3.2.3 Power Conversion Systems

The various SMR designs each use a steam turbine to convert the heat energy to mechanical energy. Waste heat from the turbine condensers is rejected to one or more cooling towers, which serve as the normal heat sink. Specific details about the power conversion system for the SMR technology selected are addressed at COLA.

3.3 PLANT WATER USE

Water is required to support the facility during construction and operation. Typical water uses for facility operation include the circulating water systems (CWS), potable and sanitary water system, fire protection system, and other auxiliary systems such as demineralized water and a liquid radioactive waste treatment system. The primary water source for plant operations is to be water withdrawn from the Clinch River arm of Watts Bar Reservoir via a new intake structure. During construction activities, water for dust control purposes is to either be provided by the City of Oak Ridge or be withdrawn from surface water. Water for potable and sanitary uses during both construction and operations are to be obtained from the City of Oak Ridge.

3.3.1 Water Consumption

A water-use diagram for the surrogate facility is provided in Figure 3.3-1. The diagram shows the average and maximum flow rates for the intake and discharge from the reservoir, the rates for consumptive uses, and the relationships between the various water flow systems. The average values are the expected limiting values for normal plant operation with cooling tower operation at four cycles of concentration, and the maximum values are those for cooling tower operation at two cycles of concentration.

The source of water for facility operations is to be the Clinch River arm of the Watts Bar Reservoir. The proposed water intake is located at approximately Clinch River Mile (CRM) 17.9. The intake is to withdraw 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) is to serve as makeup water for the CWS. The proposed CWS uses mechanical draft cooling towers for heat dissipation from the systems.

Mechanical draft cooling towers consume some water through evaporation and drift. The average and maximum drift rate is estimated to be 8 gpm, and the average and maximum evaporation rate is estimated to be 12,800 gpm. The blowdown from the cooling towers is to be distributed to a holding pond, used for discharge mixing, on the western edge of the site. The blowdown rate is estimated to be an average of 4270 gpm, and a maximum of 12,800 gpm. The holding pond, in turn, discharges water back to the reservoir through the proposed discharge located at CRM 15.5.

The operational modes for the cooling water system are to be defined once a specific reactor design is selected.

Of the total intake withdrawal volume, an average of 1345 gpm (and a maximum of 5100 gpm) is to be directed to the plant and facilities, from which it is to be distributed for use to various auxiliary systems. The consumptive uses of water within these systems are estimated to be negligible. The specific water volumes distributed to each of these individual uses have not been defined, but are to be developed once the reactor design has been selected. The estimated effluent from the miscellaneous raw water uses and demineralized water system are distributed to the holding pond at an average flow rate of 445 gpm and maximum flow rate of 4200 gpm. The effluent from the liquid radioactive waste treatment system is to be discharged directly to the reservoir through the proposed discharge at CRM 15.5, at a maximum flow rate of 900 gpm.

The UHS for the facility is to be a dedicated reservoir of water within the power block area. The source of water for the UHS is addressed at combined license application (COLA). The amount of water required for maintenance of the UHS reservoir is considered to be negligible.

The source of water for the potable and sanitary water systems is to be municipal water from the City of Oak Ridge Public Works Department. Consumptive uses of this water are expected to be negligible, and the wastewater is to be discharged to the City of Oak Ridge sanitary treatment system. The water supply rate for the potable and sanitary water systems is estimated to average 50 gpm, with a maximum rate of 100 gpm. The City of Oak Ridge obtains the municipal water from Melton Hill Reservoir (Reference 3.3-1).

Surface water may be used during construction for purposes such as dust control.

3.3.2 Water Treatment

Tennessee Valley Authority uses biocides and other chemicals to treat cooling and process water at other facilities, and expects similar treatment at the CRN Site. Specific anti-fouling methods are to be defined at COLA, following selection of a reactor design. The quantities and concentrations of chemicals to be used will be in accordance with a Biocide/Corrosion Treatment Plan, which will be submitted as part of the National Pollution Discharge Elimination System permit application to the Tennessee Department of Environment and Conservation.

3.3.3 References

Reference 3.3-1. City of Oak Ridge, Tennessee, "Annual Water Quality Report 2014," TN0000522, 2014.

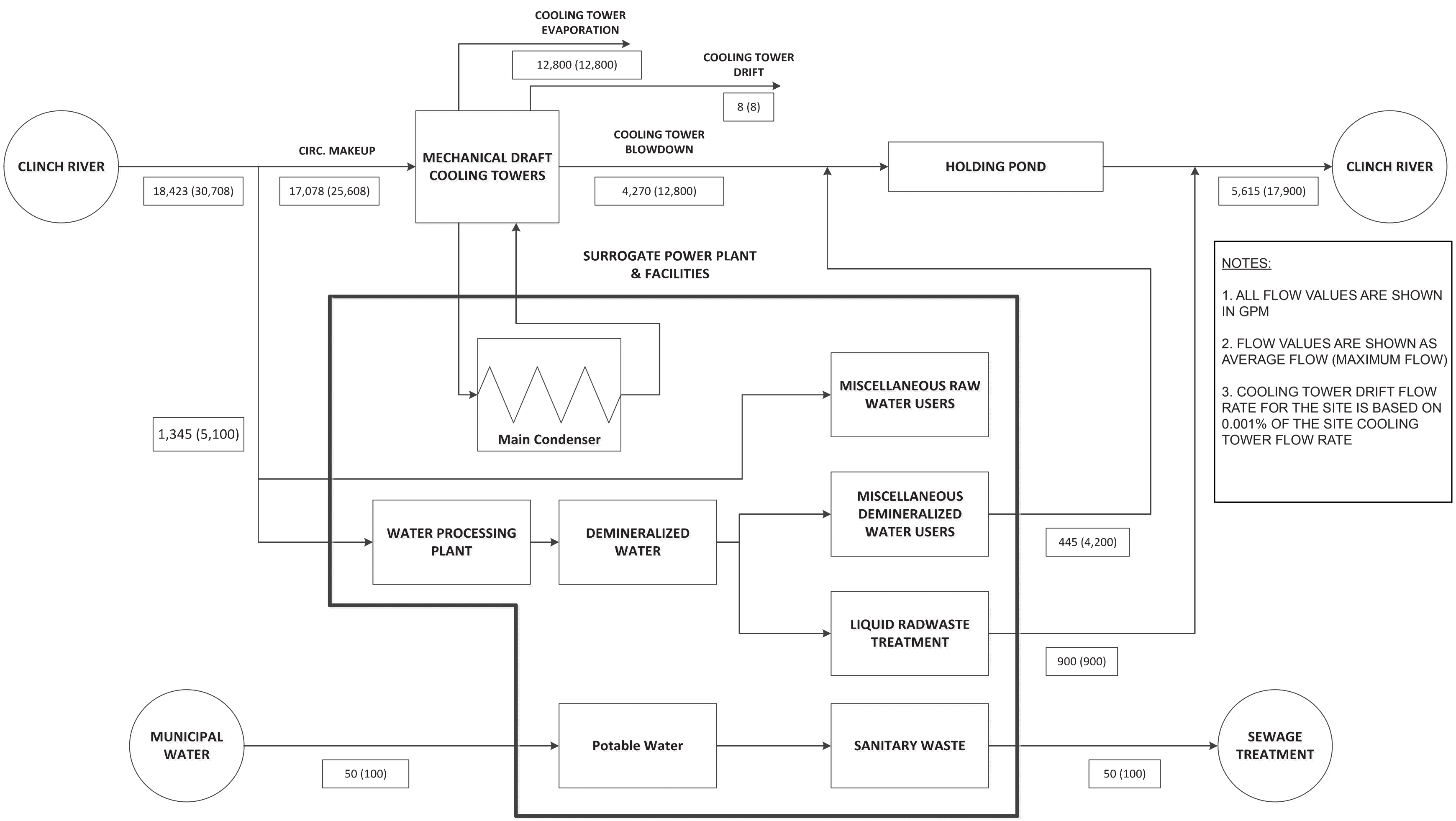

Figure 3.3-1. CRN Site Water Use Diagram

3.4 COOLING SYSTEM

The cooling systems planned for the operation of two or more small modular reactors (SMRs) at the Clinch River Nuclear (CRN) Site are described in Subsection 3.4.1. Design data and performance characteristics for these cooling system components are presented in Subsection 3.4.2. The parameters are used to evaluate the impacts to the environment from cooling system operation. The environmental interfaces of these systems are the plant intake and discharge structures as well as the cooling towers.

