ATTACHMENT 1

[HDR] HDR, INC. 2020. CLEAN WATER ACT 316(b) COMPLIANCE SUBMITTAL. PREPARED FOR DUKE ENERGY CAROLINAS LLC. NOVEMBER 10, 2020 (AQ-2)

(1 DOCUMENT)

OCONEE NUCLEAR STATION

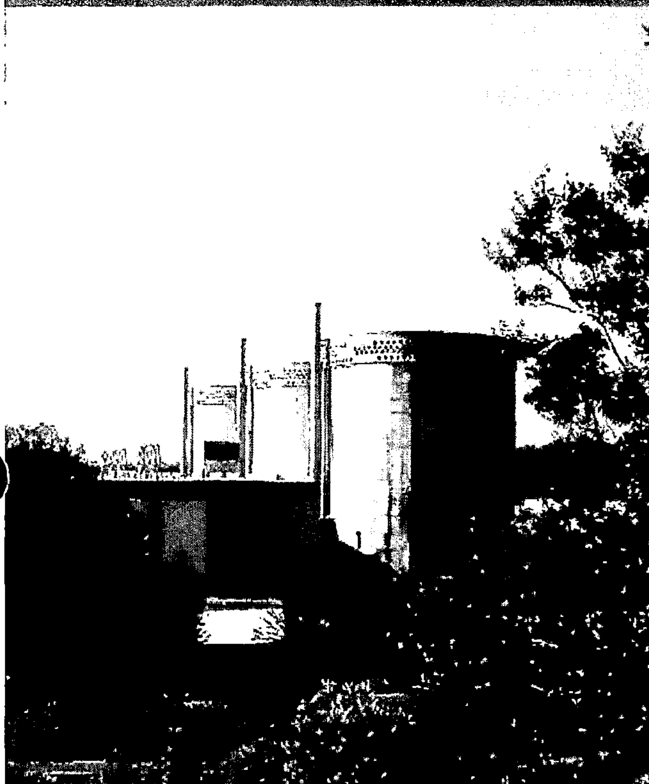
SUBSEQUENT LICENSE RENEWAL APPLICATION, APPENDIX E

ENVIRONMENTAL REPORT

DOCUMENT 1:

CLEAN WATER ACT 316(b) COMPLIANCE SUBMITTAL, PREPARED FOR DUKE ENERGY CAROLINAS, LLC, OCONEE NUCLEAR STATION OCONE COUNTY, SOUTH CAROLINA NPDES PERMIT No. SC0000515, PREPARED BY: HDR, NOVEMBER 10, 2020 (1198 PAGES)

HDR



Clean Water Act §316(b) Compliance Submittal

Prepared for:
Duke Energy Carolinas, LLC

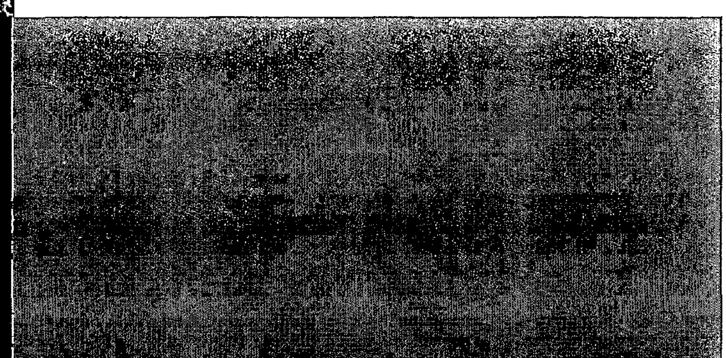
Prepared by:
HDR

November 10, 2020

OCONEE NUCLEAR STATION

Oconee County, South Carolina

NPDES Permit No. SC0000515



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Acknowledgements and Document Review

This report was prepared with substantial assistance from several external resources. Normandeau Associates, Inc., conducted the 2-year Entrainment Characterization Field Study, including all laboratory analyses, while Veritas Economic Consulting, LTD performed the Social Costs and Social Benefits evaluations. Both of these firms also supported the development and review of this document.

Report Verification

Oconee Nuclear Station
Clean Water Act §316(b) Compliance Submittal

This document has been reviewed for accuracy and quality commensurate with the intended application and has undergone technical/peer review prior to submittal.

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Acronyms and Abbreviations

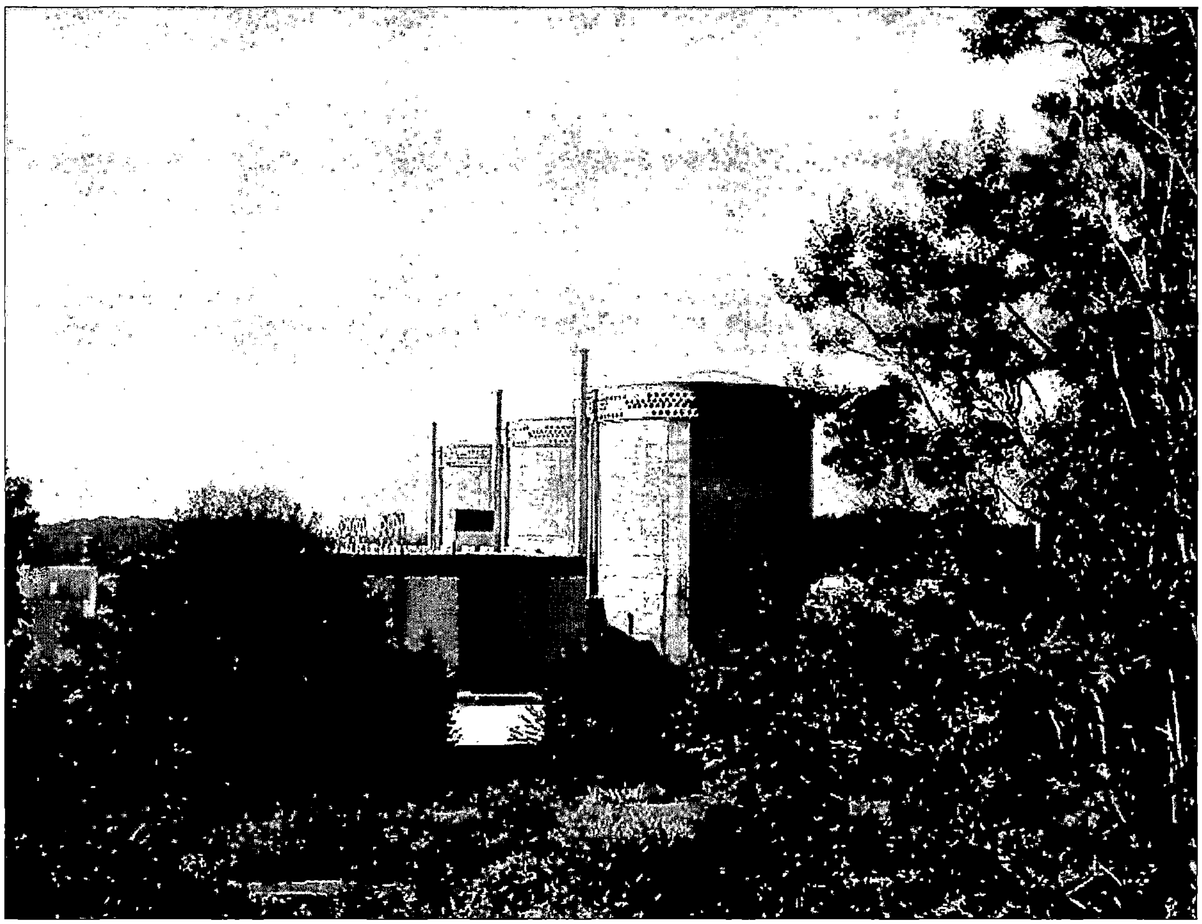
°C	degrees Celsius
°F	degrees Fahrenheit
ΔT	temperature differential (delta T)
AACE	Association for the Advancement of Cost Engineering
ACC	air-cooled condenser
AIF	actual intake flow
AOI	area of influence
ASA	ASA Analysis & Communication, Inc.
B	billion
BPJ	Best Professional Judgment
BTA	best technology available
BTU	British thermal units
CCRS	closed-cycle recirculating system
CCW	condenser cooling water
CFR	Code of Federal Regulations
COC	cycles of concentration
CO_2	carbon dioxide
cfs	cubic feet per second
CUR	capacity utilization rate
CWA	Clean Water Act
CWIS	cooling water intake structure
dB	decibels
DIF	design intake flow
Director	National Pollutant Discharge Elimination System permit Director
DO	dissolved oxygen
Duke Energy	Duke Energy Carolinas, LLC
El.	elevation
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
FMS	fine-mesh screen
fps	feet per second
FR	Federal Register
ft	feet/foot
ft msl	feet above mean sea level
gpm	gallons per minute
hp	horsepower
IPAC	Information for Planning and Consultation
IM	impingement mortality
IM Option	IM BTA compliance option
kg	kilograms
lb	pound(s)
lbm	pound mass
Lower Lake Keowee	Lower portion of Lake Keowee impounded by Little River Dam
m	meter
m^3	cubic meter

mm	millimeter
µm	micron
M	million
MDCT	mechanical draft cooling tower
MGD	million gallons per day
MGY	million gallons per year
mg/L	milligrams per liter
MPH	miles per hour
MW	megawatt
MWhr	megawatt-hour
NDCT	natural draft cooling tower
NO_X	nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
Oconee	Oconee Nuclear Station
ONAC	Office of Noise Abatement and Control
PM	particulate matter
PROSYM	Duke Energy Power System Simulation Model
PSI	pounds per square inch
PSW	protected service water
QA	quality assurance
QC	quality control
RTE	Rare, Threatened, or Endangered
Rule	CWA Section 316(b) rule for existing facilities
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCWMRD	South Carolina Wildlife and Marine Resources Department
SO_2	sulfur dioxide
SPX	SPX Cooling Technologies, Inc.
Study	Entrainment Characterization Study
TDS	total dissolved solids
TS	total solids
TSS	total suspended solids
TSV	through-screen velocity
Upper Lake Keowee	Upper portion of Lake Keowee
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USNRC	U.S. Nuclear Regulatory Commission
Veritas	Veritas Economic Consulting, LTD
WOTUS	waters of the U.S.
WMO	World Meteorological Organization
YOY	young-of-year

Clean Water Act §316(b) Evaluation to Support 40 CFR §122.21(r)

Oconee Nuclear Station

Executive Summary



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Introduction

In accordance with Section 316(b) of the Clean Water Act, Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities (79 Federal Register [FR], 48299), and 40 Code of Federal Regulations (CFR) §122 and §125, Duke Energy Carolinas, LLC (Duke Energy) submits the enclosed Clean Water Act (CWA) §316(b) rule for existing facilities (Rule) study reports and supporting information for the Oconee Nuclear Station (Oconee). This Executive Summary provides an overview of the §122.21(r)(2) through (r)(13) study reports included in Sections 2 through 13 of the main **Compliance Submittal Document.**

Duke Energy requests that determinations for impingement and entrainment best technology available (BTA) be provided for the Oconee cooling water intake structure (CWIS) located at the end of a 5,860-foot (ft)-long intake canal.

Under the current operating license authorized by the U.S. Nuclear Regulatory Commission (USNRC), Oconee will retire Units 1 and 2 in 2033 and Unit 3 in 2034; however, for the purpose of the analyses, Oconee generating units were conservatively assumed to operate through 2034. As such, 2034 was also used for the purpose of estimating the potential social costs and social benefits of candidate compliance technologies at Oconee, as detailed in Sections 10 through 12 of the Compliance Submittal Document and summarized in the following sections of the Executive Summary. A potential second license renewal, if granted by the USNRC, will extend the station's life by another 20 years; however, based on currently available information and because Duke Energy has not filed a license renewal application as of the date of this report, Oconee generating units were assumed to operate through retirement dates identified in the current USNRC operating license, as presented above, for the purposes of this evaluation. It is important to note, however, that a retirement date of 2054 would not significantly change the analysis or conclusions relative to a retirement date of 2034.

Based on the current design and operation of the CWIS and considering the anticipated end of useful life of the operating units at Oconee, Duke Energy requests concurrence that Oconee is compliant for impingement mortality (IM) reduction under IM Option 1 as a closed-cycle recirculating system (CCRS) based on the supporting information listed below:

IM Option 1 (CCRS)

- Lake Keowee and Oconee function as a CCRS as defined at 40 CFR 125.92(c)(2). In brief, Lake Keowee was constructed prior to October 14, 2014 and the impoundment was created for the purpose of serving as part of Oconee's cooling water system.
- The preamble to the Rule discusses impounded waters of the United States (WOTUS) as a CCRS[1] which is consistent with the construction and operation of Lake Keowee. Specifically, Lake Keowee serves as both a source of cooling water and heat sink for Oconee whereby the facility withdraws water from one part of the impoundment and discharges the heated effluent back to the

[1] 79 FR 48333 48334. VI. Basis of the Final Regulation. C. Technologies Considered To Minimize Impingement and Entrainment. f. Closed-Cycle Cooling Systems. iv. Impoundments

impoundment in another location to allow the heated water time to cool before reuse.

- Water withdrawal reduction at Oconee is also achieved by operating Lake Keowee as a CCRS. Runoff from the watershed (including upstream flow releases from the Jocassee Development) and direct precipitation to the reservoir replace water lost through evaporation, seepage, and downstream flow, helping to maintain water levels in the reservoir; therefore, no make-up water source (from a separate WOTUS) is required to maintain water levels in Lake Keowee. Use of WOTUS as a CCRS under the Rule suggests that (1) absence of a make-up source pumped from a separate WOTUS to the CCRS and (2) reliance on runoff and rainfall are indicative of the maximum potential flow reduction scenario relative to a potential separate source of make-up water.

Based on the following information, Oconee is also in compliance with the following standards:

IM Option 6 (system of technologies)

- A curtain wall structure is located at the entrance to the intake canal, facilitating water withdrawal from the lower 23 ft of the 90-ft Lake Keowee water column, where dissolved oxygen is naturally lower, creating less favorable conditions for fish. This effectively reduces the number of organisms in the intake canal that would be susceptible to impingement.
- A submerged weir near the entrance of the intake canal and overhanging wall at the entrance to the CWIS also help minimize the withdrawal zone and potential impingement impacts.
- The actual intake flows (AIF) withdrawn at the CWIS, as documented over the 5-year period from July 1, 2014 through June 30, 2019, results in a 14.2 percent annual flow reduction and a 34 percent maximum seasonal flow reduction when compared to the design intake flow (DIF) for the station.

De minimis rate of impingement

- Based on a 2006-2007 impingement study conducted at Oconee, approximately 95 percent of the total estimated number of fish impinged were fragile species (i.e., Threadfin Shad and Blueback Herring). Excluding fragile species from the analysis reduces the annualized IM estimates to approximately 5.6 and 5.7 fish per day (based on actual water withdrawals in 2016 and 2017).
- The Rule acknowledges that facilities like Oconee, where IM is dominated by fragile species, would be at a disadvantage when trying to design and demonstrate optimization of IM reduction technologies. As such, the existing technologies and operations at Oconee support a *de minimis* rate of impingement determination.

Further, no IM reduction technology alternative is justified based on the following:

- While the existing design through screen velocity (TSV) at the CWIS is slightly greater than 0.5 feet per second (fps), the 0.5 fps velocity contour (Appendix 6-A,

Figure 6-1), does not extend beyond on the face of the CWIS, thus providing IM reduction benefits.

- Operations at Oconee (detailed in Section 5) and the diversity and abundance of the fish community in Lake Keowee (detailed in Section 4.2) have remained consistent since the 2006-2007 impingement study, thus these data are valid and representative of current conditions.
- The estimated potential Post-IM BTA reduction was estimated under IM Option 5 (modified-Ristroph traveling screens with an aquatic organism return system) using 2006-2007 impingement data and actual water withdrawals in 2016 and 2017. The annual impingement losses estimated based on 2016 and 2017 withdrawals would equate to between 139 (29 pounds [lbs]) and 143 (29 lbs) equivalent adults and between 3,427 and 3,463 lbs of forage biomass. The reduced impact to the recreational fishery that could potentially occur is estimated to be between 13 and 14 lbs of harvestable biomass, which was driven entirely by Blueback Herring and Threadfin Shad (Section 11.5.1.3). The estimated capital cost of IM Option 5 is $105.61 million (M) and the associated net social benefit is -$461.
- The social costs of designating Lake Keowee as a CCRS are the forgone incremental impingement benefits ($461) of the next least-cost impingement compliance alternative which would be IM Option 5 (modified traveling water screens with an organism return system), resulting in a net benefit of -$461.

Duke Energy also requests a determination that the existing plant configuration and operation is BTA for reducing entrainment at Oconee based on the following:

- A 2-year Entrainment Characterization Study (Study) was performed at Oconee during 2016 and 2017. The Study documented interannual variability in estimated annual entrainment losses, with significantly lower annual estimated losses in comparison to entrainment losses documented in other southeastern U.S. reservoirs. The estimated losses were between 36.1 and 37.5 million ichthyoplankton in 2016 and 2017, respectively, based on actual cooling water withdrawal volumes during the Study. These losses are substantially less (~90% during the peak entrainment period) than would be expected due to the curtain wall at the intake canal entrance. Therefore, the level of entrainment reduction achieved by the existing curtain wall is commensurate with the reduction that could be achieved with installation of cooling towers.

- Greater than 98 percent of ichthyoplankton entrained in 2016 and 2017 were fragile forage species of the Clupeidae family, primarily eggs of the introduced Blueback Herring. Species in this family identified in Lake Keowee include the prolific, broadcast spawning Blueback Herring and Threadfin Shad. Given their high fecundity (i.e., 350,000 eggs for Blueback Herring and 22,000 eggs for Threadfin Shad) and high natural mortality, the estimated level of annual entrainment documented for Oconee is not anticipated to have an impact on population viability for these forage species.

- Recent monitoring studies of Lake Keowee near Oconee continue to document abundant populations of forage species, including Blueback Herring.

- Fish community surveys continue to document a balanced and indigenous fish community.
- No federal or state threatened or endangered fish or shellfish species are known to occur in Lake Keowee near Oconee, none were collected in the historical impingement and entrainment study, and none were collected during the 2016-2017 entrainment study or the 2017 Curtain Wall Entrainment Reduction Performance Study Report (curtain wall study).
- No freshwater mussels were collected in the historical impingement and entrainment study, and none were collected during the 2016-2017 entrainment study or the 2017 Curtain Wall Entrainment Reduction Performance Study Report. Further, entrainable-sized fish are not considered viable glochidia hosts; therefore, entrainment at the Oconee CWIS is unlikely to have an adverse effect on populations of any mussel species that may occur in Lake Keowee near Oconee.
- As required by the Rule, three potential entrainment reduction technologies were evaluated:
  - Retrofit to closed-cycle cooling through installation of mechanical draft cooling towers (MDCTs);
  - Installation and operation of fine-mesh screens (FMS) with an aquatic organism return system, and
  - Use of alternate water sources (determined to be not feasible).
- Using the anticipated unit retirement date, a comparison of social costs to social benefits (Section 11) associated with each of the entrainment technologies indicated that:
  - Installation of MDCTs would result in social benefits of $1,082 compared to social costs of $1.24 billion (B); resulting in total net benefits of -$1.24 B; and
  - Constructing a new CWIS with FMSs and aquatic organism return system would result in social benefits of $516 compared to social costs of $105.61 M; resulting in total net benefits of -$105.61 M.
  - The currently installed technologies (including the curtain wall and submerged weir) result in total net benefits between -$279 and -$362.
- Based on the evaluation of social costs and benefits of each technology, the existing or baseline configuration at Oconee represents BTA for meeting the site-specific entrainment requirements. The cost to install any new technology would be wholly disproportionate to the benefits. For the MDCT retrofit scenario, the cost benefit ratio is approximately 1,146,303:1. Constructing a new CWIS with FMSs and aquatic organism return system would result in a cost benefit ratio of approximately 204,671:1. Per 40 CFR 125.98(f)(4), an available technology may be rejected as BTA "if the social costs are not justified by the social benefits".

Station Description

Oconee is a three-unit, nuclear-fueled electric generating station located in Oconee County, South Carolina, and is owned and operated by Duke Energy. Commercial operation of Unit 1 began in

February 1973, Unit 2 began in October 1973, and Unit 3 began operations in July 1974 (USNRC 2018a; 2018b; 2018c). Oconee's cooling water intake system consists of a curtain wall at the entrance of the intake canal, a submerged weir near the entrance of the intake canal, a trash boom, and a CWIS with an overhanging wall (CWIS overhang) at its entrance, which is located at the end of a 5,860-ft-long intake canal situated on Lower Lake Keowee. The CWIS includes bar racks, trash deflector plates, fixed panel mesh screens, and vertical wet-pit circulating water pumps (commonly referred to as condenser cooling water [CCW] pumps). The Oconee CWIS includes 12 circulating CCW pumps (four for each of the three units), each pump has a designed capacity of 246,000 gallons per minute (gpm) (354.2 [million gallons per day] MGD), for a total cooling system pumping capacity of 2,952,000 gpm (4,251 MGD). Approximately 96 percent (2,929 MGD) of the total DIF (3,059 MGD) is used for non-contact cooling water and the remaining 4 percent (130 MGD) is used for service water purposes (Oconee has three service water pumps with a combined pumping capacity of 130 MGD [43.2 MGD each]).

The station's discharge to Lake Keowee is approved by the South Carolina Department of Health and Environmental Control (SCDHEC) through issuance of NPDES Permit No. SC0000515. The Oconee National Pollutant Discharge Elimination System (NPDES) permit application package was timely submitted on March 28, 2013.

Regulatory Nexus

On August 15, 2014, the U.S. Environmental Protection Agency (USEPA) published in the Federal Register the NPDES – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, referred to as the Final Rule (Rule) (USEPA 2014). The Rule establishes requirements under §316(b) of the CWA to ensure that the location, design, construction, and capacity of a CWIS reflect the BTA for minimizing impingement and entrainment at the CWIS. The Rule applies to existing facilities that withdraw more than 2 MGD from WOTUS, use at least 25 percent of that water exclusively for cooling purposes, and have an NPDES permit.

The Rule is applicable to Oconee for the following reasons:

- Oconee withdraws raw water from Lake Keowee, the source waterbody, through a shoreline-situated CWIS located at the end of a 5,860-ft-long intake canal for use in a once-through cooling water system.

- Oconee meets the minimum 2 MGD withdrawal rate criteria for AIF and DIF. The total DIF at Oconee is 4,251 MGD (354.2 MGD for CCW pumps plus 43.2 MGD for service water pumps). However, there is a condenser piping restriction in the 8-ft-diameter header pipes on the downstream side of the CCW pumps that limits the capacity of each unit to 708,000 gpm (1,019.5 MGD), for a total DIF of 2,124,000 gpm (3,059 MGD). Based on data from July 1, 2014 through June 30, 2019, average annual AIF was 2,625 MGD at the Oconee CWIS, or approximately 86 percent of the facility's DIF.

- Oconee uses greater than 25 percent of the water withdrawn from Lake Keowee, under DIF flows, exclusively for cooling water purposes (approximately 96 percent, or 2,929 MGD).

Because Oconee is subject to the Rule, Duke Energy has prepared technical information required under CFR §122.21(r)(2) through (r)(13) (see Table 1-1 of Section 1) for submittal to the SCDHEC Director to facilitate the determination of BTA for Oconee.

Under the Rule, the owner or operator of a facility must choose from one of seven compliance options for IM reduction or an alternate exemption, as provided by the Rule. The facility must also provide results from site-specific entrainment studies and information identified at §122.21(r)(2) through (r)(13) and §125.98 to the permitting authority to aid in the determination of whether site-specific controls would be required to reduce entrainment.

At §125.98, the Rule identifies specific information that the Director Must (§125.98(f)(2)) consider and information that the Director May (§125.98(f)(3)) consider in a site-specific entrainment BTA determination. This Executive Summary describes the evaluation of these compliance options and the Must and May factors for the Director to consider, as they relate to Oconee.

Impingement Mortality Compliance

Per §122.21(r)(6), the owner of a facility must identify the chosen method of compliance with the IM standard for the entire facility, or for each CWIS. Facilities may select one of seven IM BTA compliance options (IM Options) provided in §125.94(c) paragraphs (1) through (7) unless pursuing compliance under paragraphs (c)(11) *de minimis* rate of impingement or (c)(12) low capacity utilization power generating units (Table ES-1). The facility must also provide sufficient information and justification to support the selected alternative compliance approach. Methods used to assess the compliance options for addressing the requirements of §122.21(r)(6) are provided in Section 6.

Table ES-1. Impingement Mortality Compliance Options

IM Compliance Options	Select Requirements under §122.21(r)(6)
Option 1[1]	A closed-cycle recirculating system
Option 2[1]	A CWIS with a maximum design through-screen velocity of 0.5 feet per second (fps)
Option 3	A CWIS with a maximum actual through-screen velocity of 0.5 fps
Option 4[1]	An existing[2] offshore velocity cap located a minimum of 800 feet offshore with bar screens or some other marine mammal, sea turtle, and large aquatic organism exclusion device
Option 5	A modified traveling screen system (i.e., modified-Ristroph screens with a fish handling and return system, dual flow screens with smooth mesh with fish handling systems, or rotary screens with fish returns or vacuum returns)
Option 6	Any combination or system of technologies, management practices, and operational measures that the Director determines is BTA for the facility.
Option 7	Perform a 12-month impingement mortality study consisting of at least monthly monitoring and an assessment of latent mortality (measured 18 to 96 hours). For compliance under this option, results must demonstrate no more than 24 percent impingement mortality, inclusive of latent mortality, for each CWIS or total facility.
De Minimis Rate of Impingement	Option available for facilities that can demonstrate, to the Director's satisfaction, impingement rates low enough to justify that additional impingement controls are not warranted.

IM Compliance Options	Select Requirements under §122.21(r)(6)
Low Capacity Utilization Rate (CUR)	Option available for facilities or individual unit and CWIS systems that operate with low frequency and can demonstrate less than 8 percent capacity utilization, averaged over a 24-month period

[1]Represents technologies that are pre-approved and that do not require facilities to perform biological studies or biological compliance monitoring associated with the IM standard.
[2]Per the Rule at §125.94(c), the existing offshore velocity cap must have been installed on or before October 14, 2014.

The location of the CWIS (at the end of the intake canal and downstream of the curtain wall and submerged weir) provides IM reduction benefits, and since the 0.5 fps velocity contour does not extend beyond the face of the CWIS, the impingement area of influence (AOI) is within the intake structure. Additionally, the AIF withdrawn at the CWIS (from July 1, 2014 through June 30, 2019), represents a 14.2 percent annual flow reduction and a 34 percent maximum seasonal flow reduction from DIF for the station; providing further IM reduction benefits. Given the existing level of IM reduction benefits, and results of the social cost and social benefit evaluation, installation of additional IM reduction technologies at Oconee is not practical or warranted.

Duke Energy performed a screening-level evaluation of IM reduction technologies and alternative operational measures for the CWIS to identify feasible options that could be implemented to reduce impingement at Oconee. Alternatives that were not considered feasible were removed from further consideration. The remaining (i.e., short-listed) options were evaluated in greater detail and the findings, which are presented in Section 10, identify the technology or technologies that could result in the greatest benefit while minimizing implementation, maintenance, and operational costs.

The compliance options were evaluated using the following step-wise process:

1. Determine if Oconee is currently compliant with BTA for impingement under IM Options 1, 2, or 3, based on existing design and operational data.
2. Evaluate existing impingement data to determine if impingement rates support a *de minimis* rate of impingement determination by the Director.
3. Determine if the three-year average (based on most recent data) capacity utilization rate (CUR) is below the Rule-defined threshold of 8 percent.
4. Assess the potential efficacy, technical feasibility, and relative costs of IM reduction technologies and operational measures applicable to open-cycle cooling systems (IM Options 4, 5, and 6).
5. Evaluate the potential efficacy, technical feasibility, and relative costs of ceasing operations.

Results of the screening-level evaluation of IM reduction technologies and operational measures that could be implemented at Oconee to comply with the IM reduction requirements of the Rule are summarized in Table ES-2 and discussed below.

Oconee complies with IM Option 1 as Lake Keowee and the Oconee CWIS function as a closed-cycle recirculating cooling system. Oconee withdraws more than 125 MGD of raw water and the existing design and operation of the CWIS results in through-screen velocity (TSV) estimates of greater than 0.5 fps; therefore, it does not comply with BTA IM Options 2 or 3 (however, it is noted that the AOI as defined by the 0.5 fps velocity contour is contained entirely within the CWIS). Additionally, based on existing conditions, Oconee does not currently comply with IM Option 4 (typically applies to facilities in coastal environments or the Great Lakes), IM Option 5 (currently has fixed screens and no fish return system), or Option 7 (not applicable as the most recent impingement study performed did not include an assessment of latent mortality). Further, Oconee does not meet the low capacity utilization rate (CUR) compliance option, as the current 24-month capacity utilization is greater than 8 percent.

Table ES-2. Summary of Feasibility of Impingement Mortality Compliance Options

IM Compliance Options	Select Requirements under §122.21(r)(6)	Feasibility for Oconee	Basis
Option 1[1]	Closed-cycle recirculating system (CCRS)	Yes	The Oconee CWIS and Lake Keowee function as a CCRS system as defined at 40 CFR 125.92(c)(2).
Option 2[1]	CWIS with design TSV <0.5 fps	No	CWIS has design TSV >0.5 fps.
Option 3	CWIS with actual TSV <0.5 fps	No	CWIS has an actual TSV >0.5fps
Option 4[1]	Existing offshore velocity cap[2]	No	Not applicable or feasible at Oconee
Option 5	Modified fish-friendly traveling screen system	No	Feasible, not practical
Option 6	System of technologies	Yes	Applicable
Option 7	Comply with 12-month IM standard	No	No current study has been performed that included latent mortality
De Minimis Rate of Impingement	Impingement rates sufficiently low to justify no additional controls	Yes	Applicable
Low Capacity Utilization Rate (CUR)	Facility, unit, or CWIS operates with frequency less than 8 percent averaged over 24-month period	No	Typical operations exceed 8 percent CUR

[1]Represents technologies that are pre-approved and that do not require facilities to perform biological studies or biological compliance monitoring associated with the IM standard.
[2]Per the Rule at §125.94(c), the existing offshore velocity cap must have been installed on or before October 14, 2014.

Impingement Mortality Characterization

An IM characterization study was conducted at Oconee from September 2006 through August 2007 (ASA 2008). Impingement sampling occurred for a total of 26 sampling events. Since the Oconee intake structure is fitted with fixed screens, eight screens were randomly sampled during each sampling event. Prior to sampling, the selected screens were raised and cleaned, then replaced and allowed to accumulate impinged fish for 24 hours. After 24 hours, impinged fish were removed from the screens and processed.

Over the 12-month study period, a total of 1,162 fish consisting of 11 species were collected. The most abundant species impinged was Threadfin Shad (73.1 percent), followed by Blueback Herring (21.5 percent) and Bluegill (3.9 percent). These three species combined accounted for approximately 98 percent of the total number of impinged fish. The remaining species each represented less than 1.0 percent of the total number of the fish collected. No freshwater mussels or protected fish species were collected during the study (Table ES-3) (ASA 2008).

Table ES-3. Taxa List and Relative Abundance of Fish Collected during Impingement Study at Oconee Nuclear Station, September 2006 to August 2007 (ASA 2008)

Family	Scientific Name	Common Name	Total Number	Percent Composition
Clupeidae	*Dorosoma petenense*	Threadfin Shad	849	73.1
	Alosa aestivalis	Blueback Herring	250	21.5
Centrarchidae	*Lepomis macrochirus*	Bluegill	45	3.9
	Micropterus henshalli	Alabama Bass	4	0.3
	Lepomis auritus	Redbreast Sunfish	6	0.5
	Micropterus coosae	Redeye Bass	2	0.2
	Lepomis gulosus	Warmouth	1	0.1
Percidae	*Percina nigrofasciata*	Blackbanded Darter	2	0.2
Ictaluridae	*Ameiurus catus*	White Catfish	1	0.1
	Pylodictis olivaris	Flathead Catfish	1	0.1
Cyprinidae	*Notemigonus crysoleucas*	Golden Shiner	1	0.1
		Total	**1,162**	**100**

Summary of Selected Impingement Mortality Compliance Options

Based on the information presented above, estimated annual impingement at Oconee based on actual water withdrawals from 2016 and 2017 was 46,437 and 45,399 fish in 2016 and 2017, of which, approximately 95 percent were fragile species[2] (i.e., Threadfin Shad and Blueback Herring). Excluding fragile species from the analysis reduces the annualized IM estimates to 2,037 and 2,084 fish for 2016 and 2017, respectively, or around 5.6 and 5.7 non-fragile fish per day.

Analyses Performed in Support of an Entrainment BTA Determination

This section summarizes the analyses required by the Rule for submission to the Director in support of a site-specific best professional judgment (BPJ) review and entrainment BTA determination. Although information presented under the requirements of §122.21(r)(2) through (r)(8) of the Rule (i.e., Sections 2–8 of the compliance document) provides useful perspective on the location, design, and operation of the existing facility, this section focuses on reports prepared under §122.21(r)(9) through (r)(13) of the Rule (i.e., Sections 9–13), which offer perspective on entrainment BTA. The process and results for evaluating the social costs, social benefits, and other environmental impacts related to entrainment BTA, as prepared under §122.21(r)(9) through (r)(12), are outlined along with a description of and results from the peer review process in §122.21(r)(13).

[2] Blueback Herring is identified in the Rule as a fragile species. Although not listed in the Rule, Threadfin Shad are in the same family (Clupeidae) and exhibit similar life history characteristics and low impingement survival rates.

Entrainment Characterization Study – §122.21(r)(9)

A 2-year Entrainment Characterization Study was performed at Oconee from March 1 through October 31 in 2016 and 2017 (total of 16 sampling events per year). The Study plan was peer reviewed and approved by the SCDHEC. Comments were incorporated into the Study plan prior to performing the field study. Section 9 of this document summarizes the Study. The Study plan, and the Study report are provided in Appendix 9-A.

Twice-monthly ichthyoplankton sampling was performed upstream of the trash deflector plates and bar racks at the entrance to the CWIS using a pumped sampling technique. The study design (frequency and duration of sampling) allowed for collection of a representative sample of entrainable-sized organisms (i.e., ichthyoplankton) present in Lake Keowee based on life history data of species likely to be entrained at Oconee. A flexible hose attached to the sample pipe suspended in front of the CWIS was used to direct flow into a 330-micron (μm) plankton net suspended inside of a 100-gallon collection tank. The target volume of 100 cubic meters (m^3) was measured by an in-line flowmeter.

Mean daily densities for days between each of the twice-monthly sampling events were determined through linear interpolation. The daily densities were then used to calculate the mean rate of entrainment by month, which was multiplied by the total actual monthly cooling water volume withdrawn at Oconee to estimate total annual entrainment losses at the CWIS for 2016 and 2017 see Section 9). These data were also used to develop annual entrainment loss estimates under hypothetical maximum (design) water withdrawals at Oconee.

When considering results of the 2-year Entrainment Study, it should be noted that results of the curtain wall study performed in 2017 indicate that the curtain wall at the mouth of the intake canal reduced entrainment by approximately 76 percent over the 8-month study period and approximately 90 percent during the period of peak ichthyoplankton abundance, which is slightly less than what is expected with installation of wet cooling towers (i.e., 95 percent; 79 FR 158, 48303). The low numbers and diversity of ichthyoplankton collected during the 2016- 2017 Study are comparable to the results of the 2017 curtain wall study, indicating that the curtain wall is effective at reducing ichthyoplankton densities on the intake side of the wall and that the reduction extends to the Oconee CWIS. Section 7 of this document summarizes the results of the Oconee curtain wall study conducted in 2017 (HDR 2018a).

Annual entrainment at Oconee in 2016 included three distinct taxa from two families of fish and consisted primarily of eggs (92.7 percent), yolk-sac larvae (2.4 percent), post yolk-sac larvae (2.4 percent), and unidentified larval stages (2.4 percent). Annual entrainment at Oconee in 2017 included two distinct taxa from one family of fish and consisted of eggs (86.2 percent), post yolk-sac larvae (8.5 percent), and unidentified larval stages (5.3 percent).

Total annual entrainment losses at Oconee, based on the actual water withdrawn[3] over the 2-year period, were estimated at 36.1 million ichthyoplankton in 2016 and 37.5 million ichthyoplankton in 2017. Greater than 98 percent of ichthyoplankton entrained in 2016 and 2017 were forage species of

[3] Actual water withdrawals as referenced here and in Sections 9 and 11 are based on volumes withdrawn during the 2-year Study and are not the same as the AIF values as defined by the Rule at §125.95(a), which are defined as the average volume of water withdrawn on an annual basis by the CWIS over the most recent 5-year period.

the Clupeidae family with Blueback Herring eggs (78 to 92 percent) being the dominant species and life stage entrained during both years. Clupeids identified in Lake Keowee include Blueback Herring and Threadfin Shad (Duke Energy 2007 and 2013). Blueback Herring and Threadfin Shad are prolific, broadcast spawners: Blueback Herring may spawn up to 350,000 eggs (Pardue 1983) and Threadfin Shad up to 22,000 eggs (Hendrickson et al. 2015) per female. Given the high fecundity of these species, the estimated level of entrainment is not anticipated to have an impact on populations of these forage species. A single post yolk-sac sunfish (*Lepomis* spp.) larvae was the only recreational species collected throughout the entire Study.

The period of entrainment documented at Oconee was primarily during spring and summer months, from June through September in 2016 and from March through August in 2017. Peak ichthyoplankton densities occurred in June and July of both years, just after the typical spawning window in April and May; however entrainment rates were low throughout the Study period. Observed peak densities reflect the spawning period of Blueback Herring, the species with the highest rate of entrainment throughout the Study. Few ichthyoplankton were collected in March or September in both years, indicating that the sampling program successfully captured the start and end of the entrainment period.

Comprehensive Technical Feasibility and Cost Evaluation Study – §122.21(r)(10)

The Rule requires an evaluation of feasibility and costs for alternative entrainment control measures to support an entrainment BTA determination by the Director. This includes quantification of the potential social costs of alternative entrainment control measures be estimated and compared to potential social benefits. Due to the diversity in organism biology, habitat requirements, and different body sizes of entrainable organisms, the available technologies and measures expected to be reasonably effective at reducing entrainment are relatively limited. An evaluation of potential entrainment reduction technologies for Oconee was performed to identify those that are feasible and practicable to address requirements listed at §122.21(r)(10).

The process for developing this information for Oconee included:

- Evaluating potential siting locations to identify options posing minimal impact on station operations and the surrounding community;
- Assessing potential for overcoming operational problems (e.g., no negative impacts to intake velocities or flows, does not exceed pressure specifications of condensers);
- Evaluating potential for impacting operational reliability;
- Evaluating facility-level Operation and Maintenance (O&M) costs associated with each technology; and
- As required by the Rule, considering the feasibility and costs of three potential technologies that could reduce rates of entrainment at Oconee, which include:
    1. Retrofit to closed-cycle cooling;
    2. Installation and operation of FMS with an aquatic organism return system (includes fine-slot wedgewire screens and/or dual-flow screens) at the CWIS; and

3. Use of alternate water sources to replace all or some of the water used in the once-through cooling system.

Assessment of Compliance Technology Feasibility

An assessment of multiple entrainment reduction compliance technologies was performed to evaluate potential feasibility at Oconee, with analyses of conversion to MDCTs; natural draft cooling towers (NDCTs); plume-abated MDCTs; dry cooling systems; installation of 1.0-millimeter (mm) fine-slot wedgewire screens; installation of FMS under several different modification scenarios, and water reuse or alternative sources of water supply.