3.4.1 Description and Operational Modes

3.4.1.1 System Description

The circulating water systems (CWS) for the facility is planned as a closed-cycle cooling with mechanical draft cooling towers as the mechanism for cooling the main condenser. The design assumes makeup water for the CWS is obtained from an intake on the Clinch River arm of the Watts Bar Reservoir, pumped into the cooling towers, and circulated in and out of the main condenser. A portion of the water is lost as evaporation and 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 the Clinch River arm of the Watts Bar Reservoir through a discharge planned to be located at approximately Clinch River Mile 15.5.

A description of the service water system planned for the facility is beyond the level of detail required for an early site permit application.

The safety-related ultimate heat sink (UHS) planned for the facility is a dedicated reservoir of water within the power block area. The source of water for the UHS is addressed at combined license application (COLA). The amount of water required for maintenance of the UHS reservoir is considered to be negligible..

3.4.1.2 Operational Modes

The operational modes for the cooling water systems have not been defined. Once the SMR reactor technology has been selected, the operational modes for the cooling water systems are to be determined and addressed at COLA. Tables 3.1-1 and 3.1-2, the plant parameter envelope (PPE), provide enveloping cooling system parameters, including water flow rates and heat transfer characteristics, for full operation. Water flow rates and heat transfer characteristics for other operational modes are to be designed within these parameters.

3.4.1.3 Heat Generated, Dissipated to the Atmosphere, and Released in Liquid Discharges

In full power operation mode, heat is transferred to circulating cooling water in the condensers. The PPE defines a maximum heat rejection rate to the circulating water of 5593 million British Thermal Units per hour (hr) (Table 3.1-2, Item 3.1.2). The CWS releases some of this heat to the atmosphere in the mechanical draft cooling towers, and releases the remainder of the heat to the Clinch River arm of the Watts Bar Reservoir through liquid discharges during blowdown of the cooling towers. The quantities of heat generated, dissipated to the atmosphere, and released in liquid discharges depend on the SMR technology selected and are addressed at COLA.

3.4.1.4 Water Source and Quantities of Water Withdrawn, Consumed, and Discharged

In full power operation mode, the CWS requires withdrawal of makeup water from the Clinch River arm of the Watts Bar Reservoir. A flow chart showing the use of water by the facility, including the CWS, is provided in Figure 3.3-1. The makeup water is withdrawn through the intake at a maximum rate of 25,608 gallons per minute (gpm), and an average rate of 17,078 gpm (Table 3.1-2, Item 3.3.9). Cooling tower water is released to the environment through evaporation, drift, and blowdown. Evaporation and drift are consumptive losses because water is not returned to the Clinch River arm of the Watts Bar Reservoir. The expected and maximum evaporation rate is 12,800 gpm (Table 3.1-2, Item 3.3.7), and the rate of drift is 8 gpm (Table 3.1-2, Item 3.3.17). The short-term and monthly average consumptive water use is 12,808 gpm (Table 3.1-2, Item 3.3.14). The normal blowdown rate, based on four cycles of concentration, is 4270 gpm (Table 3.1-2, Item 3.3.4). The estimated maximum blowdown rate, based on two cycles of concentration, is 12,800 gpm (Table 3.1-2, Item 3.3.4).

Miscellaneous plant water is withdrawn from the Clinch River arm of the Watts Bar Reservoir at a maximum rate of 5100 gpm and an average rate of 1345 gpm (Table 3.1-2, Item 3.2.3). As shown in Figure 3.3-1, discharges from the liquid radioactive waste treatment system (at a maximum of 900 gpm; Table 3.1-2, Item 10.2.1) discharge directly to the Clinch River arm of the Watts Bar Reservoir and miscellaneous raw water and demineralized water users (at a maximum of 4200 gpm and an average of 445 gpm) flow to the holding pond. An additional source of water shown in Figure 3.3-1 is municipal water. This water services the potable water and sanitary waste systems at an average of 50 gpm and maximum of 100 gpm (Table 3.1-2, Items 5.1.1 and 5.1.2) and discharges to a sewage treatment plant at the same rate with no appreciable water loss.

3.4.2 Component Descriptions

The layout of various components of the CWS, including the intake, holding pond, and discharge, are shown on Figure 3.1-2. These systems are described in Subsections 3.4.2.1 through 3.4.2.4. Subsection 3.4.2.5 describes the modifications planned for the Melton Hill Dam to ensure a minimum flow rate in the Clinch River arm of the Watts Bar Reservoir at the facility discharge pipe. The following subsections provide a description of each of these components.

3.4.2.1 Intake System

The location of the water intake is shown in Figure 3.1-1. Figure 3.4-2 shows the general configuration of the intake structure with respect to the Clinch River arm of the Watts Bar

Reservoir, and Figure 3.4-3 provides a more detailed depiction of the intake channels, trash racks, flow baffles, and pumps. A cross-sectional view of the intake is shown in Figure 3.4-4.

As shown on Figures 3.4-3 and 3.4-4, the intake system is planned to be approximately 50 feet (ft) in width and 50 ft in length with four intake channels. Each channel includes a stop log slot and bar screen with debris raking system and trash racks, leading to dual flow screens. Once through the screens, the flow from the four channels is re-combined behind a flow baffle, and then separated again into four channels, each serviced by two pumps. Screen wash pumps allow debris to be removed from the dual flow screens. The water is then pumped to the CWS through two pipelines.

The design of the intake structure will comply with the Clean Water Act 316(b) regulations by providing aquatic life protection. The maximum intake inlet velocities, trash rack flow-through velocity, and through-flow velocity at the water screens will be less than 0.5 ft per second. A common intake structure for all reactors is planned for the shoreline with the intake structure front face located at the existing river bank as shown on Figure 3.4-2.

The flow velocities for operational modes other than full power operation have not yet been defined, pending selection of the SMR reactor technology. The anti-fouling methods to be used on the water also have not yet been defined, and is addressed at COLA. The quantities of chemicals used for treatments of intake or process waters will be in accordance with a Biocide/Corrosion Treatment Plan which will be approved by the Tennessee Department of Environment and Conservation (TDEC) and submitted as required with the National Pollutant Discharge Elimination System (NPDES) permit application for the facility.

3.4.2.2 Holding Pond

As shown in Figure 3.3-1, CWS design sends blowdown from the cooling towers through a holding pond on the western side of the CRN Site on its way to the discharge structure located on the Clinch River arm of the Watts Bar Reservoir. The location of the holding pond is shown in Figure 3.1-2.

The planned holding pond is at a grade elevation of 763 ft. The approximate dimensions of the pond are approximately 230 ft wide and approximately 980 ft long, with a water depth of approximately 13 ft. The blowdown flow to the holding pond allows mixing of the blowdown with other plant discharges that enter the holding pond (Section 3.3). This, along with a brief exposure to the atmosphere, can reduce the temperature of the blowdown. However, in the hydrothermal analysis (Section 5.3) a conservative assumption was made not to include any change in temperature of the plant discharge in the holding pond. The purpose of the holding pond is only for mixing of plant discharges.

3.4.2.3 Discharge

A conceptual layout of the discharge is shown in Figure 3.4-5. The bottom geometry of the Clinch River arm of the Watts Bar Reservoir near the discharge location is shown in Figure 3.4-5. The water surface elevation in Watts Bar Reservoir is generally maintained between 735 ft and 741 ft above mean sea level (Reference 3.4-1). The conceptual layout shows the blowdown passing through an instrumentation vault for measurement of flow and temperature, and then continuing through the approach conduits to two diffuser conduits, each approximately 15 ft long (30 ft total length) and 3 ft in diameter. Two separate diffuser conduits allow flow to be isolated to only one conduit, if needed for maintenance. It also allows the exit velocity of the diffuser ports to be maintained, and therefore the rate of mixing to be maintained, in situations where the facility is not operating at full capacity.

The design of the diffuser ports provides an exit velocity of approximately 8 to 10 ft per second (fps). The discharge is estimated to have a maximum temperature of 90 degrees Fahrenheit (°F; Table 3.1-2, Item 3.3.5). The assumed maximum potential concentrations of chemical constituents within the blowdown are provided in Table 3.6-1.

Discharges to the Clinch River arm of the Watts Bar Reservoir are regulated by the TDEC through a NPDES permit. The CRN Site's NPDES permit will include discharge limits established to protect receiving waters, and monitoring requirements to ensure compliance with those limits. Temperatures and chemical concentrations for all discharges will be in compliance with the terms and conditions of the NPDES permit.