The evaluation determined that existing and alternative water sources are unavailable or unable to provide the amount of water needed to replace the volume of cooling water required by Oconee, and thus were excluded from further consideration. Results of the assessment indicated that all but two of the evaluated compliance technologies were infeasible and/or impractical at Oconee; therefore, they were excluded from further consideration. The two entrainment reduction technologies determined to be technically feasible for implementation at Oconee are 1) installation of MDCTs and 2) installation of 1.0-mm FMS at a newly constructed CWIS with an aquatic organism return system.[4] These two technologies were retained for further evaluation.

For the two potentially feasible technologies, a conceptual design, including location of infrastructure, costs associated with engineering, scheduling, permitting, construction, and O&M costs through the remaining life of the station[5] were developed. The net present value (NPV) of the social costs of each technology was then developed based on the estimated start of operations for each technology and estimated retirement date for the facility. It should be noted that the installation of MDCTs would be very challenging due to the limited available space which would result in likely relocation of transmission lines and constructing infrastructure underneath a major local highway. Thus, while MDCTs are feasible from an engineering perspective, they are essentially impractical as construction would be very complex. The complete process and results of the evaluations are provided in Section 10. A summary of the results are presented below.

Social Costs of Compliance Technologies

Social costs were used to determine whether the potential entrainment reduction technology costs would result in the plant becoming economically unfeasible to operate. Since a premature shutdown of Oconee would result in social costs (i.e., lost jobs, income, and tax base; increased generation costs as power plants lower in the dispatch order would be called upon to make up the lost generation; and increased pollutant air emissions of replacement generation, installing entrainment reducing technologies at Oconee to comply with the Rule represents additional operational costs that would most likely be passed onto Duke Energy's electric customers in the form of higher rates.

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[4] The existing CWIS would remain in place with no modification as it contains the CCW pumps. The new FMS structure and aquatic organism return system would be constructed in the intake canal just upstream of the existing CWIS. For a baseload facility such as Oconee, this alternative would have the least impact on outage period for construction, reduces uncertainties associated with retrofitting a CWIS structure with fixed screens, and has reduced nuclear safety impacts. Furthermore, retrofitting to FMS in the existing CWIS structure would result in high through-screen velocities (i.e., over 1.5 fps) that would likely result in structural failure of the screens.

[5] The remaining life of each generating unit and technology impacts O&M costs, potential future technology repair costs (if the life of the unit is longer than the anticipated life of the technology), and benefits. For the purpose of the analyses, Oconee generating units were conservatively assumed to operate through 2034.

Thus, the social costs were determined assuming that Duke Energy would incur these additional costs and pass them on to electric customers.

The social costs of installing entrainment reduction technologies are estimated by determining the design, construction, and installation costs of the evaluated technologies along with the O&M, power system, externality, and permitting costs. Social costs include costs associated with compliance with governmental regulations, power system effects, and externalities (decreases in social wellbeing resulting from property value impacts).

Following the requirements of the Rule, Table ES-4 evaluates social costs (in 2019 dollars) under two discount rates: 3 and 7 percent (79 FR 158, 48428). The analysis discounts the future stream of each of these social costs at the relevant discount rate and sums them over the years they are specified to occur to develop the total social cost estimate presented in the next to last column in in the table; annual social costs for each technology are presented in the last column.

Also shown in Table ES-4 are the compliance costs. Compliance costs are assumed to occur over a 9-year period for both the cooling tower retrofit scenario and new CWIS with FMS and aquatic organism return system scenario, as discussed in Section 10. Power system costs are due to construction-related outage impacts and efficiency and auxiliary load impacts during operation.

Table ES-4. Total Engineering and Social Costs of Feasible Technology Options at Oconee

Discount Rate	Technology	Compliance Costs[a]		Social Costs[b]					
		Total Capital Costs	Annual O&M Costs[c]	Electricity Price Increases From: Compliance Costs	Electricity Price Increases From: Power System Costs	Externality Costs	Government Regulatory Costs	Total Social Costs[d]	Annual Social Costs
3%	Closed-cycle Cooling Tower Retrofit	$1,109.32M	$15.0M	$901.54M	$326.73M	$11.85M	$0.186M	$1,240.30M	$137.81M
3%	1.0-mm FMS Installation in a New CWIS	$122.20M	$2.3M	$103.53M	$2.06M	N/A	$0.020M	$105.61M	$11.73M
7%	Closed-cycle Cooling Tower Retrofit	$1,109.3M	$15.0M	$600.23M	$227.44M	$8.68M	$0.148M	$836.49M	$92.4M
7%	1.0-mm FMS Installation in a New CWIS	$122.20M	$2.3M	$68.93M	$1.52M	N/A	$0.016M	$70.47M	$7.83M

[a]Compliance costs are presented undiscounted and in 2019 dollars. These costs were developed as part of the engineering studies for Oconee and are represented in millions (M) of dollars. Numbers may not sum due to rounding.
[b]Social costs associated with each technology are discounted at 3 and 7 percent using the specifications outlined in Table 10-24 of Section 10. These costs are represented in M of dollars. Source: Veritas 2020; Appendix 10-J.[c] O&M costs vary by year, annual O&M costs represent the average for each technology.
[d]For the Cooling Tower retrofit scenario, the relatively high power system costs offset the effect of the 3 percent discount rate such that the Total Social Costs are greater than values provided under Compliance Costs. For the FMS installation in a new CWIS scenario, the relatively low power systems costs do not offset the effect of the 3 percent discount rate, and as a result, the Total Social Cost is lower than the values provided under Compliance Costs. Under the 7 percent discount rate, the difference between Compliance Costs and Total Social Costs are slightly different due the effect of using a higher discount rate.

Benefits Valuation Study – §122.21(r)(11)

The goal of the Benefits Valuation Study is to demonstrate the estimated social benefits that would result from impingement and entrainment reductions based on implementation of one or more technologies at Oconee.

Incremental Change in in Losses from Entrainment and Impingement Mortality under Technology Scenarios

Impingement and entrainment losses under actual withdrawal volumes for each Reduced-Entrainment scenario (i.e., Post-IM BTA [for impingement], FMS, and MDCT) were converted to net benefits, defined as the potential reduction in entrainment or impingement from the baseline or With-Entrainment scenario. For comparison purposes, an additional scenario (Without-Entrainment) was added to represent the total benefit that would occur to the fishery with the complete elimination of entrainment at Oconee, and assumes a 100 percent elimination of baseline entrainment losses estimated under actual water withdrawal volumes recorded at Oconee over the 2-year entrainment characterization Study. This option assumes a shutdown and subsequent retirement of both units at Oconee, as described in Section 11 of the compliance document.

Reductions in entrainment and impingement were estimated with the following assumptions:

- Without Entrainment scenario (Baseline) – Losses based on existing design and operations under actual water withdrawal volumes from 2016 and 2017.
- MDCT scenario - Based on estimated reduction in percent water withdrawal anticipated under the preliminary design assumptions (Section 10),
- FMS scenario - Based on exclusion efficacy of 1.0-mm FMS (Section 10), on-screen survival (Appendix 11-A), and assumes a 100 percent effective organism return system.

The detailed methodology for developing species and life-stage specific estimates of the potential incremental reductions in entrainment or impingement among compliance technology scenarios is detailed in Section 11. The entrainment and impingement loss reductions estimated for each technology are provided in Appendix 11-A, and summarized below in Table ES-5 and Table ES-6.

Table ES-5. Summary of Estimated Incremental Reductions in Entrainment Losses by Technology Scenario for 2016 and 2017

Scenario	2016		2017	
	Total No. Lost[1]	Percent Reduction	Total No. Lost	Percent Reduction
Baseline[2]	36,102,094	--	37,534,245	--
FMS in new CWIS[3,4]	8,361,087	76.8	11,881,297	68.3
MDCT	938,654	97.4	975,890	97.4

[1] Total No. Lost were rounded to the nearest whole number.

[2] Baseline condition represents the current configuration of 3/8-inch coarse-mesh fixed panel water screens and no aquatic organism return system. This technology represents the losses that would be eliminated under the "Without-Entrainment" scenario.

[3] Total number lost and percent reduction for the FMS scenario includes convert mortalities.

[4] These values likely represent a conservative representation of technology benefits as this scenario is based on the assumption of 100 percent survival of the egg life stage. The on-screen survival values used to develop these estimates are provided in Appendix 11-B.

Table ES-6. Summary of Potential Incremental Reductions in Losses due to Impingement by Compliance Alternative Scenario for 2016 and 2017

Scenario	2016		2017	
	Total No. Lost[1]	Percent Reduction	Total No. Lost	Percent Reduction
Basline[2]	46,437	--	45,399	--
Post-IM BTA	42,714	8.0	41,709	8.1
MDCT	1,208	97.4	1,181	97.4

[1] Total No. Lost were rounded to the nearest whole number.

[2] Baseline condition is the current configuration of 3/8-inch coarse-mesh fixed panel water screens and no organism return system. This technology represents the losses that would be eliminated if Oconee's units were retired and impingement was eliminated.

Estimated Changes in Stock Size or Harvest Levels

The potential benefits to the fishery, due to changes in stock size or harvest levels, of the estimated entrainment reductions were estimated using commonly applied population and harvest models (EPRI 2004, 2012) that use numeric- and mass-based data in the Production Foregone, Equivalent Adult, and Equivalent Yield models. These three models were used to determine the potential entrainment reduction benefits (for both "use" and "nonuse" scenarios) on recreational harvest (as harvest foregone), as well as the effects of loss of forage associated with the entrainment of other finfish (as production foregone). Parameters used in population modeling were derived from the literature (EPRI 2004; USEPA 2006) and also reflect site-specific information on the Lake Keowee fishery (when available) and data specific to the recreational uses of the fishery.

Table ES-7 presents the annual stock size and harvest level benefits that would occur in response to the entrainment reductions estimated under the MDCT and FMS scenarios. The models estimate a maximum benefit of 0 to 39 equivalent adults and 0 to 3 lbs of estimated yield returned to the fishery under the FMS and MDCT entrainment-reducing technology scenarios. The degree of interannual variation in equivalent adults, production foregone, and harvest foregone estimates documented in demonstrate the potential annual variation in benefits that can be anticipated for fishery stocks in Lake Keowee near the Oconee CWIS under an entrainment reduction technology. Furthermore, it is important to consider how non-operational factors (e.g., year class strength, annual precipitation and flow changes, annual temperature patterns and fluctuations) can influence fishery stocks and annual entrainment estimates. Therefore, it is important to note that annual entrainment estimates and potential entrainment reduction benefits are intended to be generally representative of potential conditions at Oconee and are not intended to represent minimum or maximum scenarios.

Uncertainty is an inherent aspect of model-based estimation techniques (i.e., equivalent adult and production foregone models) due to the complexities of economics and natural biological systems. The equivalent adult (recreational species) and production foregone (forage or non-game species) estimates for Oconee were used to determine the benefits achievable under each candidate entrainment reduction technology scenario. Although unlikely to substantially change the results of the benefits analysis performed for Oconee, the BPJ decisions and assumptions made in the development of equivalent adult and production foregone models cumulatively have the potential to affect the monetization of benefits. Therefore, a qualitative evaluation was performed on the primary sources of uncertainty associated with this analysis (Appendix 11-F). While efforts were made to control uncertainty to the maximum extent practicable, the models used are "ecologically simplistic and ignore important ecological processes that affect the growth and survival of fish" (EPRI 2004). For example, the equivalent adult and production foregone models do not incorporate density-dependence, nor do they assume that entrained and impinged fish are returned to the waterbody (which is often the case, where they can support future primary and secondary production). However, as a means to present the maximum benefits possible with entrainment or impingement-reducing technologies, input parameters used in the Benefits Valuation Study were based on the most conservative data from literature, and therefore overestimate the potential benefits that would likely occur in the fishery of Lake Keowee.

Table ES-7. Annual Stock and Harvest Level Changes Estimated for Each Entrainment Reduction Technology for 2016 and 2017 at Oconee Nuclear Station[1]

Scenario	Total Reduction (No. Saved[2])	Benefits to the Fishery			
		Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Recreational Yield (lbs)
2016					
FMS in new CWIS[3]	27,741,007	15	3	1,435	1
MDCT	35,163,440	39	8	2,360	3
2017					
FMS in new CWIS[3]	25,652,948	--	--	1,387	--
MDCT	36,558,355	--	--	3,095	--

[1] Numbers were rounded to the nearest whole number.
[2] Total reduction in losses under specified technology in comparison to baseline losses (i.e., entrainment reduction benefit).
[3] Total FMS losses include convert mortalities.

Table ES-8 presents the annual stock size and harvest level benefits estimated to occur in response to the impingement reductions estimated under the Post-IMP BTA and MDCT scenarios. As with estimates presented in the table above for entrainment-reducing technologies, impingement reductions are conservative and represent the maximum benefit that may be observed with each candidate technology.

Table ES-8. Annual Stock and Harvest Level Changes Estimated for Each Impingement Reduction Technology for 2016 and 2017 at Oconee Nuclear Station[1]

Scenario	Total Reduction (No. Saved[2])	Benefits to the Fishery			
		Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Recreational Yield (lbs)
2016					
Post-IM BTA[3]	3,723	432	87	87	39
MDCT	45,229	556	113	3,458	51
2017					
Post-IM BTA[3]	3,690	446	91	85	40
MDCT	44,218	574	117	3,421	53

[1] Numbers were rounded to the nearest whole number.
[2] Total reduction in losses under specified technology in comparison to baseline losses (i.e., entrainment reduction benefit).
[3] Assumes fish friendly or modified Ristroph traveling screens with aquatic organism return system.

Monetization of Benefits

The benefits of reductions in entrainment and impingement losses of early life stage fish are best evaluated by translating losses to an ecological or human-use context, and assessing differences in total losses among compliance technology scenarios discussed in Section 10. The estimation of social benefits was based on use benefits derived from potential changes in recreational fish stocks (e.g., equivalent adults, forage production foregone, and equivalent yield) and their associated economic effects annualized over the remaining useful plant life.

Another benefit category, nonuse benefits, results from changes in values that people may hold for a resource, independent of their use of the resource. Given the precepts of nonuse values and consideration of estimated entrainment reduction costs and benefits, and the absence of federal or state listed species in entrainment (Section 9), impingement (Section 4 and Section 6), and source waterbody assessments (Section 4), and with entrainment reduction costs that are hundreds to thousands of times the level of benefits, correctly measured nonuse benefits would not influence a BTA determination that considers benefits and costs based on historically applied criteria. A detailed discussion of the typical methods used to evaluate nonuse benefits and the justification for not applying those at Oconee is provided in Appendix 11-E.

The present and annual recreational benefit values for each evaluated technology are presented in Table ES-9. To develop the present value estimates, the benefits estimated for each feasible alternative are discounted at 3 and 7 percent annually and summed over the specified time period.

Table ES-9. Summary of Monetized Commercial and Recreational Social Benefits of Entrainment Reduction Alternatives at Oconee (Source: Veritas 2020)

Discount Rate	Technology	2016 Entrainment Data		2017 Entrainment Data	
		Present Value	Annual Value	Present Value	Annual Value
3%	Without-Entrainment (100% Reduction)[1]	$279	$35	$362	$45
	Reduced Entrainment (With Technology)				
	MDCT	$272	$34	$353	$44
	FMS in new CWIS	$164	$20	$158	$20
7%	Without-Entrainment (100% Reduction)[1]	$165	$21	$214	$27
	Reduced Entrainment (With Technology)				
	MDCT	$160	$20	$209	$26
	FMS in new CWIS	$97	$12	$93	$12

Note: FMS benefits begin accruing two years earlier and result in higher estimated present values (Social Costs of Compliance Technologies).
Totals may not sum due to rounding.
[1]Maximum potential benefit with complete elimination of entrainment at the CWIS by facility end of life closure.

The potential entrainment reduction benefits (both ecological and economic) based on the 2016 and 2017 annual entrainment estimates are minimal under each of the scenarios presented in Table ES-9, even in comparison to potential benefits that could be realized if Oconee were to retire (between $279 and $362 in present value and an annual value between $35 and $45); and further validates the efficacy of the existing system of technologies (curtain wall, submerged weir, overhang at the CWIS, and seasonal/annual intake flow reductions compared to DIF). Regardless of technology, year of estimated loss, or discount rate assumptions, the present value of reductions in entrainment were estimated to range between $93 and $353 (MDCT in 2017) and the annual value was estimated to range between $12 and $44.

Barnthouse (2013) notes that the available peer-reviewed literature does not support a conclusion that entrainment reductions will produce measurable improvements in recreational or commercial fish populations. The potential social benefits estimated for Oconee based on entrainment reduction scenarios are minimal and thus are consistent with this position.

Other Benefits

Other benefits from reducing entrainment can include ecosystem effects such as population resilience and support, nutrient cycling, natural species assemblages, and ecosystem health and integrity (79 FR 158, 48371). The fisheries benefits study (summarized in Section 11) does not quantify other effects on the fish community, such as density-dependent influences including increased competition, predation, or increased abundance of introduced or non-native species populations. Further, potential non-use values or effects which many occur in the absence of entrainment or impingement are expected to be minimal and thus, were addressed qualitatively for Oconee.

Based on the relatively low number of annual entrainment losses documented at Oconee (Section 9), regardless of specific reduction technology, the potential entrainment reduction benefits were estimated to be an additional 3,095 lbs of forage biomass added to the fishery, with an equivalent annual recreational yield of 1 to 2 fish. As such, the reduction of entrainment at Oconee is not expected to yield measureable ecological benefits. Further, source water monitoring data demonstrate a balanced fishery continues to exist in Lake Keowee with the ongoing operation of the Oconee CWIS.

Non-water Quality Environmental and Other Impacts Study – §122.21(r)(12)

The Rule at §122.21(r)(12) requires an assessment of other non-water quality environmental impacts, including estimates of the level of impact, for each technology or operational measure considered under §12.21(r)(10). It also requires a discussion of reasonable efforts to mitigate the impacts; this information is presented in Section 12. The evaluation must address, if relevant to the alternative technology being assessed, the following items:

- Estimates of changes to energy consumption, including but not limited to, auxiliary power consumption and turbine backpressure energy penalty;
- Estimates of increases in air pollutant emissions;
- Estimates of changes in noise generation;
- A discussion of potential impacts to safety;

- A discussion of facility reliability;
- Estimation of changes in water consumption; and
- Discussion of efforts to mitigate these adverse impacts.

The conceptual approach to each technology (e.g., location and design of the cooling towers), as defined in Section 10, has an important effect on the level of impacts discussed in Section 12. The quantitative engineering and costing analyses presented in Section 10 includes an evaluation of potential impacts and incorporates reasonable estimates of impact mitigation and associated costs, thus concepts and approaches presented in Section 10 and 12 are related.

Impact information presented in Section 12 of the compliance document are summarized and discussed below in the sections addressing the "Must" and "May" factors.

Peer Review – §122.21(r)(13)

As required by the Rule at §122.21(r)(13), the reports prepared under §122.21(r)(10)–(r)(12) underwent external peer review by subject matter experts. Five expert peer reviewers were selected in fields relevant to the material presented in the submittal package (i.e., power plant engineering, aquatic biology, and resource economics). Section 13 of this document provides a summary of the peer reviewer qualifications (Appendix 13-A), a log of written/electronic/phone communication with peer reviewers (Appendix 13-B), documentation of formal peer review comments and responses to those comments (Appendix 13-C and 13-D), and includes confirmation from reviewers of their satisfaction with responses to comments and recommended revisions.