3.4.2.4 Heat Dissipation

The heat dissipation mechanism for the planned CWS is through mechanical draft cooling towers. The location of the cooling towers is within the plant area shown in Figure 3.1-2. The cooling tower location occupies an area of approximately 6 acres (Table 3.1-2, Item 3.3.1), and are expected to be a maximum of 65 ft high above plant grade (Table 3.1-2, Item 3.3.8). The quantity of water to be stored in the cooling towers is 5,000,000 gallons (Table 3.1-2, Item 3.3.16), and the water circulates through the cooling towers at a maximum rate of 755,000 gpm (Table 3.1-2, Item 3.3.12). The planned cooling towers are designed for a maximum blowdown temperature of 90°F at the point of discharge to the Clinch River arm of the Watts Bar Reservoir (Table 3.1-2, Item 3.3.5) and an 18°F temperature difference between the cooling water entering and leaving the cooling tower (Table 3.1-2, Item 3.3.11). A minimum of two and a maximum of four cycles of concentration are assumed within the cooling towers (Table 3.1-2, Item 3.3.6).

3.4.2.5 Bypass Flow

To maintain acceptable thermal limits for the cooling system, a bypass capable of providing a continuous flow of approximately 400 cubic ft per second (cfs) will be installed at Melton Hill Dam. The operating policy for Melton Hill Dam requires a minimum daily average release of 400 cfs (Reference 3.4-2). This minimum daily average release can be met, and has in the past been met, by operating the hydropower generating units for a period of only one hour per day. This can result in periods, potentially lasting up to 46 hr, where there are no releases from Melton Hill Dam. However, events during which there is no release from Melton Hill Dam for periods in excess of 36 hr are extremely rare. When this occurs, the flow in the Clinch River arm of the Watts Bar Reservoir becomes quiescent, making it difficult to dilute the plant thermal discharge without exceeding mixing zone guidelines or temperature requirements. Therefore, a bypass, which can produce a continuous flow rate of 400 cfs even when the hydropower generating units are not operating, will be installed at the dam.

3.4.3 References

Reference 3.4-1. Tennessee Valley Authority, "Clinch River Small Modular Reactor Site Regional Surface Water Use Study - Revision 2," April 24, 2015.

Reference 3.4-2. Tennessee Valley Authority, "Programmatic Environmental Impact Statement, Reservoir Operations Study," May, 2004.

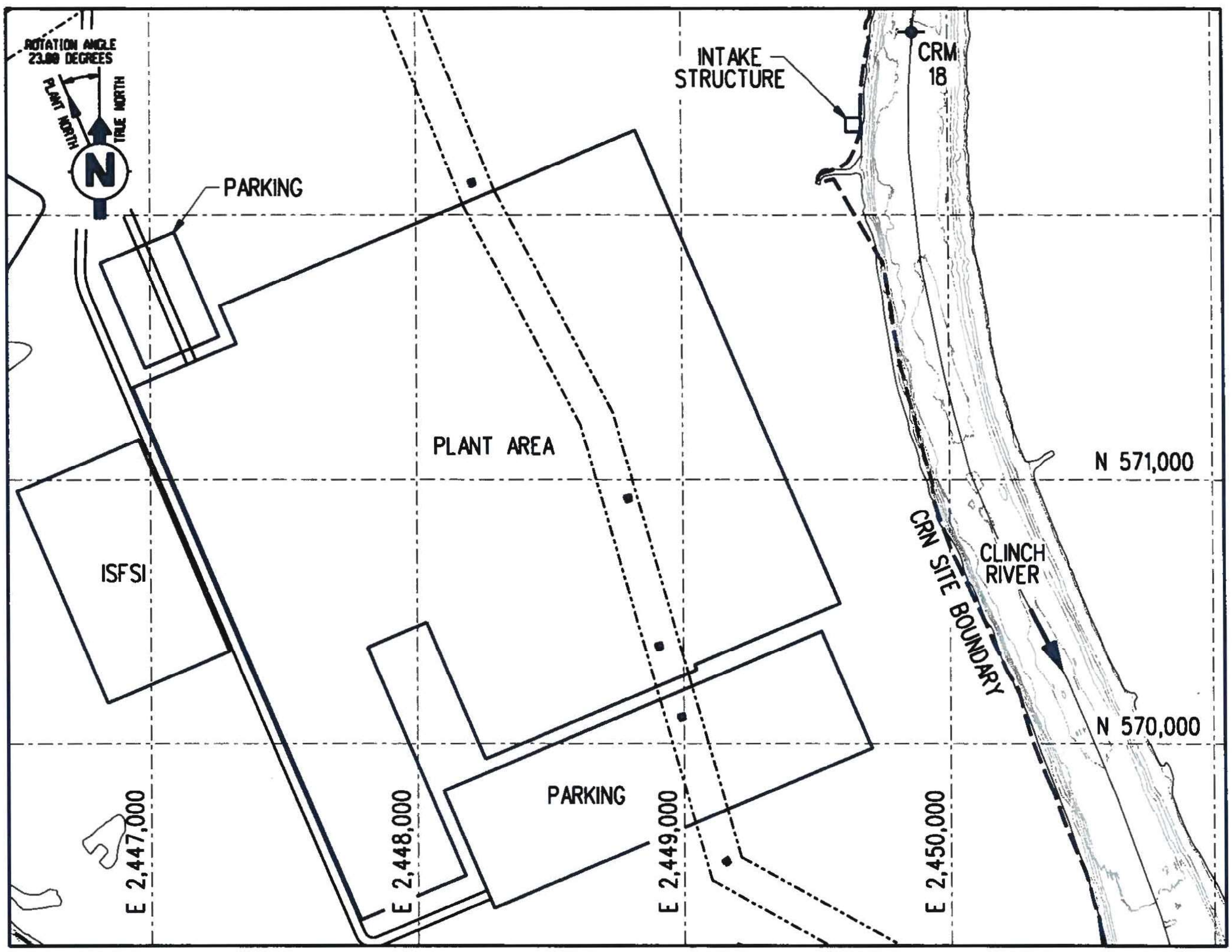

Figure 3.4-1. Location Plan of Intake Structure

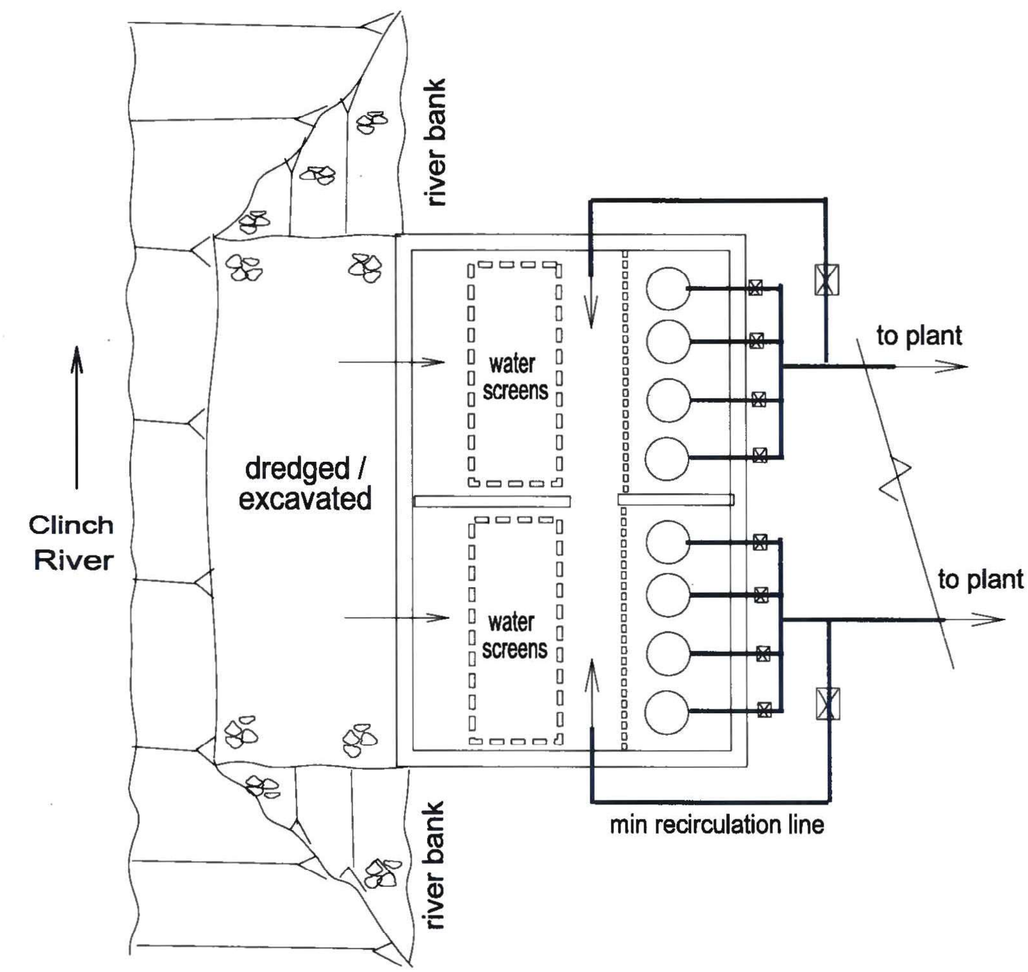

Figure 3.4-2. Conceptual Intake Structure Arrangement

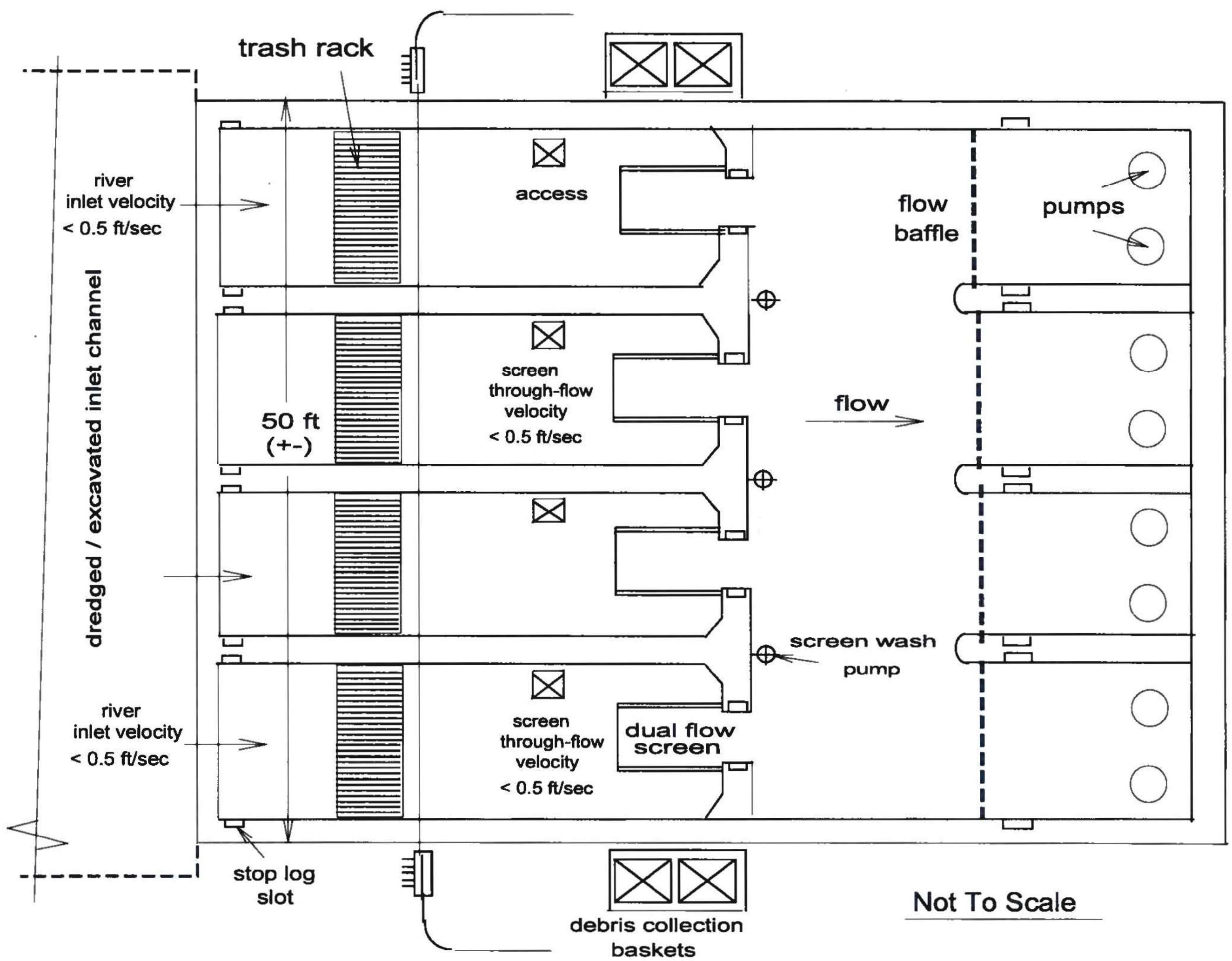

Figure 3.4-3. Conceptual Plan View of Intake Structure

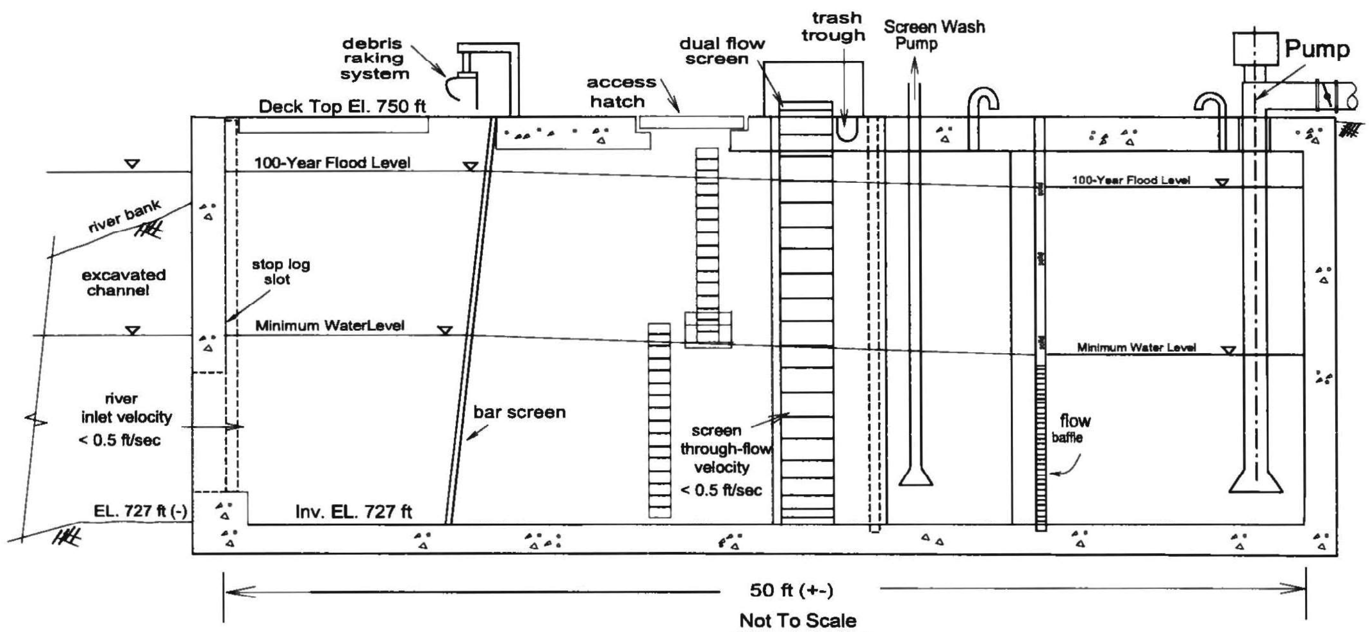

Figure 3.4-4. Conceptual Section View of Intake Structure

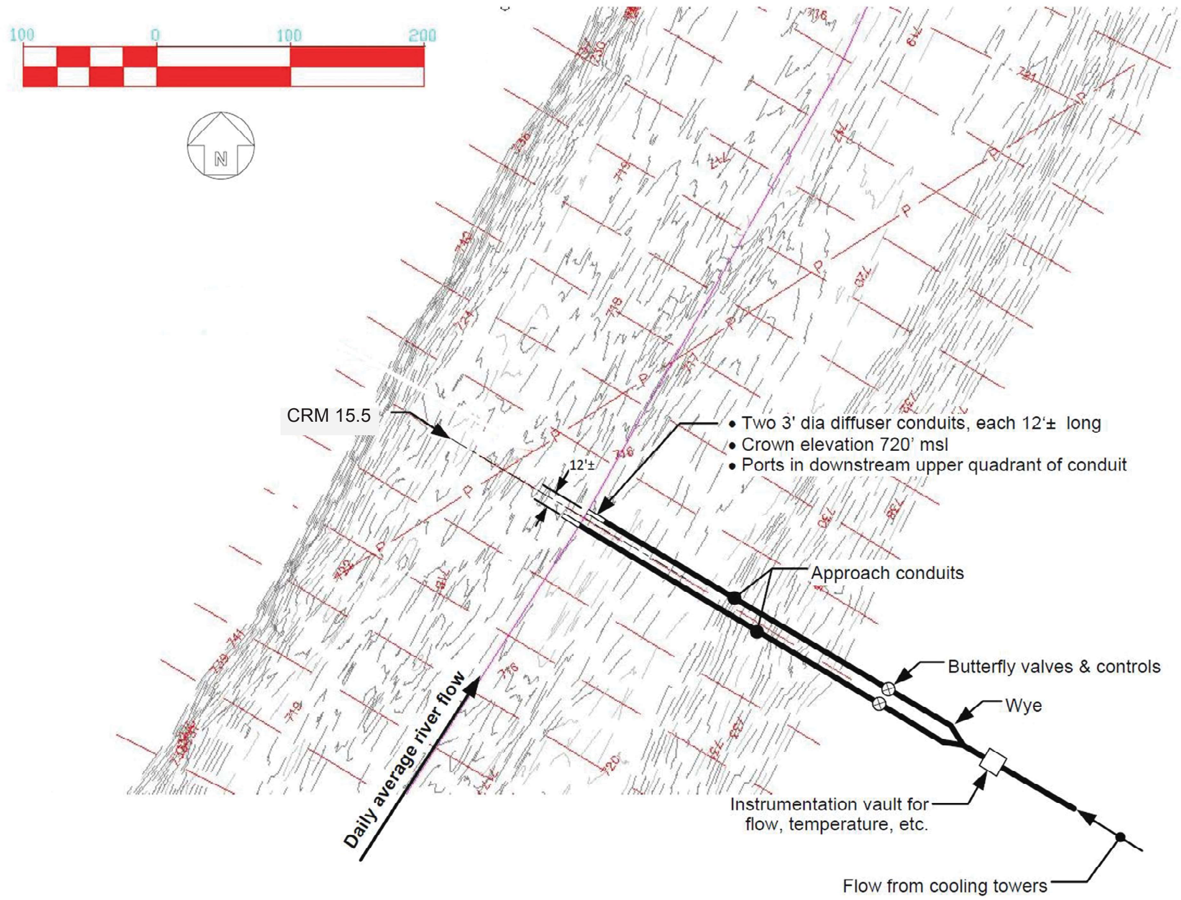

Figure 3.4-5. Conceptual Layout of Proposed Discharge Structure

3.5 RADIOACTIVE WASTE MANAGEMENT SYSTEM

Radioisotopes are produced during the normal operation of nuclear reactors through the processes of fission and activation. Fission products may enter the reactor coolant by diffusing from the fuel and then passing through the fuel cladding via leaks or by diffusion. The primary cooling water may contain dissolved or suspended corrosion products and nonradioactive materials leached from plant components. These products and materials can be activated by the neutrons in the reactor core as the water passes through the core. These radioisotopes leave the reactor coolant via plant systems designed to remove impurities, via small leaks that occur in the reactor coolant system and auxiliary systems, or via breaching of systems for maintenance. Therefore, each plant generates radioactive waste that can be liquid, solid, or gaseous.

This section describes the liquid, gaseous, and solid radioactive waste management systems proposed to be used as part of the operation of two or more Small Modular Reactors (SMRs) at the Clinch River Nuclear (CRN) Site. Because a reactor design has not been chosen for the project, bounding values have been developed for the quantities of radioactive wastes that are projected to be generated and processed and then stored or released as liquid or gaseous effluents or as solid waste. The radioactive waste management system is designed to minimize releases from reactor operations to values as low as reasonably achievable (ALARA). These systems are designed and maintained to meet the requirements of Title 10 of the Code of Federal Regulations (10 CFR) Part 20 and 10 CFR Part 50, Appendix I. The dose impacts from normal operation of the facility, including the management of the radioactive waste system, are provided in Section 5.4.

3.5.1 Liquid Waste Management Subsystem

The liquid radioactive waste system will be designed to control, collect, process, handle, store, and dispose of liquid radioactive waste generated as the result of normal operation, including anticipated operational occurrences. Sources of liquid radioactive waste include leakage from systems, wastes generated by processing systems, and maintenance activities. During the design phase of the proposed project, these sources and potential sources will be identified and collection and processing systems will be designed to remove the radioactivity to the extent that the processed liquid can be recycled or discharged in accordance with the requirements of 10 CFR 20 and the ALARA principles of 10 CFR Part 50, Appendix I. Discharges will be to the Clinch River arm of the Watts Bar Reservoir and will be controlled and monitored to measure the activity released. Liquid waste processing systems will be designed to maintain the radiation exposures of plant personnel as low as reasonably achievable. As provided in Table 3.5-1, the total projected bounding annual release activity in liquid effluents from the CRN Site is 887 curies per year (Ci/yr). Table 3.5-2 provides the total projected bounding annual release activity in liquid effluents from a single SMR unit as 221 Ci/yr.