Entrainment BTA Factors that Must Be Considered

The Rule requires that the Director consider several factors in the written explanation of the proposed entrainment BTA determination. The following Must factors to be considered for entrainment BTA (§125.98(f)(2)) are:

- Numbers and types of organisms entrained, including federally listed, threatened and endangered species, and designated critical habitat (e.g., prey base, glochidial host species);
- Impact of changes in particulate emissions or other pollutants associated with entrainment technologies;
- Land availability as it relates to the feasibility of entrainment technology;
- Remaining useful plant life; and
- Quantitative and qualitative social benefits and costs of available entrainment technologies.

While each of the Must factors is considered separately in Section 10 for the potential technologies considered (i.e., MDCT and FMS with an aquatic organism return), a brief summary of findings for each factor is presented below along with references to the relevant section(s) of the report.

Numbers and Types of Organisms Entrained

Sections 9 and 11 present the number and types of organisms entrained based on the 2-year Study at Oconee; these data were annualized and adjusted for station flows (maximum and actual intake flows) to estimate total annual entrainment losses. The annual estimates are presented separately for 2016 and 2017 based on the rates of entrainment documented during the 2016-2017 Study, and demonstrate the range of interannual variation in entrainment losses that can occur at the Oconee CWIS.

A combined two-year total of 176 ichthyoplankton representing three distinct taxa from two families were collected during the Study. No federally protected species are listed in the vicinity of the Oconee CWIS (USFWS 2019) and none were collected during the Study; therefore, it is unlikely that federally protected species are susceptible to entrainment at the Oconee CWIS. No mussels or shellfish were collected during the Study and based on habitat requirements, none are expected to occur near the Oconee CWIS.

The average annual number of ichthyoplankton entrained at the Oconee CWIS over the two-year Study was estimated at 37.5 million based on actual water withdrawals. A single sunfish post yolk-sac larvae was the only recreational species collected throughout the Study. Greater than 98 percent of ichthyoplankton entrained in 2016 and 2017 were fragile forage species of the Clupeidae family. Species in this family identified in Lake Keowee include Blueback Herring and Threadfin Shad (Duke Energy 2007 and 2013). Blueback Herring and Threadfin Shad species are prolific, broadcast spawners: Blueback Herring may spawn up to 350,000 eggs (Pardue 1983) and Threadfin Shad up to 22,000 eggs (Hendrickson et al. 2015) per female. Given the high fecundity and high natural mortality of Threadfin Shad and Blueback Herring, the estimated level of annual entrainment documented for Oconee is not anticipated to have an impact on population viability for these forage species. Further, Blueback Herring are not native to Lake Keowee, as they were inadvertently stocked to the impoundment in the 1970s (Prince and Barwick 1981).

The low numbers and diversity of ichthyoplankton collected during the 2016 to 2017 Study are comparable to the results of the Oconee curtain wall efficacy study, providing concurring evidence that the curtain wall is effective at reducing ichthyoplankton densities on the intake side of the wall and that the reduction extends to the Oconee CWIS. Section 7 of this document summarizes the results of the 2017 Oconee curtain wall study (HDR 2018a).

It is important to place the rates of entrainment at Oconee into the context of the trends documented for Lake Keowee, the source waterbody (see Section 4):

- Duke Energy performs annual monitoring of the Lake Keowee fishery, with results that continue to demonstrate a stable and balanced, self-sustaining population with a robust forage fish base supportive of predatory species (ASA 2008; Duke Energy 2007, 2013).
- Some variation has occurred as a result of species introductions. Long-term monitoring data indicate Largemouth Bass (*Micropterus salmoides)* and Redeye Bass (*Micropterus coosae*) have both decreased in abundance since 1996 while the abundance of introduced species such as Alabama Bass and Flathead Catfish has increased (Duke Energy 2007). Blueback Herring and Threadfin Shad dominated the forage fish populations, influenced spatially and temporally by water temperature. The abundant littoral zone and pelagic forage fish species continue to provide a consistent and diverse prey base for predators.
- The direct and indirect effects of the small loss of organisms at Oconee, as demonstrated through modeling (specifically designed to overestimate effects), does not result in a negative impact to the recreational fishery (see Section 11).

These findings are interrelated and driven by the same factors: (1) Oconee entrainment consisted of early life stages of highly fecund, fragile, and invasive species, many of which exhibit high natural mortality, and (2) entrainment losses represent a small portion of the available Lake Keowee resources, a result of the effectiveness of the curtain wall at reducing entrainment at the Oconee CWIS. Based on the estimated annual losses under existing conditions, the total annual harvest foregone was estimated to be 3 lbs in 2016 (no recreational species were entrained in 2017). Harvest foregone represents the total annual biomass lost from the recreational fishery due to entrainment at Oconee. Given the low annual entrainment loss estimates documented at Oconee for 2016 and 2017, the losses resulting from entrainment are not expected to impact the Lake Keowee fishery.

The incremental reductions in estimated entrainment losses, and their effect on the fishery as represented by production foregone, equivalent adults, and harvest foregone, were modeled for each of the potential compliance scenarios described in Section 11. Entrainment was estimated to be reduced by 97.4 percent under a closed-cycle cooling (MCDT) retrofit, while entrainment under a 1.0-mm FMS retrofit (i.e., the product of the rate of exclusion and post-exclusion on-screen survival) was estimated to be 59.2 percent in 2016 and 43.6 percent in 2017 for production foregone (Table ES-10). The reduction in harvest foregone under a 1.0-mm FMS retrofit was estimated to be 33.3 percent in 2016. Interannual variation due to the composition and abundance of species and life stages within entrainment samples (i.e., no recreational species were collected) resulted in no equivalent adults or harvest foregone losses estimated for 2017, therefore there are no reductions and benefits calculated for that year.

Table ES-10. Percent Reductions under Entrainment Compliance Technology Scenarios Relative to the Baseline Condition at Oconee Nuclear Station

Scenario	Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Harvest Foregone (lbs)
2016 Annual Percent Entrainment Loss Reduction				
Baseline (Existing Condition)	--	--	--	--
FMS[1]	37.5	37.5	59.2	33.3
MDCT	97.4	97.4	97.4	97.4
2017 Annual Percent Entrainment Loss Reduction				
Baseline (Existing Condition)	--	--	--	--
FMS[1]	--	--	43.6	--
MDCT	--	--	97.4	--

[1]FMS scenario includes convert mortalities.

Based on these findings, the low number and types of organisms entrained (highly fecund or invasive species and absence of protected species) do not provide a compelling basis under the Rule to evaluate additional entrainment measures. The low entrainment rates at Oconee do not negatively affect the Lake Keowee fishery, which continues to reflect a balanced and indigenous community.

Impacts of Changes in Air Emissions of Particulates and Other Pollutants

The assessment of entrainment technologies for BTA considers changes in pollutant air emissions in Section 12. The increase in emissions is associated with two factors: (1) particulate matter (PM) emissions from the cooling tower associated with the concentration of total dissolved solids (TDS) and total suspended solids (TSS) in the make-up water, and (2) loss of generation capacity associated with parasitic loads and loss of efficiency based on the entrainment technology operating requirements. As shown in Table ES-11 increased emissions are estimated to be far more substantial for a potential retrofit to cooling towers than a retrofit to FMS.

Table ES-11. Impacts to Air Emissions under Entrainment Reduction Technology Scenarios Evaluated for Oconee Nuclear Station

Technology	MDCT Retrofit	1.0-mm FMS in New CWIS
Increase in PM Emissions:		
$PM_{2.5}$ (tons/year)	1.1	0
PM_{10} (tons/year)	1.7	0
Total Annual PM (tons/year)	1.8	0
Increase in CO_2, SO_2, NO_x Emissions:		**(tons/year)**
CO_2	470,223	7,172
SO_2	110	2.2
NO_x	297	6.7

[1]This scenario assumes 1.0-mm fine-mesh modified-Ristroph screens with organism return system. Also, there is no increase in particulate emissions associated with a FMS retrofit.
Note: CO_2 = carbon dioxide; SO_2 = sulfur dioxide; NO_x = nitrogen oxides

Emissions associated with the replacement of lost zero-carbon baseload generation would mostly include increases in carbon dioxide with substantially lower amounts of sulfur dioxide, nitrogen oxides, and PM. These increased emissions are based on assumptions and results of Duke Energy's Power System Simulation Model (PROSYM). No attempt was made to monetize the social costs of the increased emissions.

Land Availability Related to Technology Retrofit Options

The availability of space for infrastructure associated with retrofitting for entrainment technologies was considered in the assessment of entrainment BTA for Oconee. While land is technically available at Oconee to facilitate a closed-cycle cooling tower retrofit, there are substantial site constraints that impact the placement, required infrastructure, and associated costs.

The most practical location for placing three MDCTs, one for each unit, is to the southwest of the station in an undeveloped, forested area (shown on Figure 10-12). New piping and other supporting systems would be installed across Oconee's existing station infrastructure and under the Walhalla State Highway, which would require significant permitting and construction. Steep topography throughout the site at this hypothetical MDCT location would require significant site clearing, regrading, and restoration. Construction and operation of the hypothetical cooling towers would occur in the vicinity of existing overhead transmission lines. This could cause potential icing concerns and would likely require transmission line relocation. Cooling tower blowdown would be routed back to Lake Keowee after treatment in settling/treatment basins to reduce solids and other constituent concentrations prior to discharge. The necessary construction to install piping or to relocate the existing station features would be very expensive and would result in substantial station downtime (extended outages). While this is not an ideal location for siting cooling towers, other potential locations considered were less suitable as they pose construction constraints including the relocation of existing station infrastructure (including a large office building), steep topography, and the relocation of existing overhead transmission lines and are, therefore, considered impractical.

To maximize the potential entrainment reduction efficacy of the 1.0-mm FMS at Oconee, a new CWIS would be constructed upstream of the existing intake to accommodate the new screens and associated equipment while achieving TSV of less than 1.5 fps. Without expanding the CWIS, the TSV would increase to approximately 7.3 fps (50 percent clogging scenario), which could result in the loss of cooling water flow and structural damage to the FMS. Assuming a 1.0-mm mesh size and maximum TSV of 1.5 fps, the new intake structure would span the entire width of the Oconee intake canal and would accommodate thirty 1.0-mm FMS units (10 for each of the 3 intake bays).

Remaining Useful Plant Life

The remaining life of each generating unit impacts technology selection, O&M costs, potential future technology repair costs (if the life of the unit is longer than the anticipated life of the technology), and the benefits. Under the current operating license authorized by the USNRC, Oconee will retire Units 1 and 2 in 2033 and Unit 3 in 2034. However, the remaining useful plant life was based on the conservative assumption of all units operating through 2034. As such, 2034 was also used for the purpose of estimating the potential social costs and social benefits of candidate compliance technologies at Oconee, as detailed in Sections 10 through 12 of the Compliance Submittal Document and summarized in the following sections of the Executive Summary. If the original entrainment reduction technology is in good operating order at the respective retirement date, it is assumed that the technology would be retired (no salvage value has been evaluated). If the anticipated life of the technology is shorter than the anticipated life of the units (2034 for all units), this evaluation assumes that the technology would be repaired or rebuilt and remain in service until the unit is retired.

Note that if the USNRC approves a 20-year operating license extension, the costs to operate new entrainment technology would be higher than using an earlier retirement date (2034) due to the additional years the technology would be in operation. These higher costs would be driven by routine equipment replacement and continued annual operations and maintenance costs from 2034 through 2054. While the social benefits associated with the new entrainment technology would also be higher due to the additional 20 years of operation, the total net benefits would still be negative (as described above) and the overall results and conclusions associated with the retirement date of 2034 would remain unchanged.

Quantitative & Qualitative Social Benefits and Costs of Available Entrainment Technologies

The social costs and social benefits for each compliance technology option evaluated for Oconee are summarized in Section 10, and provides the present value estimates discounted at 3 and 7 percent based on the estimated annual losses for entrainment and impingement for 2016 and 2017.

The social benefits include both the impingement and entrainment benefits estimated for each compliance option. The methodology and results for estimating the entrainment benefits are presented in the Entrainment Reduction Benefits Study (Appendix 11-E). The methods and results for estimating the social costs are presented in the Social Costs of Purchasing and Installing Entrainment Reduction Technologies Study (Appendix 10-J).

Quantitative Cost to Benefit Comparison

The social costs and benefits of the entrainment compliance options for Oconee are presented as present values discounted at 3 percent in Figure ES-1. The figure also illustrates social costs and benefits of the IM compliance option identified in Section 6. Including the impingement technology provides context for determining the entrainment BTA under the Rule's site-specific entrainment evaluation. Specifically, the Rule has two separate regulatory components:

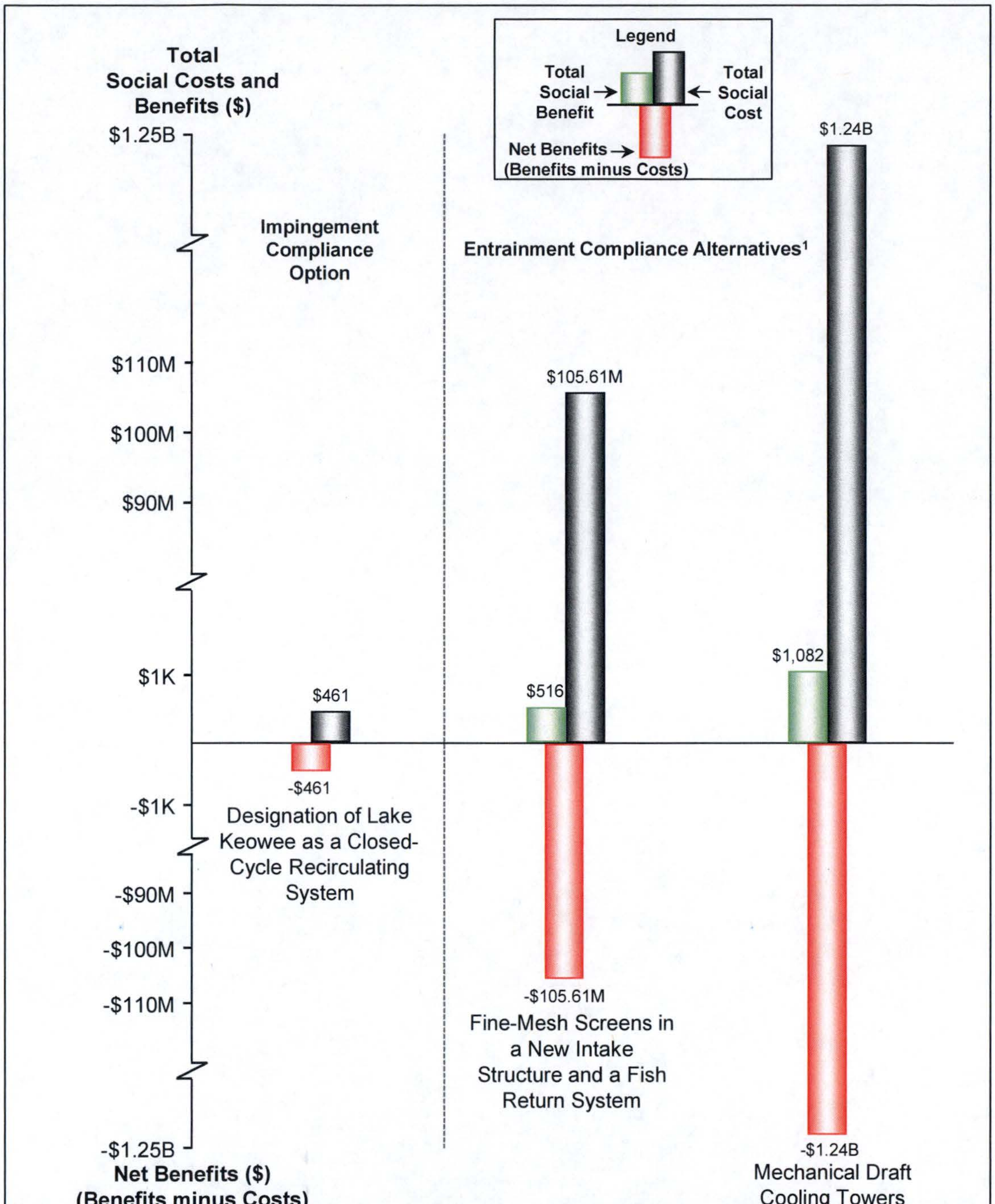
- a command and control component in which the facility must implement one of seven impingement compliance alternatives (§ 125.94(c)) if not currently installed, or demonstrate that its rate of impingement is *de minimis* (§ 125.94(c)(11)), and
- a site-specific best technology available evaluation to determine the maximum entrainment reduction warranted based, in part, on the social costs and social benefits of each technology.

By comparing the entrainment reduction options to the impingement option, the evaluation provides context for what is warranted for entrainment versus what is required for impingement.

The vertical axis in the top portion of Figure ES-1 presents the total social costs and total social benefits of each compliance option, and the bottom portion presents the net benefits (total social benefits minus total social costs) of each compliance option. The total social benefits are illustrated by the green bar, and the total social costs are illustrated by the black bar. The horizontal axis presents each compliance option. As the top portion of the figure shows, the total social costs are greater than the social benefits for each of the impingement and entrainment compliance options.

The bottom portion of the figure illustrates the net benefits of each compliance option. As the figure shows, the impingement compliance option (as identified in Section 6), represents the current configuration and has net benefits of -$461. By comparison, the entrainment compliance options of FMS and MDCT have net benefits of -$105.61 M and -$1.24 B, respectively.

Entrainment BTA determinations require consideration of both benefits and costs. Under the criterion that governs benefit-cost-based determinations, only technologies that have social benefits that exceed their social costs are justified (Boardman et al., 2018; Freeman et al., 2014). As noted in the Rule, "[i]f all technologies considered have social costs not justified by the social benefits…the Director may determine that no additional control requirements are necessary beyond what the facility is already doing. The Director may reject an otherwise available technology as a BTA standard for entrainment if the social costs are not justified by the social benefits (§ 125.98(f)(4))." Given that the net benefits are negative for each of the alternatives shown on Figure ES-1, the social costs are not justified by the potential social benefits. Therefore, neither the FMS nor MDCT entrainment compliance option is justified as the BTA under the Rule's site-specific entrainment compliance requirements. Additionally, the existing Oconee CWIS design and operation meets the definition of a closed-cycle recirculating cooling system and entrainment monitoring data clearly demonstrate that the existing system of technologies (curtain wall, submerged weir, CWIS overhang, and seasonal/annual intake flow reductions compared to DIF) substantially reduce entrainment at the CWIS.



Notes:
Social benefits are estimated using the 2017 impingement and entrainment data because 2017 is the sample year with the highest total taxa entrained (HDR 2020). Social costs and social benefits are discounted at 3%.
[1] Each of the entrainment options include the impingement benefits.

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Figure ES-1. Comparison of Social Benefits and Costs at Oconee (Assumes all units will be retired in 2034)

Qualitative Cost to Benefit Comparison

The qualitative costs and benefits of reducing entrainment and IM are difficult to evaluate and quantify and therefore are not included in the benefits valuation presented in Section 11. These qualitative effects, however, may result in ecosystem benefits such as increased population resilience and support, nutrient cycling, and overall health and integrity of the ecosystem (79 FR 158, 48371). The reduction in entrainment losses could also result in qualitative costs to the fish community due to density-dependent influences such as increased competition, predation, or increased populations of introduced species.