3.5.2 Gaseous Radioactive Waste Management Subsystem

Typical gaseous radioactive wastes include vents from collection tanks and processing equipment and non-condensables in steam systems. The radioactive isotopes contained in these waste streams include fission product iodines and the noble gas fission products xenon and krypton as well as activation products such as argon-41 and cobalt-60. These wastes will be collected and processed to decrease the radioactivity content to the point that they can be released to the environment through a controlled and monitored release point (plant vent or plant stack). The typical processing technique is one of holdup or delay to allow the short-lived activity to decay. Adsorption on activated charcoal or compression and storage are two methods used to create the necessary holdup time. Processing systems will be designed to process gaseous wastes generated by normal plant operation and anticipated operational occurrences.

Minor leakage of radioactive gases from plant systems to building atmosphere will be detected by area radiation monitors. Ventilation systems will process these gases by filtration, if needed, and direct them to a controlled and monitored release point.

Gaseous radioactive waste discharges will be controlled to the requirements of 10 CFR 20 and the ALARA principles of 10 CFR Part 50, Appendix I. Gaseous radioactive waste system equipment will be designed to ensure occupational exposures to plant personnel are as low as reasonable achievable. As provided in Table 3.5-3, the total projected bounding release activity in gaseous waste from the CRN Site is 7130 Ci/yr. Table 3.5-4 provides the total projected bounding annual release activity in gaseous waste from a single SMR unit as 1550 Ci/yr.

3.5.3 Solid Radioactive Waste Management Subsystem

Solid radioactive wastes are produced by multiple activities in a nuclear power station. The solid waste can be either wet or dry, depending on whether the source is a processing activity, maintenance, or other function such as housekeeping. The solid radioactive waste management system is designed to collect, monitor, segregate, process, and prepare solid radioactive wastes prior to and for their shipment or onsite storage. The system design will ensure that the wastes are handled, processed, and stored in a manner that minimizes exposure to plant personnel and the public in accordance with 10 CFR 20 and 10 CFR Part 50, Appendix I. Wastes will be packaged to meet U.S. Department of Transportation (49 CFR 173 and 178) and U.S. Nuclear Regulatory Commission (10 CFR 71) regulations for transportation of radioactive material. Radioactive waste will be transported to either a licensed waste processing facility or a licensed low-level radioactive waste disposal facility. As provided in Table 3.5-5, the projected bounding total annual activity of solid radioactive waste from the CRN Site is 57,200 Ci/yr and, as provided in Table 3.1-2, Item 11.2.3, the projected bounding generated volume of solid radioactive waste from the CRN Site is 5000 cubic feet per year.

Table 3.5-1 (Sheet 1 of 2)
CRN Site Projected Average Normal Liquid Radioactive Release

Radionuclide	Release (Ci/yr)	Radionuclide	Release (Ci/yr)
Ag-110	3.48E-08	La-140	4.27E-03
Ag-110m	2.66E-02	La-141	8.80E-08
Am-241	1.85E-10	La-142	1.19E-08
Ba-137m	2.07E-03	Mn-54	6.53E-02
Ba-139	6.16E-08	Mn-56	1.09E-03
Ba-140	4.80E-02	Mo-99	4.52E-02
Br-82	7.48E-06	Na-24	8.40E-03
Br-83	1.41E-05	Nb-95	1.07E-03
Br-84	1.01E-03	Nd-147	1.07E-06
Br-85	9.68E-09	Ni-63	1.84E-01
C-14	9.83E-03	Np-239	2.99E-02
Ce-141	1.58E-04	P-32	3.03E-04
Ce-143	3.25E-04	Pr-143	6.93E-05
Ce-144	2.99E-03	Pr-144	1.69E-03
Cm-242	3.78E-08	Pu-238	2.64E-09
Cm-244	1.76E-09	Pu-239	3.39E-10
Co-58	5.51E-02	Pu-240	4.27E-10
Co-60	8.21E-03	Pu-241	1.28E-07
Cr-51	1.28E-01	Rb-86	7.48E-05
Cs-134	3.44E-02	Rb-88	1.49E-02
Cs-136	1.17E-02	Rb-89	6.18E-04
Cs-137	4.24E-02	Rh-103m	4.37E-06
Cs-138	1.42E-02	Rh-105	4.27E-07
Cu-64	6.72E-03	Rh-106	3.74E-07
Fe-55	4.87E-02	Ru-103	2.63E-03
Fe-59	1.19E-02	Ru-105	7.04E-08
H-3	8.85E+02	Ru-106	3.92E-02
I-129	5.04E-09	Sb-124	2.29E-04
I-130	1.85E-05	Sb-125	7.92E-09
I-131	1.66E-01	Sb-127	4.40E-08
I-132	1.32E-01	Sb-129	1.76E-08
I-133	2.76E-01	Sr-89	1.67E-04
I-134	3.91E-02	Sr-90	1.43E-05
I-135	1.64E-01	Sr-91	6.67E-04

Table 3.5-1 (Sheet 2 of 2)
CRN Site Projected Average Normal Liquid Radioactive Release

Radionuclide	Release (Ci/yr)	Radionuclide	Release (Ci/yr)
Sr-92	2.36E-04	Te-134	1.06E-06
Tc-99	1.76E-08	W-187	6.30E-04
Tc-99m	2.27E-02	Y-90	1.86E-06
Te-127	1.28E-05	Y-91	1.25E-04
Te-127m	5.72E-06	Y-91m	2.67E-05
Te-129	1.28E-05	Y-92	9.01E-04
Te-129m	6.90E-02	Y-93	7.25E-04
Te-131	9.24E-06	Zn-65	2.11E-02
Te-131m	1.98E-03	Zr-95	2.20E-03
Te-132	1.32E-01	Zr-97	4.40E-07
Total Liquid Radionuclide Release Activity			8.87E+02

Table 3.5-2 (Sheet 1 of 2)
Liquid Effluent Activities Per Reactor

Isotope	Release (Ci/yr)	Isotope	Release (Ci/yr)
Ag-110	8.69E-09	I-134	3.26E-03
Ag-110m	2.22E-03	I-135	1.37E-02
Am-241	4.62E-11	La-140	1.07E-03
Ba-137m	5.17E-04	La-141	2.20E-08
Ba-139	1.54E-08	La-142	2.97E-09
Ba-140	1.60E-02	Mn-54	5.44E-03
Br-82	1.87E-06	Mn-56	2.72E-04
Br-83	3.52E-06	Mo-99	3.77E-03
Br-84	8.38E-05	Na-24	2.80E-03
Br-85	2.42E-09	Nb-95	2.67E-04
C-14	8.19E-04	Nd-147	2.67E-07
Ce-141	3.96E-05	Ni-63	1.53E-02
Ce-143	8.13E-05	Np-239	2.49E-03
Ce-144	7.47E-04	P-32	7.57E-05
Cm-242	9.46E-09	Pr-143	1.73E-05
Cm-244	4.40E-10	Pr-144	4.21E-04
Co-58	5.20E-03	Pu-238	6.60E-10
Co-60	2.05E-03	Pu-239	8.47E-11
Cr-51	1.07E-02	Pu-240	1.07E-10
Cs-134	2.87E-03	Pu-241	3.19E-08
Cs-136	2.93E-03	Rb-86	1.87E-05
Cs-137	3.53E-03	Rb-88	3.73E-03
Cs-138	1.18E-03	Rb-89	5.15E-05
Cu-64	1.68E-03	Rh-103m	3.64E-07
Fe-55	4.06E-03	Rh-105	1.07E-07
Fe-59	9.92E-04	Rh-106	9.35E-08
H-3	2.21E+02	Ru-103	6.57E-04
I-129	4.20E-10	Ru-105	1.76E-08
I-130	4.62E-06	Ru-106	9.80E-03
I-131	1.38E-02	Sb-124	5.73E-05
I-132	4.40E-02	Sb-125	1.98E-09
I-133	2.30E-02	Sb-127	1.10E-08

Table 3.5-2 (Sheet 2 of 2)
Liquid Effluent Activities Per Reactor

Isotope	Release (Ci/yr)	Isotope	Release (Ci/yr)
Sb-129	4.40E-09	Te-131m	6.60E-04
Sr-89	4.19E-05	Te-132	4.40E-02
Sr-90	3.57E-06	Te-134	2.64E-07
Sr-91	1.67E-04	W-187	2.10E-04
Sr-92	5.91E-05	Y-90	1.55E-07
Tc-99	4.40E-09	Y-91	3.13E-05
Tc-99m	1.89E-03	Y-91m	6.67E-06
Te-127	3.19E-06	Y-92	2.25E-04
Te-127m	1.43E-06	Y-93	1.81E-04
Te-129	3.19E-06	Zn-65	1.76E-03
Te-129m	2.30E-02	Zr-95	1.83E-04
Te-131	2.31E-06	Zr-97	1.10E-07
		Total Liquid Effluent Activity	2.21E+02

Table 3.5-3 (Sheet 1 of 2)
CRN Site Project Average Normal Gaseous Radioactive Release

Radionuclide	Release (Ci/yr)	Radionuclide	Release (Ci/yr)
Ag-110m	2.14E-03	La-140	1.12E-03
Ar-41	5.44E+02	Mn-54	5.22E-03
Ba-140	1.67E-02	Mn-56	2.17E-03
Br-84	1.28E-05	Mo-99	3.68E-02
C-14	1.00E+01	Na-24	2.50E-03
Ce-141	5.68E-03	Nb-95	7.50E-03
Ce-143	1.16E-07	Ni-63	1.46E-02
Ce-144	1.17E-05	Np-239	7.35E-03
Co-57	1.10E-04	P-32	5.68E-04
Co-58	6.90E-02	Pr-144	1.17E-05
Co-60	2.64E-02	Rb-88	9.80E-06
Cr-51	2.17E-02	Rb-89	2.67E-05
Cs-134	6.90E-03	Rh-103m	1.48E-08
Cs-136	3.68E-04	Rh-106	4.57E-11
Cs-137	3.26E-02	Ru-103	2.17E-03
Cs-138	1.05E-04	Ru-106	2.34E-04
Cu-64	6.18E-03	Sb-124	1.12E-04
Fe-55	4.01E-03	Sb-125	3.77E-05
Fe-59	9.55E-04	Sr-89	9.00E-03
H-3	1.01E+03	Sr-90	3.60E-03
I-129	8.02E-11	Sr-91	6.18E-04
I-131	2.31E-01	Sr-92	4.84E-04
I-132	1.35E+00	Tc-99m	1.83E-04
I-133	1.05E+00	Te-129m	1.35E-04
I-134	2.33E+00	Te-131m	4.68E-05
I-135	1.49E+00	Te-132	7.13E-05
Kr-83m	1.28E-02	W-187	1.17E-04
Kr-85	7.20E+02	Xe-131m	1.67E+03
Kr-85m	3.39E+02	Xe-133	2.24E+03
Kr-87	3.27E+01	Xe-133m	1.05E+02
Kr-88	1.45E+02	Xe-135	2.82E+02
Kr-89	5.00E-07	Xe-135m	1.28E+01

Table 3.5-3 (Sheet 2 of 2)
CRN Site Projected Average Normal Gaseous Radioactive Release

Radionuclide	Release (Ci/yr)	Radionuclide	Release (Ci/yr)
Xe-137	3.00E+00	Y-92	3.84E-04
Xe-138	1.14E+01	Y-93	6.86E-04
Y-90	2.84E-05	Zn-65	6.86E-03
Y-91	1.49E-04	Zr-95	3.00E-03
		Total Gaseous Radionuclide Release Activity	7.13E+03