The elimination of warm water discharges at Oconee is a potential outcome under the MDCT scenario (see Section 11), which could lead to social costs or social benefits. Heated water discharged into Lake Keowee from Oconee creates favorable habitat conditions during colder winter months by forming a warm water refuge in the vicinity of Oconee and supporting a winter fishery for recreational anglers. Under MDCT operation, there may be a social cost related to loss of this fishery. Estimating the impacts of the loss of Oconee's winter fishery requires assessing the relationship between the thermal discharge, fishery changes, and the impact that fishery changes have on people. For recreational values, this includes understanding how Oconee's thermal discharge affects recreational fishing catch rates and how changes in catch rates affect angler well-being. The Recreational Angling Demand Model links fishery-specific catch and effort rates. This forms a bio-economic equilibrium for the Lake Keowee fishery expected to be affected by the loss of Oconee's thermal discharge. The integrated partial equilibrium model simulates conditions under With Thermal Discharge (baseline) and Without Thermal Discharge conditions, and the monetized welfare differences between these two conditions determine the impacts of the loss of Oconee's thermal discharge. As described in USEPA's Guidelines for Preparing Economic Analysis (USEPA 2016), equilibrium modeling using the With- and Without-Impact approach is central to all sound benefit estimation processes and regulatory impact analyses.

The thermal discharge is specified in the model to be eliminated in 2026, corresponding with the proposed start-up timeline of the hypothetical cooling towers. The elimination of the thermal discharge is modeled through 2034, with the baseline conditions being changed from With-Thermal to Without-Thermal-Discharge. The model accounts for the closing of the plant in 2034, resulting in a lack of thermal discharge and subsequent loss of a winter fishery under baseline conditions. In the absence of the thermal discharge, there is a loss of approximately 32 angler trips at the affected site and produces a present value estimate of the social cost ranging from a loss of $5,727 (7 percent discount rate) to $8,602 (3 percent discount rate) (Veritas 2020).

The fish species composition found in the vicinity of the discharge may also change in response to reduced warm water discharges. Depending on the species, this may be seen as either a cost or a benefit. An example of a species which may use the thermal discharge as refuge in Lake Keowee is the Threadfin Shad, which even as a non-native species still provides an important forage base for recreational predator species (Duke Energy 2007, 2013).

The elimination of warm water discharges into the Lake Keowee would result in cooler water temperatures immediately downstream from Oconee's discharge canal; however, since ongoing monitoring activities continue to demonstrate a balanced and indigenous community near Oconee, the potential for the fish community to benefit from elimination of warm water discharges is expected to be minimal.

Summary of <u>Must</u> Factors Analysis

A summary of the information relevant to the <u>Must</u> factors at Oconee is presented in Table ES-12.

Table ES-12. Summary of Must Factors Analysis

BTA Factors	Summary of Supporting Information
Numbers and types of organisms entrained	2016 – 2017 entrainment dominated by non-native clupeids; Blueback Herring and Threadfin Shad. A single sunfish post yolk-sac larvae was the only recreational species collected during the Study.
	The primary period of entrainment occurred from March to September, with peak abundance occurring in June and July.
	Organisms collected represented only two families. When samples were characterized by life stage, samples were dominated by eggs during both years.
	No federal or state-listed fish or shellfish, or their designated critical habitat (e.g., prey base, glochidial hosts) have been impacted by entrainment at Oconee.
	Forage species comprised greater than 98 percent of annual entrainment losses based on actual water withdrawals for both years, the majority of which were Blueback Herring eggs, representing 92.3 percent (2016) and 77.6 percent (2017) of annual losses.
	The curtain wall located at the mouth of the intake canal reduces entrainment by approximately 76 percent over the 8-month entrainment study period and approximately 90 percent during the period peak ichthyoplankton abundance, a reduction that is slightly less than what is expected with installation of wet cooling towers.
Impact of changes on particulate emission or other pollutants	Increased PM and pollutant air emissions are estimated to be more substantial for a retrofit to cooling towers than a retrofit to FMS.
Land availability	Land is available at and around the facility; however substantial construction would be required to support either MDCTs or FMS retrofit scenarios. Furthermore, limited availability of land to support the MDCTs result in substantial construction challenges.
Remaining useful plant life	For the purpose of estimating the potential social costs and benefits of candidate entrainment reduction technologies, the remaining useful plant life was assumed to be 2034, the later of the current anticipated retirement dates of 2033 for Units 1 and 2 and 2034 for Unit 3, based on the current USNRC license[1].
Quantified and Qualified Social Benefits and Costs	Total social costs including electricity rate increases resulting from compliance costs, power system costs, externality costs (impacts to property value, hydroelectric generation, and winter fishery), and government regulatory costs were estimated at \$105.61M for FMS in a new CWIS and \$1,240.30M for MDCTs (at a 3 percent discount rate) and \$70.47M for FMS in a new CWIS and \$836.49M for MDCTs (at a 7 percent discount rate).
	Social benefits in 2016, including the effects to the recreational fishery, were estimated at \$164 for FMS and \$272 for MDCTs (at a 3 percent discount rate) and \$97 for FMS and \$160 for MDCTs (at a 7 percent discount rate). Social benefits in 2017 were estimated at \$214 for FMS and \$353 for MDCTs (at a 3 percent discount rate) and \$93 for FMS and \$209 for MDCTs (at a 7 percent discount rate). Regardless of technology, year of estimated loss, or discount rate assumptions, the annual value was estimated to range between \$12 and \$44.
	The direct and indirect effects of the loss of organisms at Oconee, as demonstrated through modeling (specifically designed to overestimate effects), resulted in a minimal measurable impact to the recreational fishery.
	The social cost to social benefit comparison indicates that all modeled scenarios result in net-negative benefits.

BTA Factors	Summary of Supporting Information
	The potential qualitative benefits of an entrainment and impingement mortality reduction at Oconee are not substantial and would not warrant the qualitative costs associated with the reduction.

[1] An application for a 20 year life extension will be made to the USNRC; however, this will result in higher social costs and benefits and likely result in a greater magnitude of net negative benefits compared to those presented in this report that are based on current anticipated retirement dates.

Entrainment BTA Factors that May Be Considered

The May factors to be considered for entrainment BTA (§125.98(f)(3)) are:

- Entrainment impacts on the waterbody;
- Thermal discharge impacts;
- Credit for reductions in flow associated with the retirement of units occurring within the ten years preceding October 14, 2014;
- Impacts on the reliability of energy delivery within the immediate area;
- Impacts on water consumption; and
- Availability of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for reuse as cooling water.

The information from this list is included or addressed in detail in the study reports and supporting documentation provided in Sections 2 through 12 of the compliance submittal document. The findings of the entrainment BTA assessment relative to the factors that SCDHEC may consider are provided below.

Entrainment Impacts on the Waterbody

The degree of susceptibility of aquatic organisms to entrainment can be quite variable depending on their size, swimming ability, wind speed and direction, bathymetry of the lake and intake canal, and the rate and variability of flows withdrawn at the Oconee CWIS. Due to the variability associated with these factors, an entrainment AOI at Oconee was not quantified, but is discussed qualitatively. Most entrainable-sized organisms are unable to swim and, thus float within the water column or at the water surface where they are subject to ambient flows and currents within Lake Keowee and the Oconee intake canal.

The potential exists for entrainment of aquatic organisms within the intake canal at Oconee, and the likelihood of entrainment would increase as an organism's proximity to the Oconee CWIS increases. However, a curtain wall located at the entrance of the intake canal, which facilitates water withdrawal from the lower portion of the water column, was shown to be effective at reducing the number of ichthyoplankton (see Section 7.1.2) passing from Lake Keowee into the Oconee intake canal by 76.6 percent and by nearly 90 percent during the peak entrainment period (HDR 2018). Additionally, an overhang at the face of the Oconee CWIS restricts water withdrawal at the intake to a 20-ft opening at the bottom of the overhang, which provides additional entrainment reduction benefits. The efficacy of these technologies are further demonstrated by the relatively low estimated annual entrainment losses presented in Section 9.

Based on the information presented above and in Sections 2 through 12 of the compliance document, entrainment at Oconee does not result in substantial or adverse impacts to Lake Keowee, with no observable or measureable impacts occurring based on the stability of the fishery and presence of a balanced indigenous community (Sections 4 and 9). This position is further supported by the results of the quantitative modeling of the effects of entrainment, using recent entrainment monitoring data collected at Oconee in 2016 and 2017 (Section 9), including direct losses of recreational species as well as indirect losses from trophic transfer of forage species to consumers or predators (see Section 11).

Credit for Flow Reductions

No unit retirements or associated reductions in flow occurred at Oconee within the preceding 10-year period. Oconee does have seasonal flow reductions that may occur depending on seasonal temperatures. While Oconee does not have planned seasonal reductions in total water withdrawals, one to two of the four CCW pumps per unit are generally not operated based on lake temperatures. Generally, two pumps are operated in colder winter months (December – February), three pumps are operated in cooler spring and fall months, and all four pumps are operated during the hottest summer months (Table 5-1).

Oconee's DIF per unit (including all four CCW pumps) is 1,019.5 MGD (Table 3-2). With two CCW pumps per unit turned off (during colder winter months), typical cooling water withdrawal is reduced by approximately 34 percent. With one CCW pump per unit turned off (during cooler spring and fall months), typical cooling water withdrawal is reduced by approximately 14 percent. It is expected that reductions in cooling water withdrawal proportionately reduces impingement and entrainment.

Impacts on the Reliability of Energy Delivery

Oconee is a large zero carbon baseload generating asset that supports the reliable supply of electricity to Duke Energy's customers. Maintaining safe and reliable energy delivery is imperative to Duke Energy, their customers, and their shareholders, and has been considered in this entrainment BTA assessment in the following manner:

- During the conceptual design phase for potential entrainment technologies, consideration was given to the location, configuration, operational requirements, and other design specifics for each potential technology to improve generation reliability. This information was incorporated into capital and social costs estimated for each potential retrofit option.
- PROSYM was performed by Duke Energy to evaluate the extent and impact (system-wide) of loss of generation capacity associated with potential retrofit options to ensure reliable energy delivery and to estimate the social costs of securing it.

Under the MDCT retrofit scenario, the station would need to operate at reduced power during the warmest and most humid periods; the reduction is anticipated to result in reliability impacts due to main condenser backpressure energy penalty. Additionally, during periods of peak demand in winter, there would be potential for icing on Oconee's transmission lines due to cooling tower plume formation, which could impact station reliability during periods of peak winter electricity demand.

Under the new CWIS with FMSs scenario, the 1.0-mm mesh panels would cause significant increases to TSV and headloss across the screens, which would impact the performance of the existing CCW pumps, and could cause pump cavitation, damage, or failure, with potential to significantly impact station reliability and nuclear safety at Oconee. It is noted that retrofitting a nuclear station presents different challenges than constructing a new facility as maintaining safe plant conditions is paramount during a retrofit. The Rule (§125.94[f]) states that if compliance with the Rule conflicts with the safety requirements established by the USNRC, the Director must make a site-specific determination that would resolve the conflict with such safety requirements. Modifications to the station would also need to be approved by the USNRC.

Availability of Alternate Water Sources for Reuse as Cooling Water

Alternate water sources, such as groundwater and grey water sources, were evaluated for potential use to supplement the current water needs at Oconee. These sources were evaluated by first comparing the distance and available flow of the potential alternate water source to the location of the station, and then by determining its practicability as a source of cooling water for Oconee. Due to permitting challenges such as stream and wetlands crossings, numerous rights-of-way required over private properties, and prohibitive construction costs, alternate water sources greater than a distance of 5 miles from the station are not considered practicable. Groundwater and wastewater supplies within 5 miles of Oconee were determined to be of insufficient quantity to support Oconee's cooling water requirements. The only potential reusable existing water source would be service water, which has existing heat loads and treatment requirements and is not a viable option.

Summary of May Factors Analysis

A summary of the information relevant to the May factors at Oconee is presented in Table ES-13.

Table ES-13. Summary of May Factors Analysis

BTA Factors	Summary of Supporting Information
Entrainment impacts on the water body (including volume of water used for plant operations vs. total available from source water)	Ongoing monitoring of Lake Keowee indicates no impacts to the aquatic community or water quality from current operations. Studies indicate that Lake Keowee near Oconee supports a balanced and indigenous community. The existing installed entrainment reduction technologies (curtain wall, submerged weir, overhang) substantially reduce entrainment.
	From July 1, 2014 through June 30, 2019, the percentage of streamflow withdrawn on a monthly basis based on AIF ranged from 19 percent (in February) to 31 percent (in August). The annual average percentage of water withdrawn at AIF was 26 percent and the average percentage withdrawn over the months where entrainable-sized organisms are present (March through September) was 27 percent.
Thermal discharge impacts	The existing thermal variance is protective of a balanced and indigenous community in Lake Keowee.
	Loss of thermal discharge would have minimal beneficial or social impacts, including local economic impacts. However, in the absence of the thermal discharge, there is a loss of approximately 32 winter angling trips to the affected sites and produces a present value estimate of the social cost ranging from a loss of $5,727 (7 percent discount rate) to $8,602 (3 percent discount rate).
Credit for reductions in flow associated with retirement of units occurring within preceding 10 years	No credits available associated with flow reductions due to unit retirements during the past 10 years.

BTA Factors	Summary of Supporting Information
Impacts of reliability of energy delivery within immediate area	Oconee is a large zero carbon baseload generating asset that supports the reliable supply of electricity to Duke Energy's customers. Maintaining safe and reliable energy delivery is imperative to Duke Energy, their customers, and their shareholders. As such, reduced availability (during construction tie-ins), increased energy demands (to offset additional parasitic loads and backpressure energy penalties), and winter transmission line icing impacts (in the case of a MDCT retrofit) could negatively impact reliability of energy delivery within the service area.
Impacts on water consumption	Changes in water consumption for FMS would be negligible.
	Consumptive water use would increase by an average of 85.7% and a maximum of 143.2% at design conditions. MDCT retrofit could impact Lake Keowee discharges to downstream reservoirs.
Availability of alternate water sources	No other viable source with necessary yield.

Conclusions

Based on the current design (location and depth) and operations of the Oconee CWIS and the prevalence of fragile and introduced species in entrainment and IM losses, and with consideration of the anticipated 2034 facility retirement, a determination that the existing configuration (closed-cycle recirculating cooling) is appropriate for impingement is requested as the IM Option for the Oconee CWIS. The data presented in Section 6 and summarized in this Executive Summary demonstrate that the current design and operations at Oconee result in IM primarily composed of fragile clupeids and that the social costs of implementing additional impingement-reduction technology for the Oconee CWIS do not justify the potential social benefits.

As outlined in the Rule, the requirements of the NPDES Director include the following (40 CFR §125.98(f), Site-specific Entrainment Requirements):

(4) If all technologies considered have social costs not justified by the social benefits, or have unacceptable adverse impacts that cannot be mitigated, the Director may determine that no additional control requirements are necessary beyond what the facility is already doing. The Director may reject an otherwise available technology as a BTA standard for entrainment if the social costs are not justified by the social benefits.

Model-based estimates of the direct and indirect effects of the loss of organisms at Oconee, based on conservative assumptions and BPJ decisions, indicated that losses do not have a negative impact on the recreational fishery of Lake Keowee. The existing Oconee CWIS incorporates entrainment reduction technologies, such as closed-cycle recirculating cooling (via Lake Keowee), a curtain wall that facilitates water withdrawals from the lower portion of Lake Keowee, a submerged weir, and an integral CWIS overhang.

The model-based estimates of entrainment losses were used to assess the social costs and social benefits of potential entrainment reduction technologies, including: (1) installation of MDCT and (2) the installation of FMS with an organism return system. Monetized social costs and social benefits were estimated for both technologies to provide a common basis for comparison, which is consistent with the goals and requirements of the Rule. The estimates were based on conservative assumptions (e.g., all entrained organisms were considered to affect recreational fisheries either directly as equivalent adults or indirectly through trophic transfer of production foregone biomass) and include evaluations of uncertainty at multiple stages of the development process. The social cost to social benefit comparison yielded substantial net-negative benefits for the modeled entrainment reduction technologies, and unavoidable adverse effects were identified for both technologies evaluated. For example, a potential MDCT retrofit would result in increased air emissions, increased noise, and potential impacts to system reliability. Installing FMSs would result in increased TSV and headloss across the screens, which could negatively impact existing CCW pump operation, station reliability, availability of cooling flow, and nuclear safety.

Based on historical and periodic biological monitoring data, historical impingement and entrainment monitoring, and results of the 2016-2017 entrainment Study presented in Section 9, Lake Keowee supports a diverse and balanced community in the presence of ongoing operations at Oconee. No federal or state threatened or endangered species are known to occur in Lake Keowee near Oconee, none were collected in the historical impingement and entrainment study, and none were collected during the entrainment sampling activities or the 2017 curtain wall study. These data, combined with the evaluations described in Sections 10 through 12, demonstrate that the additional entrainment reduction technologies that were identified as feasible in Section 10 (MDCT and FMS) are not justified as BTA for entrainment at Oconee as they would result in adverse effects (described above and in more detail in Section 10) and the estimated social costs would be wholly disproportionate compared to the potential social benefits.

The NPDES Director must consider the social costs and benefits of each evaluated entrainment compliance option when determining the maximum entrainment reduction warranted; however, from a practical standpoint, any modifications to the existing intake structure or station operations would provide minimal biological benefits. For the purposes of the current compliance submittal, all units at Oconee are expected to retire in 2034 at the end of the current license authorization from the USNRC. Based on the evaluation of social costs and benefits of each technology, the existing (i.e., baseline) configuration at Oconee represents BTA for meeting the entrainment requirements of the Rule.

Furthermore, per §122.21(r)(6), the owner of a facility must identify the chosen method of compliance with the IM standard for the entire facility and provide sufficient information and justification to support the selected alternative compliance approach. Based on the current IM reduction benefits at the station (i.e., location of the CWIS, reduction in AIF relative to DIF) and the results of the social cost and social benefit evaluation, installation of additional IM reduction technologies at Oconee is not practical or warranted for this existing closed-cycle recirculating cooling facility.

Executive Summary References

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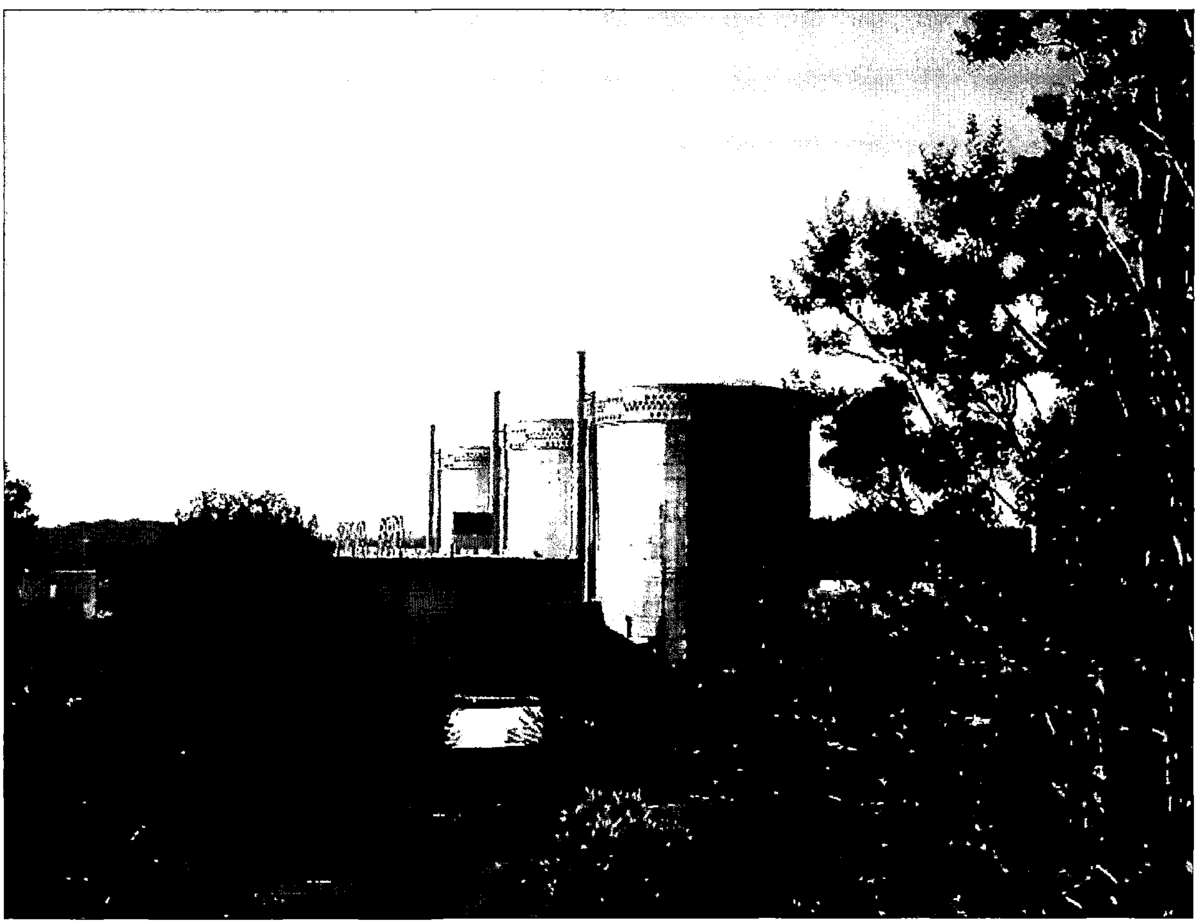
Clean Water Act §316(b) Evaluation to Support 40 CFR §122.21(r)

Oconee Nuclear Station

Compliance Submittal Document



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1 Introduction

Section 316(b) was enacted under the 1972 U.S. Environmental Protection Agency (USEPA) Clean Water Act (CWA), which also introduced the National Pollutant Discharge Elimination System (NPDES) permit program. Certain facilities with NPDES permits are subject to §316(b) requirements, which mandate that the location, design, construction, and capacity of the facility's cooling water intake structure (CWIS)[6] reflect Best Technology Available (BTA) for minimizing potential adverse environmental impacts. Cooling water intakes can cause adverse environmental impacts by drawing early life-stage fish and shellfish into and through cooling water systems (entrainment) or trapping juvenile or adult fish against the screens at the opening of an intake structure (impingement).