Table 3.5-4 (Sheet 1 of 2)
Gaseous Effluent Activities Per Reactor

Radionuclide	Release (Ci/yr)	Radionuclide	Release (Ci/yr)
Ag-110m	1.78E-04	La-140	2.79E-04
Ar-41	4.00E+01	Mn-54	8.35E-04
Ba-140	4.17E-03	Mn-56	5.42E-04
Br-84	1.07E-06	Mo-99	9.19E-03
C-14	7.30E+00	Na-24	6.25E-04
Ce-141	1.42E-03	Nb-95	2.50E-03
Ce-143	9.63E-09	Ni-63	1.22E-03
Ce-144	2.92E-06	Np-239	1.84E-03
Co-57	2.75E-05	P-32	1.42E-04
Co-58	2.30E-02	Pr-144	2.92E-06
Co-60	8.80E-03	Rb-88	8.17E-07
Cr-51	5.42E-03	Rb-89	6.67E-06
Cs-134	2.30E-03	Rh-103m	1.23E-09
Cs-136	9.19E-05	Rh-106	3.81E-12
Cs-137	8.14E-03	Ru-103	5.42E-04
Cs-138	2.63E-05	Ru-106	7.80E-05
Cu-64	1.54E-03	Sb-124	2.79E-05
Fe-55	1.00E-03	Sb-125	9.42E-06
Fe-59	1.25E-04	Sr-89	3.00E-03
H-3	3.10E+02	Sr-90	1.20E-03
I-129	6.68E-12	Sr-91	1.54E-04
I-131	7.70E-02	Sr-92	1.21E-04
I-132	3.38E-01	Tc-99m	4.59E-05
I-133	2.63E-01	Te-129m	3.38E-05
I-134	5.84E-01	Te-131m	1.17E-05
I-135	3.72E-01	Te-132	5.94E-06
Kr-83m	1.07E-03	W-187	2.92E-05
Kr-85	1.21E+02	Xe-131m	2.75E+02
Kr-85m	8.47E+01	Xe-133	5.61E+02
Kr-87	8.18E+00	Xe-133m	2.63E+01
Kr-88	3.63E+01	Xe-135	7.04E+01
Kr-89	1.25E-07	Xe-135m	3.19E+00

Table 3.5-4 (Sheet 2 of 2)
Gaseous Effluent Activities Per Reactor

Radionuclide	Release (Ci/yr)	Radionuclide	Release (Ci/yr)
Xe-137	7.50E-01	Y-92	9.60E-05
Xe-138	2.86E+00	Y-93	1.71E-04
Y-90	7.09E-06	Zn-65	1.71E-03
Y-91	3.72E-05	Zr-95	1.00E-03
		Total Gaseous Effluent Activity	1.55E+03

Table 3.5-5
Projected Principal Radionuclides in Solid Radioactive Waste from the CRN Site

Radionuclide	Composite (Site Value) (Ci/yr)	Radionuclide	Composite (Site Value) (Ci/yr)
Ag-110m	2.84E-02	Mn-54	1.57E+03
Ba-137m	1.01E+04	Mn-56	5.52E+02
Ba-140	1.38E+01	Mo-99	1.24E+01
Br-83	8.16E+00	Nb-95	2.00E-01
Br-84	3.96E-01	Ni-63	8.78E+03
Br-85	4.35E-03	Np-239	6.98E+00
C-14	1.76E-01	Pu-241	7.04E-02
Ce-144	6.60E-01	Rb-86	3.45E+01
Co-58	3.77E+02	Rb-88	2.93E+01
Co-60	2.84E+02	Rb-89	1.14E+00
Cr-51	3.44E+02	Sr-89	5.28E+01
Cs-134	1.11E+04	Sr-90	1.27E+01
Cs-136	2.00E+03	Sr-91	1.35E+00
Cs-137	1.06E+04	Sr-92	1.16E-01
Cs-138	1.23E+01	Tc-99m	5.64E-01
Fe-55	1.85E+03	Te-127m	5.78E-01
Fe-59	5.14E+01	Te-131m	1.75E-01
H-3	9.92E-01	Te-132	5.51E+00
I-129	3.99E-03	Y-90	1.24E+01
I-130	1.04E+01	Y-91	6.36E-01
I-131	6.33E+03	Y-91m	4.05E-01
I-132	2.29E+02	Y-92	4.86E-02
I-133	1.93E+03	Y-93	1.05E-04
I-134	8.49E+00	Zn-65	4.33E+02
I-135	4.41E+02	Zr-95	4.42E-02
La-140	1.24E+01	Other	1.852E+01
		Total Activity from Solid Waste	5.72E+04

3.6 NON-RADIOACTIVE WASTE SYSTEM

This section provides a general discussion of typical non-radioactive solid, liquid, and gaseous waste streams generated by the construction and operation of two or more small modular reactors (SMRs) at the Clinch River Nuclear (CRN) Site. Typical non-radioactive waste streams include cooling water that may contain water treatment chemicals or biocides, water-treatment wastes, waste from floor and equipment drains, stormwater runoff, water pumped from excavations during construction, laboratory waste, trash, hazardous waste, effluents from the sanitary sewer system, and miscellaneous gaseous, liquid and solid effluents.

Detailed information regarding the non-radioactive waste management and effluent control systems, process/instrumentation diagrams, and system process flow diagrams are provided as part of the combined license application, submitted following reactor technology selection. The system design in this section is derived from the surrogate plant described by the plant parameter envelope detailed in Section 3.1.

3.6.1 Effluents Containing Chemicals or Biocides

As discussed in Subsection 3.3.2, water used in various SMR operational systems requires treatment using chemicals and/or biocides to avoid scaling or fouling. The rates of inflow into and blowdown out of the water systems are to be managed, and effluents from the systems are to be processed to minimize the concentrations of the chemicals and biocides contained in facility discharges. However, facility discharges may contain low-level concentrations of chemicals and/or biocides. The chemical concentrations in effluent streams are to be controlled through engineering and operational/administrative controls to meet the requirements of a Tennessee Department of Environment and Conservation (TDEC)-approved Biocide/Corrosion Treatment Plan and of a National Pollutant Discharge Elimination System (NPDES) permit, as well as requirements and limitations set by relevant federal, regional, or local regulatory agencies at the time of construction and operation. The specific chemicals and biocides to be used depend upon the characteristics of the water to be treated and the design requirements of the SMR systems. The anticipated constituents and their concentrations in the facility's non-radioactive liquid waste discharges are provided in Table 3.6-1.

3.6.2 Sanitary System Effluents

The proposed facility discharges sanitary wastewaters to the City of Oak Ridge Public Works Department. The City of Oak Ridge operates two wastewater treatment plants. The main plant has a capacity of 30.0 million gallons per day (mgd), and the Rarity Ridge plant, which serves the Clinch River Industrial Park, East Tennessee Technology Park, Horizon Center, and Rarity Ridge, has a capacity of 0.6 mgd. The plants treat a combined flow of 5.6 mgd (Reference 3.6-1). The main plant discharges effluent to East Fork Poplar Creek under TDEC NPDES Permit TN0024155 (Reference 3.6-2). The Rarity Ridge Plant discharges effluent to the Clinch River arm of the Watts Bar Reservoir at Clinch River Mile (CRM) 12.85 under TDEC NPDES Permit TN0078051 (Reference 3.6-3).

The projected effluent flow 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, and is estimated to average 50 gallons per minute (gpm). This equates to an average daily flow of 72,000 gallons per day (gpd). The estimated maximum flow rate, included in Table 3.1-2, Item 5.1.2, is 100 gpm, or a maximum daily flow of 144,000 gpd.

The City of Oak Ridge manages an Industrial Pretreatment Program for Industrial Users (IUs) of their wastewater system. IUs are required to obtain and comply with industrial pretreatment discharge permits (Reference 3.6-4). Prior to construction, Tennessee Valley Authority (TVA) will coordinate with the City of Oak Ridge to determine whether or not the facility qualifies as an IU; if so, TVA will apply for an industrial pretreatment discharge permit.

3.6.3 Other Effluents

This subsection addresses gaseous, liquid, and solid effluents that are non-radioactive.

3.6.3.1 Gaseous Effluents

Operation of two or more SMRs emits gaseous and particulate emissions to the air. The cooling tower is expected to be the primary source of particulate emissions. The primary sources of emissions from auxiliary systems are expected to be auxiliary boilers, standby diesel generators, and emergency standby gas turbine generators. These effluents commonly include particulates, sulfur oxides, carbon monoxide, hydrocarbons, and nitrogen oxides. The auxiliary boilers are to be 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 to be used intermittently and for brief durations.