On August 15, 2014, §316(b) of the final CWA rule for existing facilities (Rule) was published in the Federal Register (FR) with an effective date of October 14, 2014 (USEPA 2014). The Rule applies to existing facilities that withdraw more than 2 million gallons per day (MGD) from waters of the U.S. (WOTUS), use at least 25 percent of that water exclusively for cooling purposes, and have an NPDES permit. Owner(s) of a facility subject to the Rule must develop and submit technical information, as identified in the Rule, to the NPDES Director (Director) to facilitate the determination of BTA for the facility.

The actual intake flow (AIF)[7] and design intake flow (DIF)[8] at a facility are used to identify the entrainment-specific reporting requirements, while all facilities will generally be required to select from the impingement compliance options contained in the Rule. Facilities with an AIF greater than of 125 MGD are required to address both impingement and entrainment and provide specific entrainment information (Table 1-1), which may involve extensive field studies and the analysis of alternative methods to reduce entrainment (40 U.S. Code of Federal Regulations [CFR] §122.21(r)(9)-(13)). The compliance schedule for the Rule is dependent on the individual facility's NPDES permit renewal date.

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[6] CWIS is defined as the total physical structure and any associated constructed waterways used to withdraw cooling water from WOTUS. The CWIS extends from the point at which water is first withdrawn from WOTUS up to, and including, the intake pumps.

[7] AIF is defined as the average volume of water withdrawn on an annual basis by the CWIS over the most recent 5-year period. The calculation of AIF includes days of zero flow. AIF does not include flows associated with emergency and fire suppression capacity.

[8] DIF is defined as the value assigned during the intake structure design to the maximum instantaneous rate of flow of water the CWIS is capable of withdrawing from a source waterbody. The facility's DIF may be adjusted to reflect permanent changes to the maximum capabilities of the cooling water intake system to withdraw cooling water, including pumps permanently removed from service, flow limit devices, and physical limitations of the piping. DIF does not include values associated with emergency and fire suppression capacity or redundant pumps (i.e., back-up pumps).

Table 1-1. Facility Flow Attributes and Permit Application Requirements

Facility and Flow Attributes	Permit Application Requirements
Existing facility with DIF of 2 MGD or less, or less than 25 percent of AIF used for cooling purposes	Best Professional Judgment (BPJ) of Director
Existing facility with DIF greater than 2 MGD and AIF less than 125 MGD	§122.21(r)(2)-(8)
Existing facility with DIF greater than 2 MGD and AIF greater than 125 MGD	§122.21(r)(2)-(13)

Oconee Nuclear Station (Oconee) is owned by Duke Energy Carolinas, LLC (Duke Energy) and withdraws cooling water from Lake Keowee in Oconee County, South Carolina (Figure 1-1). Oconee consists of three nuclear-fueled generating units, Units 1, 2, and 3, with a total gross generating capacity of 2,725 megawatts (MW). Unit 1 began operations in February 1973, Unit 2 began operations in October 1973, and Unit 3 began operations in July 1974 (USNRC 2018a; 2018b; 2018c). Water is withdrawn through a CWIS and the station's discharge to Lake Keowee is approved through the South Carolina Department of Health and Environmental Control (SCDHEC) NPDES Permit No. SC0000515[9]. Oconee withdraws greater than 125 MGD of raw water from the CWIS, using more than 25 percent of the total water withdrawn for cooling purposes; therefore it is subject to the Rule and required to submit each of the §122.21(r)(2)-(13) submittal requirements shown in Table 1-2.

[9] Oconee last submitted an NPDES permit renewal application on March 28, 2013 and is currently operating on an annual permit extension until a new permit is issued by SCDHEC.

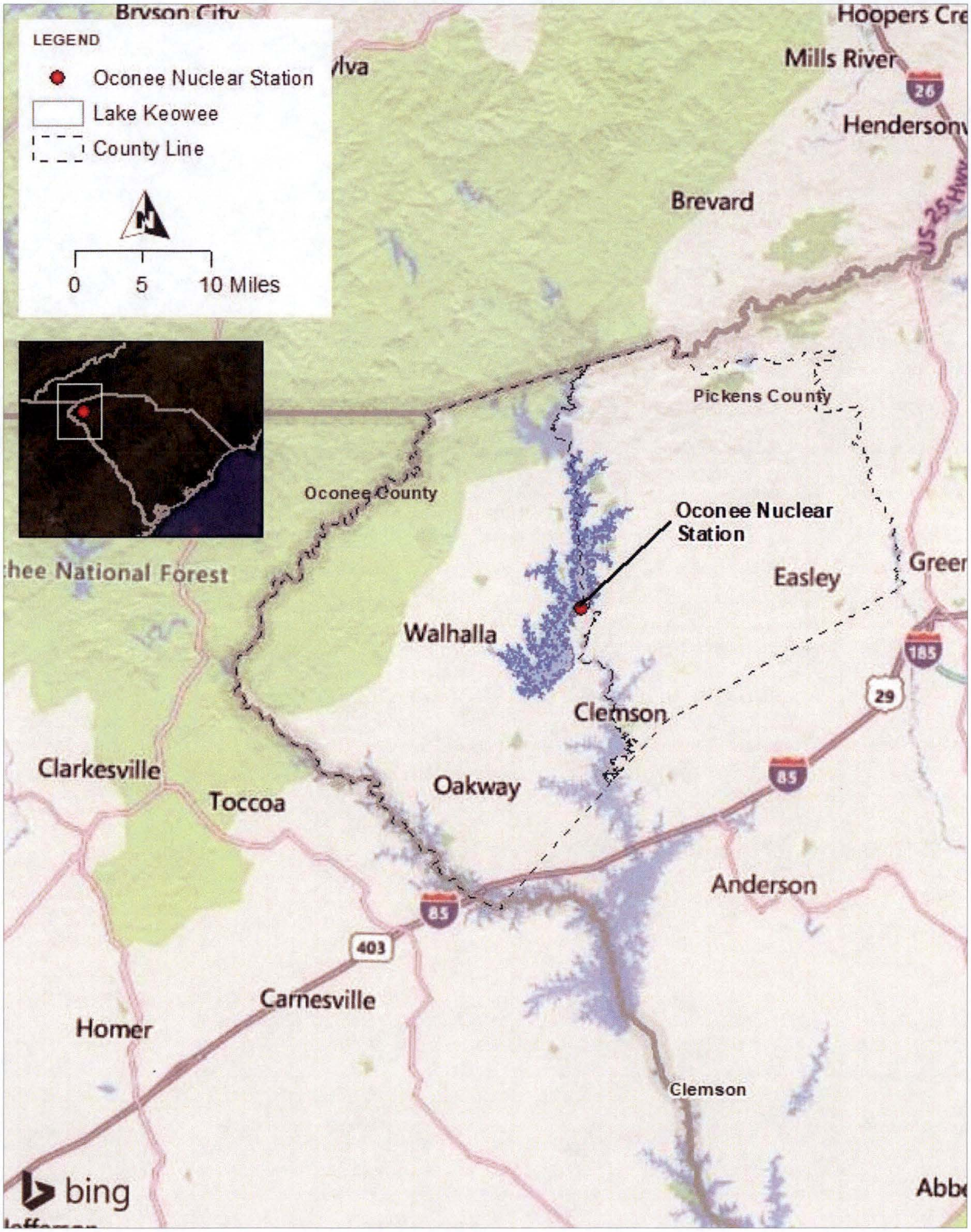

Figure 1-1. Oconee Nuclear Station Vicinity Map

Table 1-2. Summary of §316(b) Rule for Existing Facilities Submittal Requirements for §122.21(r)(2)-(13)

Submittal Requirements at §122.21(r)		Submittal Description
(2)	Source Water Physical Data	Characterization of the source waterbody including intake area of influence.
(3)	Cooling Water Intake Structure Data	Characterization of the cooling water intake system; includes drawings and narrative; description of operation; water balance.
(4)	Source Water Baseline Biological Characterization Data	Characterization of the biological community in the vicinity of the intake; life history summaries; susceptibility to impingement and entrainment; existing data; identification of missing data; threatened and endangered species and designated critical habitat summary for action area; identification of fragile fish and shellfish species list (<30 percent impingement survival).
(5)	Cooling Water System Data	Narrative description of cooling water system and intake structure; proportion of design flow used; water reuse summary; proportion of source waterbody withdrawn (monthly); seasonal operation summary; existing impingement mortality and entrainment reduction measures; flow/MW efficiency.
(6)	Chosen Method of Compliance with Impingement Mortality Standard	Provides facility's proposed approach to meet the impingement mortality requirement (chosen from seven options); provides detailed study plan for monitoring compliance, if required by selected compliance option; addresses entrapment where required.
(7)	Entrainment Performance Studies	Provides summary of relevant entrainment studies (latent mortality, technology efficacy); can be from the facility or elsewhere with justification; studies should not be more than 10 years old without justification; new studies are not required.
(8)	Operational Status	Provides operational status for each unit; age and capacity utilization for the past 5 years; upgrades within last 15 years; uprates and U.S. Nuclear Regulatory Commission relicensing status for nuclear facilities; decommissioning and replacement plans; current and future operation as it relates to actual and design intake flow.
(9)	Entrainment Characterization Study	Provides detailed information regarding the study methodology, data collection period and frequency, and analytical techniques used to identify and document the life stages of fish and shellfish in the vicinity of the cooling water intake structure(s) that are susceptible to entrainment, including any organisms identified by the Director, and any species protected under Federal, State, or Tribal law, including threatened or endangered species with a habitat range that includes waters in the vicinity of the cooling water intake structure. The owner or operator of the facility must identify and document how the location of the cooling water intake structure in the waterbody and the water column are accounted for by the data collection locations.
(10)	Comprehensive Technical Feasibility and Cost Evaluation Study	An evaluation of the technical feasibility of closed cycle recirculating systems as defined at §125.92(c), fine-mesh screens with a mesh size of 2 millimeters or smaller, and water reuse or alternate sources of cooling water. In addition, this study must provide a discussion of: (A) All technologies and operational measures considered (including alternative designs of closed-cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements); (B) Land availability, to include an evaluation of adjacent land, and acres potentially available due to generating unit retirements,

Submittal Requirements at §122.21(r)		Submittal Description
		production unit retirements, other buildings and equipment retirements, and potential for repurposing of areas devoted to ponds, coal piles, rail yards, transmission yards, and parking lots; (C) Available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility; and (D) Provide documentation of factors other than cost that may make a candidate technology impractical or infeasible for further evaluation.
11)	Benefits Valuation Study	Provide documentation of the incremental changes in the numbers of individual fish and shellfish lost due to impingement mortality and entrainment. Provides a description of basis for estimated changes in the stock sizes or harvest levels of commercial and recreational fish or shellfish species or forage fish species. Provides a description of the basis for monetized values assigned to changes in the stock size or harvest levels of commercial and recreational fish or shellfish species, forage fish, and to any other ecosystem or nonuse benefits. Details mitigation efforts completed prior to October 14, 2014 (as relevant) including how long they have been in effect and how effective they have been. Discusses, with quantification and monetization, where possible, of other benefits expected to accrue to the environment and local communities, including but not limited to improvements for mammals, birds, and other organisms and aquatic habitats.
(12)	Non-water Quality Environmental and Other Impacts Study	Estimates of changes to energy consumption, including but not limited to auxiliary power consumption and turbine backpressure energy penalty. Estimates of air pollutant emissions and of the human health and environmental impacts associated with such emissions. Estimates of changes in noise and a discussion of impacts to safety, including documentation of the potential for plumes, icing, and availability of emergency cooling water.
(13)	Peer Review	If the applicant is required to submit studies under §122.21(r)(10) to (r)(12), the applicant must conduct an external peer review of each report to be submitted with the permit application.

This document is arranged into sections that correspond with the headings listed for each of the §122.21(r)(2)-(13) compliance reporting requirements summarized in Table 1-2. Appendix 1-A provides a checklist of the submittal requirements under §122.21(r)(2)-(13) and summarizes how each of the requirements is addressed in this document.

1.1 Section 1 References

U.S. Environmental Protection Agency (USEPA). 2014. National Pollutant Discharge Elimination System – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, 79 FR 158, 48299 (August 15, 2014).

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2 Source Water Physical Data [§122.21(r)(2)]

The information required to be submitted per §122.21(r)(2), *Source Water Physical Data*, is outlined as follows:

(i) *A narrative description and scaled drawings showing the physical configuration of all source water bodies used by your facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports your determination of the waterbody type where each cooling water intake structure is located;*

(ii) *Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies;*

(iii) *Locational maps; and*

(iv) *For new offshore oil and gas facilities that are not fixed facilities, a narrative description and/or locational maps providing information on predicted locations within the waterbody during the permit term in sufficient detail for the Director to determine the appropriateness of additional impingement requirements under §125.134(b)(4).*

Each of these requirements is addressed in the following subsections.

2.1 Description of Source Waterbody

Oconee is located on Lake Keowee in eastern Oconee County, South Carolina, approximately eight miles northeast of Seneca, South Carolina. Lake Keowee is an impoundment created by the construction of the Keowee and Little River dams in 1971. The U.S. Army Corps of Engineers' (USACE) Lake Hartwell is located downstream of Oconee, and Lake Jocassee is approximately 11 miles to the north. Lake Jocassee and Lake Keowee are in the headwaters of the Savannah River Basin.

Lake Keowee is approximately 18.0 miles long, measured from the tailrace of Jocassee Dam downstream to the Little River Dam (Figure 2-1). The lower portion of Lake Keowee, which is impounded by the Little River Dam (referred to in this document as Lower Lake Keowee), is approximately 27 percent larger than upper portion of Lake Keowee (referred to herein as Upper Lake Keowee) with respect to volume, surface area, and shoreline length (Table 2-1). The upper and lower sections of the lake are joined by a man-made (i.e., excavated) canal that extends across the middle part of the lake. The CWIS at Oconee withdraws raw water for cooling purposes through an intake canal from Lower Lake Keowee.

Lake Keowee is part of the Keowee-Toxaway Project which provides water for the Jocassee Development on the northern reach of Lake Keowee and the Keowee Development, which includes a two-unit conventional hydroelectric plant located at the Keowee Dam (Federal Energy Regulatory Commission [FERC] No. 2503; Duke Energy 2014). Therefore, Lake Keowee is influenced by several adjacent energy and water uses including Oconee and three hydroelectric generating facilities (Jocassee and Keowee Developments and the Bad Creek Pumped-Storage Project) (Figure 2-1). The Bad Creek Pumped Storage Project is located to the northwest of Lake Jocassee while the Jocassee Development discharges into and withdraws water from the upper portion of Lake Keowee. Water released from the Keowee Development flows through the Seneca River to Lake Hartwell.

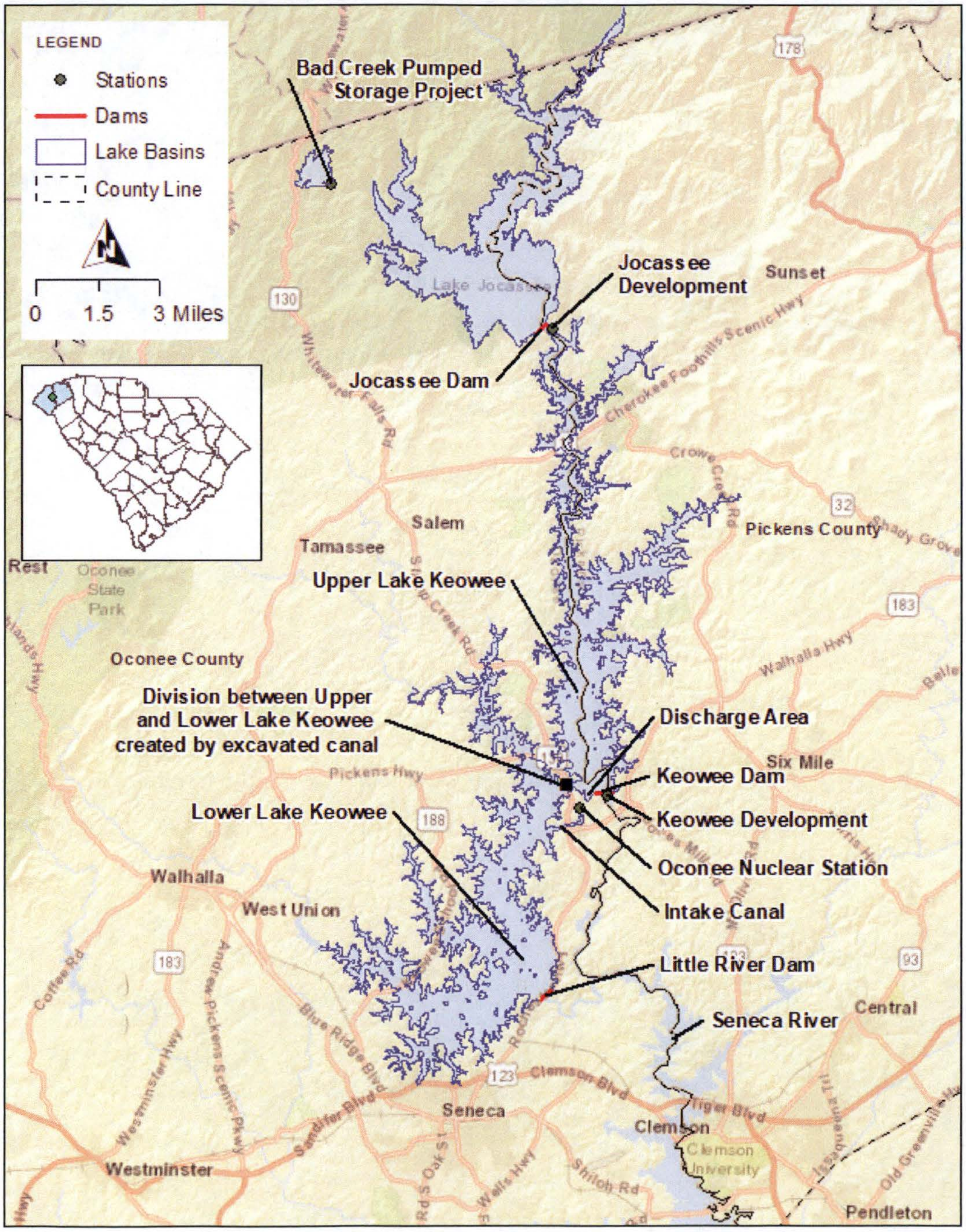

Figure 2-1. Keowee-Toxaway Project

Lake Keowee also provides municipal water to Seneca, South Carolina (Lower Lake Keowee) and Greenville, South Carolina (Upper Lake Keowee) (USACE 2014). Mean retention time of Lake Keowee is 420 days at an average river flow of 1,148 cubic feet per second (cfs) released through the Keowee Development (ASA 2008).