As stated in Table 3.1-2, Item 13.1, the design auxiliary boiler exhausts at grade, and its estimated emissions are provided in Table 3.6-2. The standby diesel generators' exhaust is at a design elevation of 25 feet (ft) above grade (Table 3.1-2, Item 14.1.2), and their estimated emissions are provided in Table 3.6-3. The design gas turbine exhaust elevation is 50 ft above grade (Table 3.1-2, Item 14.2.2), and its estimated emissions are provided in Table 3.6-4.

TVA will consult with TDEC on air permit requirements following technology selection.

3.6.3.2 Liquid Effluents

Non-radioactive liquid effluents are designed to be discharged to the Clinch River arm of Watts Bar Reservoir. Nonradioactive discharges to surface water from the facility during construction include water pumped from excavations and stormwater. Nonradioactive wastewater discharges to surface water from the facility during operations 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.

Effluent from cooling water system is designed to be discharged via mechanical draft cooling tower.

The preliminary 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 sanitary wastes and some stormwater discharges. The proposed holding pond discharges to Watts Bar Reservoir through one or more diffusers located at CRM 15.5.

The facility's wastewater discharges will be regulated by TDEC through the NPDES permit. The NPDES permit will include discharge limits established to protect receiving waters, and monitoring to ensure compliance with those limits. Temperatures and chemical concentrations for all discharges will be in compliance with the terms and conditions of the NPDES permit.

The CRN Site currently has a stormwater management system consisting of stormwater runoff/collection ponds and piping. This system is to be modified, as needed, to support the CR SMR Project. Stormwater will be managed in accordance with a site-specific Stormwater Pollution Prevention Plan (SWPPP), which will be developed to prevent or minimize the discharge of pollutants with stormwater, and best management practices (BMPs) initiated through the SWPPP will be employed to control stormwater runoff. BMPs are to be implemented in accordance with existing TVA BMPs and the Construction Stormwater Permit, and may include one or more of the methods described in the State of Tennessee Erosion and Sediment Control Handbook (Reference 3.6-5).

The stormwater management system may include use of existing ponds and/or construction of one or more new ponds, depending on the facility configuration and the technology chosen. Stormwater management may include settling of solids, but would not involve any additional treatment, oil/water separators, or settling tanks. As part of the application for a NPDES permit, TVA will submit a Notice of Intent for Construction Activity Stormwater Discharges and an associated SWPPP to TDEC. The NPDES permit would be obtained before any construction activities take place.

Water pumped from excavations during construction are also to be managed through the stormwater management system. Flow from de-watering would be routed to either an existing stormwater retention pond or to a new pond installed as part of the initial phase of construction. The water would be managed using the same BMPs and under the same SWPPP as stormwater (Reference 3.6-5).

3.6.3.3 Solid Effluents

Operation of the proposed facility results in the generation of hazardous and nonhazardous nonradioactive solid waste. Non-radioactive solid wastes include typical industrial wastes such as metal, wood, and paper, as well as process wastes including hazardous and universal wastes. TVA maintains multiple procedures related to the management of non-radioactive solid waste.

The facility is expected to generate used oil from equipment maintenance. TVA maintains procedures for management of used oil at their facilities, and these TVA procedures are to be followed for used oil wastes generated at the CR SMR Project. Used oil wastes are to be disposed using a TVA-approved vendor.

The facility is also expected to generate paint wastes, solvent wastes, and laboratory wastes, and is expected to be a Small Quantity Generator of Hazardous Wastes. These wastes are to be disposed using a TVA-approved vendor. TVA maintains procedures for management of hazardous waste at their facilities, and these TVA procedures are to be followed for hazardous wastes generated at the CR SMR Project.

Typical nonhazardous solid waste generated include municipal solid waste, debris collected on trash screens at the water intake structure, and construction and demolition waste. Solid waste is to be managed by a TVA-approved solid waste disposal vendor and disposed in a state-approved sanitary landfill. Debris collected on trash screens at the water intake structure would likely be designated as special wastes, and managed and disposed in accordance with TVA procedures.

Universal wastes (i.e., lamps, batteries, and pesticides) would also be generated and are to be managed using TVA-approved vendors. Universal wastes, including batteries, lamps, and pesticides, are to be managed in accordance with TVA procedures.

TVA will comply with applicable federal, state, and local requirements and standards for handling, transporting, and disposing of solid waste. These include the 1976 Resource Conservation and Recovery Act, which amended the 1965 Solid Waste Disposal Act.

3.6.4 References

Reference 3.6-1. City of Oak Ridge, City of Oak Ridge Wastewater Treatment System Webpage, Website: http://www.oakridgetn.gov/department/PublicWorks/Divisions/Wastewater-Treatment, 2015.

Reference 3.6-2. Tennessee Department of Environment and Conservation, Oak Ridge Main Sewage Treatment Plant NPDES Permit TN0024155, Website: http://environment-online.state.tn.us:8080/pls/enf_reports/, 2015.

Reference 3.6-3. Tennessee Department of Environment and Conservation, Rarity Ridge WWTP NPDES Permit TN0078051, Website: http://environment-online.state.tn.us:8080/pls/enf_reports/, 2015.

Reference 3.6-4. City of Oak Ridge, Tennessee, "City of Oak Ridge, Tennessee, Management-Operations-Maintenance Programs (MOM)," January 23, 2012.

Reference 3.6-5. Tennessee Department of Environment and Conservation, "Tennessee Erosion & Sediment Control Handbook - Fourth Edition," August, 2012.

Table 3.6-1
Projected Blowdown Constituents and Concentrations

Constituent	Maximum Potential Concentration (ppm)[1]
Chlorine demand	1000
Free available chlorine	0.5
Chromium	--
Copper	6
Iron	3.5
Zinc	0.6
Phosphate	7.2
Sulfate	3500
Oil and grease	< 10
Total dissolved solids	17000
Total suspended solids	150
Biological Oxygen Demand (BOD), 5-day	< 5
Calcium	260
Magnesium	85
Sodium	990
Manganese	0.1
Alkalinity as $CaCO_3$	150
Nitrate (NO_3)	52
Silicon Dioxide (SiO_2)	150
pH Range	7.5-8.5

1 Assumed 4 cycles of concentration.

Table 3.6-2
Projected Maximum Annual Emissions from Auxiliary Boilers

Pollutant	Bounding Value (lbs/yr)
Particulates	7700
Sulfur oxides	41,575
Carbon monoxide	5930
Hydrocarbons	465
Nitrogen oxides	33,875

Notes:
The emissions are based on inputs as follows:
1. Auxiliary boiler operation during each startup: 36 days/year, 864 hr/yr.
2. Auxiliary boiler size: 75,000 lb/hr at 150 psig, saturation temperature (89.1 MMBtu/hr).
3. Quantity one auxiliary boiler operating at 100% load.
4. Auxiliary boiler without "low NO_x" burners.

Table 3.6-3
Projected Maximum Annual Emissions from Standby Diesel Generators

Pollutant Discharged	Emissions (lbs/yr)
Particulates	281
Sulfur Oxides	Not Available
Carbon Monoxide	3124
Hydrocarbons	740
Nitrogen oxides	38,983

Notes:
The emissions are based on inputs as follows:
1. Fuel used is No. 2 diesel oil with 35° API and LHV of 18,390 Btu/lb.
2. Standby diesel generators operating at 100% load.

Table 3.6-4
Projected Standby Power System Gas Turbines Flue Gas Effluents

Effluent	Consumption Rate/Unit	
	ppmvd	(lbs)
NO_x (ppmvd @ 15% 02)	20-220	2280
NO_x as NO_2	2-20	22
CO	5-330	584
Underlying Hazardous Constituents (UHC)	unavailable	unavailable
Volatile Organic Compounds (VOC)	unavailable	15
SO_2	0-100	25
SO_3	0-4	not provided
Sulfur Mist	unavailable	unavailable
Particulates	unavailable	unavailable
Exhaust Analysis	% volume	
Argon	unavailable	
Nitrogen	66-72%	
Oxygen	12-18%	
Carbon Dioxide	1-5%	

Assumption: 4 hr/month operation for testing.

Notes:
Fuel: distillate 20°F ambient
9890 BTU/KWH (LHV)
10,480 BTU/KWH (HHV)
96,960 lb/hr