Lake Keowee has a full pond elevation (El.) of 800 feet (ft) above mean sea level (ft msl), a total surface area of 18,357 acres, a maximum water depth of 141 ft, and a mean depth of 52 ft (Table 2-1) (Duke Energy 2013). There are no permanent residences or commercial activities permitted within a 1-mile radius (Exclusion Zone) around Oconee (Duke Power Company 1998). However, some limited non-commercial activities are allowed such as highway traffic on SC-130, SC-183, and SC-6, as well as recreational use on Lake Keowee. The Old Pickens Presbyterian Church and Cemetery, a historic property not in regular service, and the Hartwell Reservoir, 9.8 acres of government-owned property, are also located within the Exclusion Zone (Duke Energy 2015).

Table 2-1. Physical Characteristics of Lake Keowee (Duke Energy 2013)

Parameter	Lower Lake Keowee	Upper Lake Keowee	Lake Keowee (Upper and Lower)
Watershed Drainage[1] (square miles)	164	272	436
Surface area (acres)	10,281	8,076	18,357
Volume (acre-ft)	533,547	418,753	952,300
Full pond elevation (ft msl)	800.0	800.0	800.0
Maximum depth (ft)	132.2	140.7	140.7
Mean depth (ft)	51.9	51.85	51.88
Maximum lake drawdown (ft)	10.0	10.0	10.0
Shoreline length (miles)	217.3	170.7	388

[1]USGS 2019

2.2 Characterization of Source Waterbody

2.2.1 Geomorphology

Lake Keowee is situated at the intersection of the Blue Ridge and Piedmont provinces; specifically, the Southern Crystalline Ridges and Mountains and Southern Inner Piedmont Level IV ecoregions (Griffith et al. 2002). The Southern Crystalline Ridges and Mountains consist of gneiss and schist bedrock underlying well-drained, acidic, loamy soils; approximate relief in the region is between 1,200 and 4,500 ft msl. The geology of the Lake Keowee basin is primarily composed of metamorphic bedrock consisting of granitic gneiss interspersed with layers of biotite-hornblende gneiss, biotite schist, and mica schist (Duke Energy 2007). The dominant soil types at Lake Keowee consist of sandy loam with some clay (USDA 2018).

2.2.2 Hydrology

Lake Keowee is part of the Savannah River Basin, which extends from the southeastern slopes of the Blue Ridge Mountains to the Atlantic Ocean along the South Carolina-Georgia border (Figure 2-2). Lake Keowee discharges to the Seneca River, which joins the Tugaloo River to form Lake Hartwell and becomes the Upper Savannah River farther downstream. These rivers form the Savannah River Basin (Hydrologic Unit Code 030601), which has a total drainage area of 10,400 square miles (USGS 2019).

Groundwater in the Piedmont region is derived from local precipitation and infiltration. Groundwater typically flows from topographically higher areas to areas of lower elevation; groundwater at Oconee flows from the northwest toward the southeast (S&ME 2008).

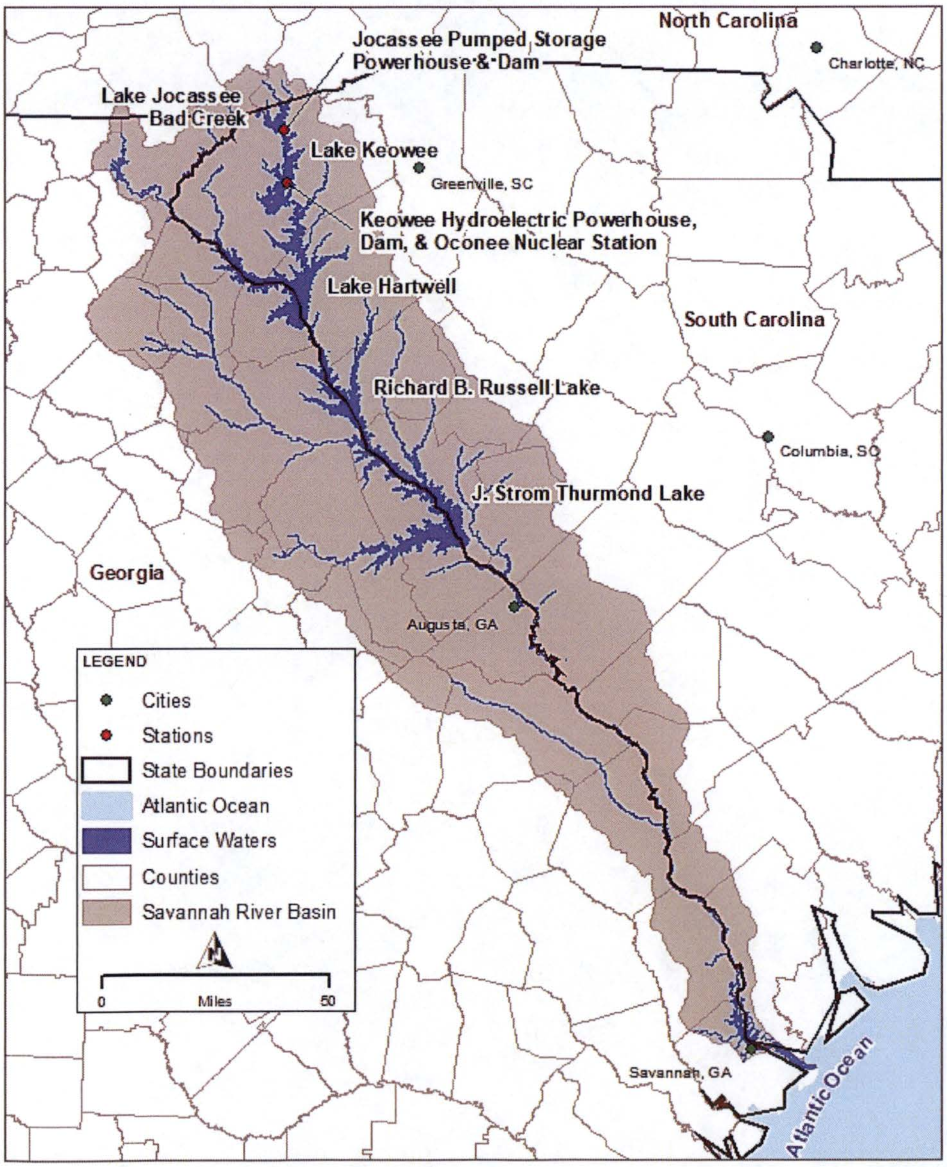

Figure 2-2. Savannah River Basin Map

2.2.3 Water Quality

Lake Keowee is classified as a monomictic (one stratification and turnover period per year), oligotrophic (low productivity) to oligo-mesotrophic (low to moderate productivity) reservoir (Duke Energy 2013). Oligotrophic reservoirs contain low nutrient levels with limited phytoplankton production and high water clarity, supporting limited fish and plant communities (USNRC 1999; Dobson and Frid 2009). Factors influencing the spatial and temporal variability in water quality throughout Lake Keowee include lake morphology, seasonal climate, water movement patterns associated with operations at the Jocassee Development, and the effects of Oconee cooling water withdrawals and thermal discharges (Duke Energy 2013).

Duke Energy collects water quality data in Lake Keowee during periodic environmental monitoring activities as part of CWA Section 316(a) demonstration studies required by the station's NPDES permit. Recent water quality measurements were collected at multiple locations in Lake Keowee, as illustrated in Figure 2-3, using a Hydrolab® data sonde to document in-situ measurements of temperature (degrees Celsius [°C]), dissolved oxygen (DO) in milligrams per liter (mg/L), pH, and specific conductivity. Depth profiles for each of the water quality parameters were established by collecting water samples at one-meter intervals between the surface and the lake bottom (Duke Power Company 1995; Duke Energy 2007, 2013). Additional details of Lake Keowee water quality sampling, water quality data analysis, and influence of Oconee operations on Lake Keowee are presented in CWA Section 316(a) demonstration reports.

2.2.3.1 Temperature

Although Upper Lake Keowee and Lower Lake Keowee are connected, there are differences in temperature within each impoundment due to the influence of the thermal plume generated by the Oconee discharge into Upper Lake Keowee, which is more profound in the winter months (Duke Energy 2013). Between 2013 and 2017, surface temperatures near the Oconee CWIS intake canal upstream of the curtain wall (water quality station 502) ranged from a minimum of 11.2°C to a maximum of 31.5°C (Table 2-2). Based on annual depth profiles collected from 1990 to 2017 (Duke Energy 2018), water temperatures documented for station 502 were consistently lower than those documented at stations in Upper Lake Keowee near Oconee's thermal discharge (stations station numbers 504, 504.5, and 508) (Figure 2-4). The pattern of spatial and seasonal variation in surface temperatures between Upper and Lower Lake Keowee demonstrated in Table 2-2 and Figure 2-4 are consistent with results from other historical monitoring data (Duke Power Company 1995; Duke Energy 2007).

Table 2-2. Annual Minimum, Maximum, and Mean Surface Temperature and DO in mg/L at Station 502 of Lake Keowee, 2013-2017

Year	2013 [1]	2014 [1]	2015 [2]	2016 [2]	2017 [2]
Temperature (°C)					
Min	12.9	11.2	15.4	12.3	19.5
Mean	19.7	19.6	20.8	18.9	17.8
Max	29.5	29.7	31.5	29.3	29.7
Dissolved Oxygen (mg/L)					
Min	6.9	6.7	7	7.6	7.3
Mean	8	8.2	8.3	8.5	8
Max	9.8	10.3	10.2	9.7	9.2

[1]Data collected once per month
[2] Data represent three sample periods per year: 2015 (March, August, and November); 2016 (February, June, and November); 2017 (March, May, and September).
Source: Duke Energy 2018

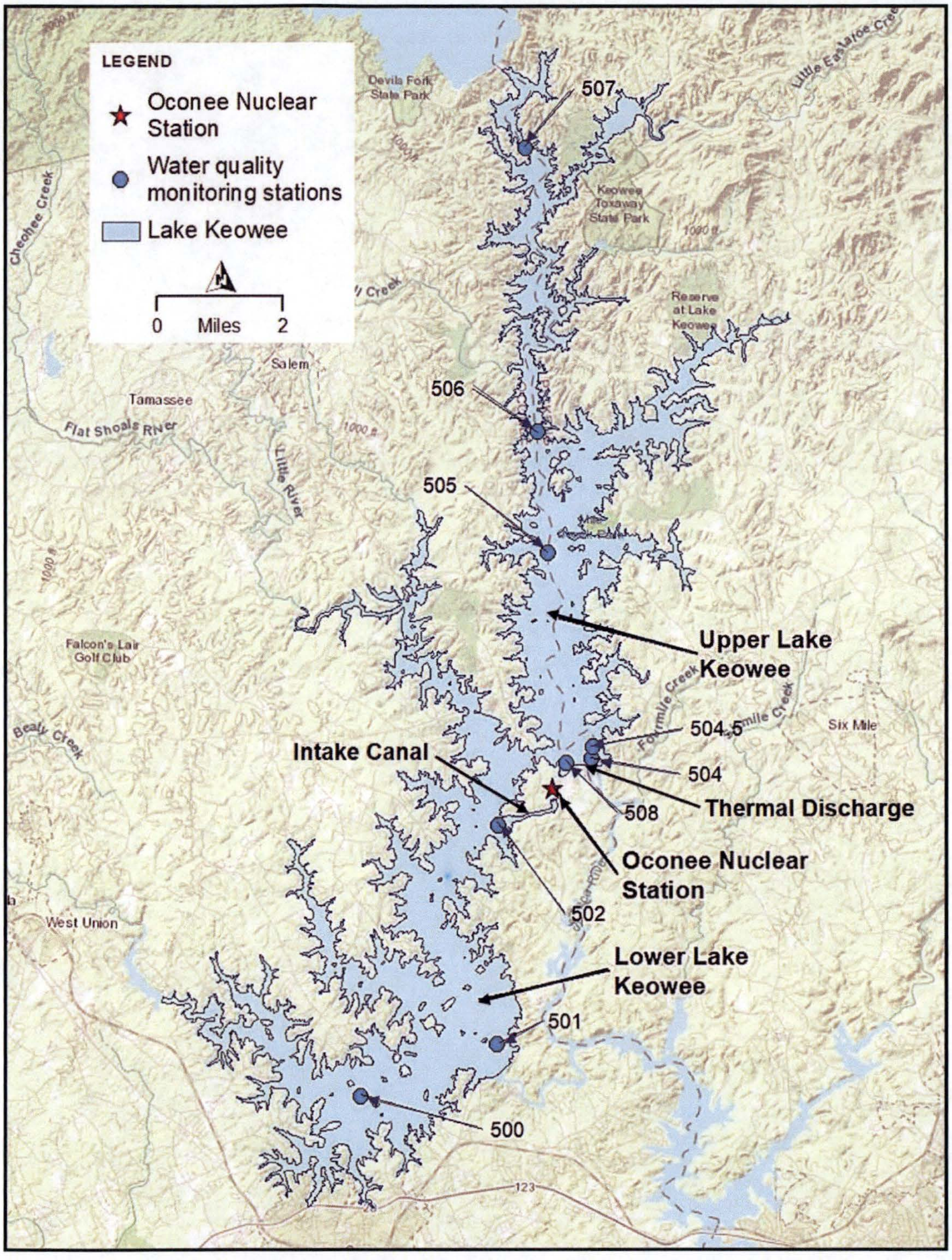

Figure 2-3. Water Quality Sampling Locations

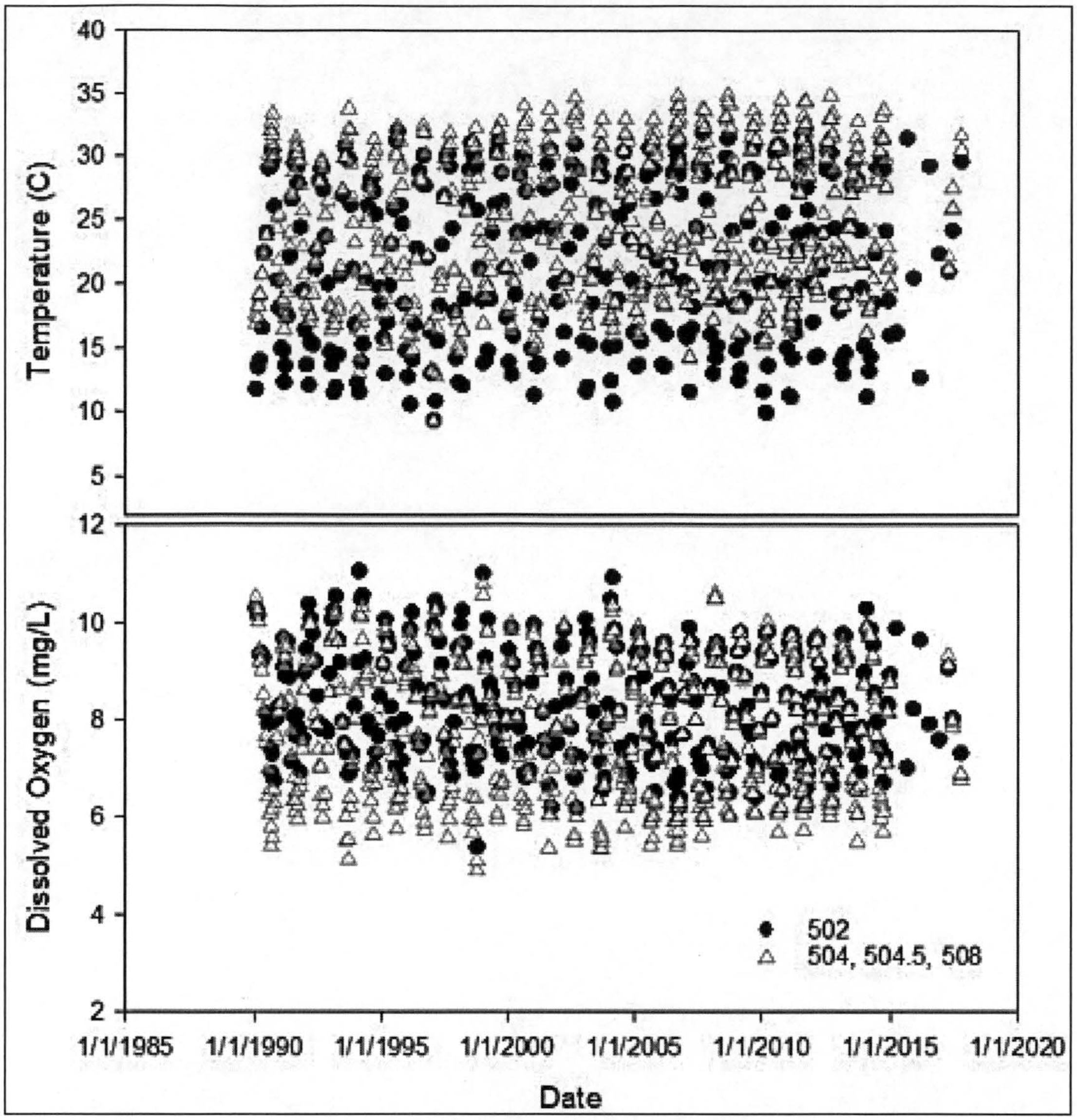

Figure 2-4. Annual Water Temperature (°C) and Dissolved Oxygen (mg/L) Profiles Collected Near the Intake Canal (Station 502) and Thermal Discharge (Stations 504, 504.5, and 508) in Lake Keowee from 1990 to 2017 (Duke Energy 2018)

The curtain wall located at the inlet of the intake canal also influences the spatial variation of water temperature in Lake Keowee (see Figure 3-1 in Section 3). In a 2017 study of curtain wall efficacy for reducing entrainment (HDR 2018; Appendix 7-A), surface water temperatures on the intake side of the curtain wall were between 0.5°C and 5.0°C cooler than on the lake side of the curtain wall (Figure 2-5). This trend is most pronounced in the late spring and summer months when Lake Keowee is stratified and water is withdrawn from below the thermocline. The curtain wall was constructed to help facilitate withdrawal from these cooler hypolimnetic waters to provide for greater plant cooling efficiency.

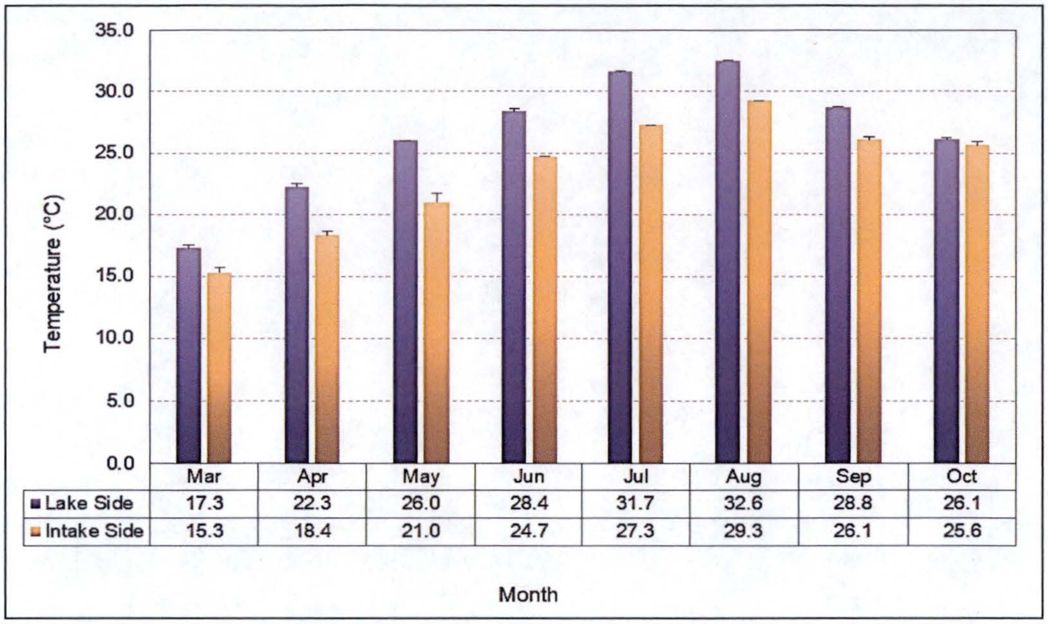

Figure 2-5. Surface Temperatures Documented (°C) on the Lake Side and Intake Side of the Oconee Curtain Wall, 2017 Curtain Wall Study at Oconee Nuclear Station (HDR 2018)

2.2.3.2 Dissolved Oxygen

Differences in DO concentrations have also been documented between the intake canal (water quality station 502) and the location of the thermal discharge. DO concentrations at water quality station 502 were generally higher than concentrations near the thermal discharge location (station numbers 504, 504.5, and 508) in response to higher temperatures in this area (Figure 2-4). DO levels near the Oconee CWIS ranged from 5.4 mg/L to 11.1 mg/L from 1993 to 2005 (Duke Energy 2007) and from 6.4 mg/L to 9.9 mg/L between 2006 and 2011 (Duke Energy 2013). Stratification of Lake Keowee increased through the summer and fall months with the most pronounced stratification and lowest DO concentrations observed in August and September. However, minimum DO concentrations in the upper 60 feet of the lake were consistently above the SCDHEC water quality standard of 5.0 mg/L in both Upper and Lower Lake Keowee (comprising approximately 90 percent of the lake water), which allowed adequate DO concentrations for sustained warm-water fish populations through the summer (Duke Energy 2007; Duke Energy 2013a). Available monitoring data indicate that water quality in Lake Keowee meets state water quality standards and designated uses year-round.

2.2.3.3 Nutrient and Ion Concentrations

Nutrient and major ion concentrations in surface waters in Lake Keowee were typically low during the years of the monitoring studies, frequently below the analytical reporting limit and did not exceed the state water quality standard for these parameters (Duke Energy 2013). Nutrient concentrations demonstrate minimal spatial or temporal variability with the exception of annual chloride and potassium concentrations, which exhibited an increasing trend from 1993 to 2011, and calcium, which exhibited a decreasing trend during the same time period. Nutrient concentrations in Lake Keowee were consistently lower than those recorded for other South Carolina impoundments, which reflects the basin geology and lack of significant point and non-point chemical loading to the reservoir (Duke Energy 2013).

2.3 Section 2 References

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3 Cooling Water Intake Structure Data [§122.21(r)(3)]

The information required to be submitted per §122.21(r)(3), *Cooling Water Intake Structure Data*, is outlined as follows:

- *(i)* *A narrative description of the configuration of each of the cooling water intake structures and where it is located in the waterbody and in the water column;*
- *(ii)* *Latitude and longitude in degrees, minutes, and seconds for each of the cooling water intake structures;*
- *(iii)* *A narrative description of the operation of each of the cooling water intake structures, including design intake flows, daily hours of operation, number of days of the year in operation and seasonal changes, if applicable;*
- *(iv)* *A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and*
- *(v)* *Engineering drawings of the cooling water intake structure.*

Each of these requirements is addressed in the following subsections.

3.1 Cooling Water Intake Structure Configuration [§122.21(r)(3)(i)]

Oconee withdraws cooling water through a CWIS at the end of a 5,860-foot (ft) long intake canal situated on Lower Lake Keowee. Oconee's cooling water intake system consists of a curtain wall at the entrance of the intake canal, a submerged weir near the entrance of the intake canal, a trash boom, and a CWIS at the downstream end of the intake canal as shown on Figure 3-1. The CWIS includes bar racks, trash deflector plates, fixed panel mesh screens, and vertical wet-pit circulating water pumps (commonly referred to as condenser cooling water [CCW] pumps).

Full pond in Lake Keowee is at El. 800 ft msl and the normal maximum drawdown is 10 ft at El. 790 ft msl (USACE 2014). The main purpose of the curtain wall at the entrance of the intake canal is to facilitate the withdrawal of cooler water from the bottom of Lake Keowee to Oconee's cooling water system. The curtain wall extends from El. 800.5 ft msl (i.e., 0.5 ft above full pond) down to El. 733 ft msl, effectively blocking the upper 67 ft of the water column, while leaving the bottom 23 ft open (the lake bottom is at approximately El. 710 ft msl) (Duke Power Company 1984). A sketch showing the curtain wall parameters is provided on Figure 3-2. The curtain wall also effectively reduces the number of fish eggs and larvae in the upper portion of the water column from entering the intake canal and CWIS and subsequently from becoming entrained in the CWIS. The existing curtain wall is discussed further in Section 5.3 and Section 6 of this document and the 2017 Curtain Wall Entrainment Reduction Performance Study is summarized in Section 7.1.2

A submerged weir is located approximately 850-ft downstream of the curtain wall and acts as a barrier to maintain enough water inside the intake canal for safe station shutdown in the event of an emergency, whereby cooling water from Lake Keowee is no longer available. The weir extends from

El. 770 ft msl down to El. 725 ft msl, and is approximately 630 ft in length as shown on Figure 3-2 (Duke Power Company 1984; EPRI 2008). The weir has a top width of 10 ft, a bottom width of 113 ft, and a 2.5:1 slope ratio on both its upstream and downstream sides (Duke Power Company 1984).

A trash boom spans the width of the intake canal approximately 900-ft upstream of the CWIS. The boom is angled towards the east side of the intake canal to collect and funnel debris towards the shore, where it is removed and disposed of in a landfill (EPRI 2008).

The CWIS is divided into three sections, one for each of Units 1, 2, and 3, and has 24 total intake bays (8 intake bays per unit). Figure 3-3 depicts the layout of the Unit 1 portion of the CWIS and is representative of Units 2 and 3, as well. Each 11.3-ft-wide intake bay is equipped with a bar rack and a trash deflector plate (8 bar racks per unit, 24 total) that prevent large debris from entering the CWIS and a fixed panel mesh screen (8 fixed screens per unit, 24 total) that filters finer debris. The bar racks are composed of stainless steel and have a 2.5-inch vertical bar spacing (Duke Power Company 1994b). The fixed panel mesh screens are equipped with 3/8-inch coarse mesh with 1/8-inch wire diameter, and are 10.75-ft wide and 50-ft tall (EPRI 2008). The bar rack and fixed screen invert is at El. 761 ft msl (Duke Power Company 2000).

The overhang at the face of the CWIS is located on the downstream side of the fixed panel mesh screens and extends from the top of the CWIS (El. 810 ft msl) down to El. 781 ft msl. The bottom of the CWIS is at El. 761 ft msl, resulting in a 20-ft opening through which cooling water is withdrawn as shown on Figure 3-4 (Duke Power Company 2000). As a result, the CWIS overhang functions like a curtain wall structure and provides additional entrainment reduction benefits (see Section 4.3.2).

Screen cleaning is performed manually when an alarm for high screen differential pressure is received; affected screens are lifted with a mobile crane and sprayed with high pressure water to remove debris (Duke Energy 2013).

Each unit has four vertical, wet-pit type CCW pumps (1 pump for every 2 intake bays, 12 pumps total). Table 3-1 and Table 3-2 provide information on CCW pump capacity and operation.

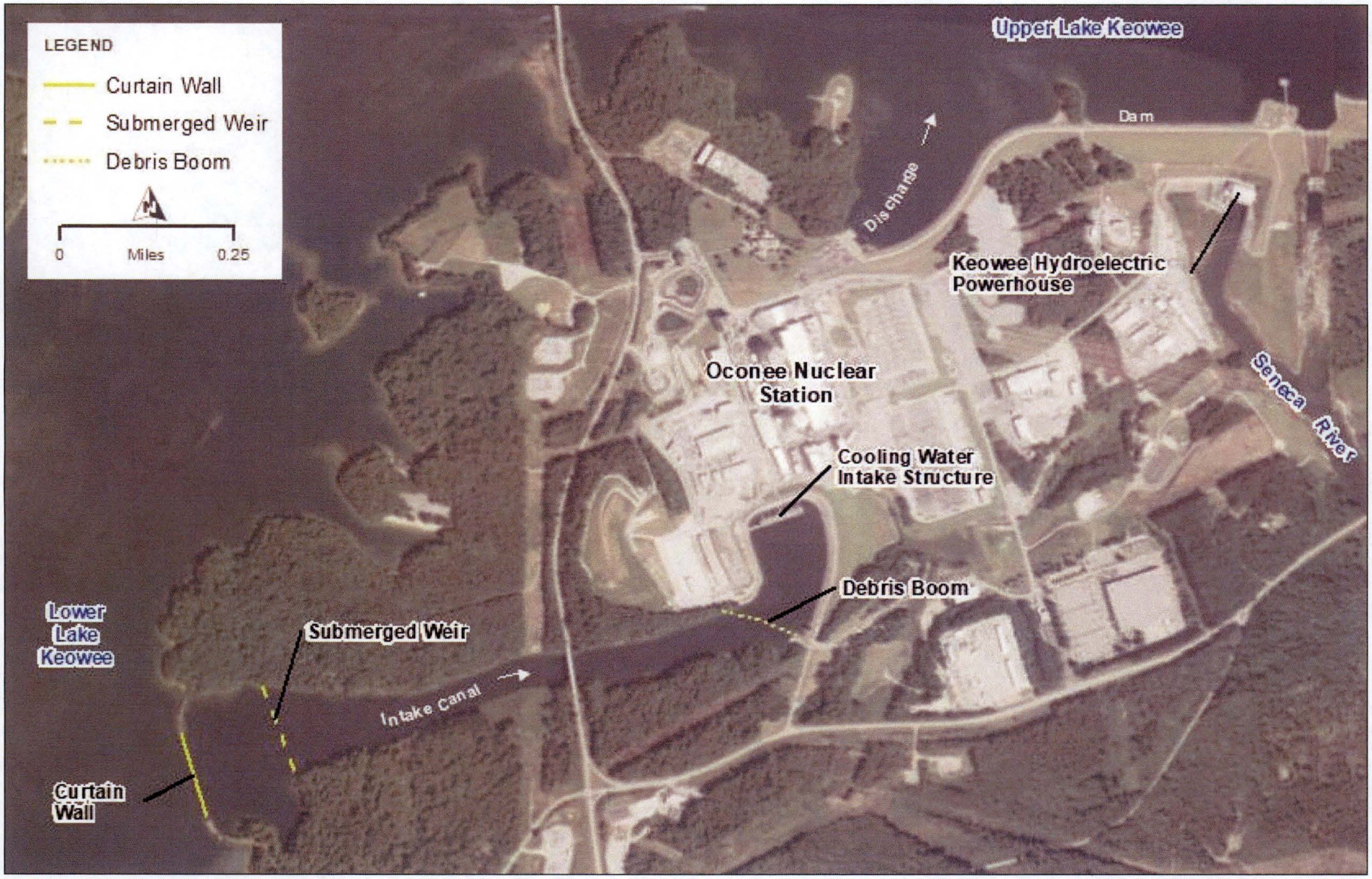


Figure 3-1. Oconee Nuclear Station Location Map

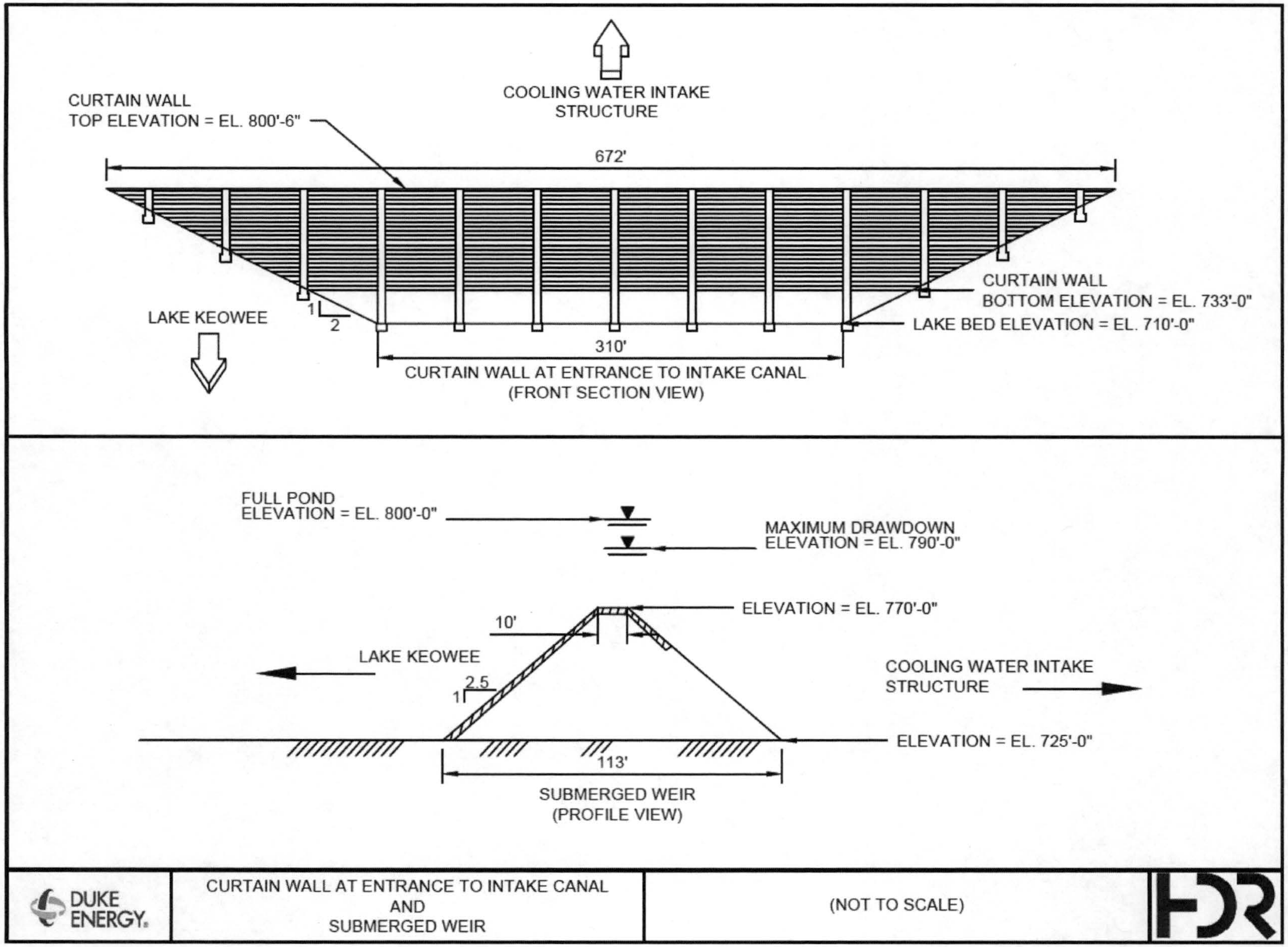


Figure 3-2. Oconee Nuclear Station Curtain Wall at Entrance to Intake Canal and Submerged Weir (Duke Power Company 1984)

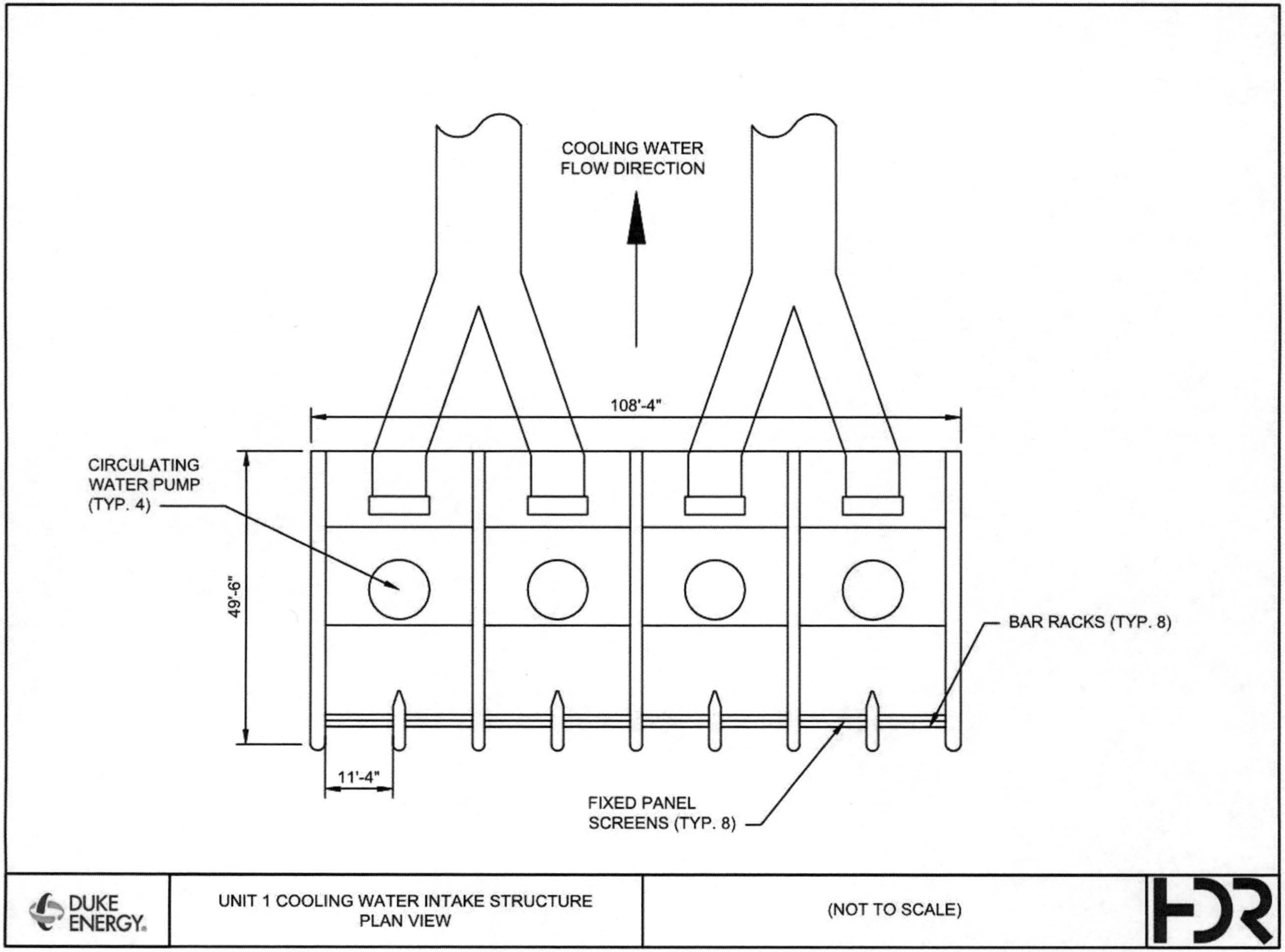


Figure 3-3. Oconee Nuclear Station Unit 1 Cooling Water Intake Structure Plan View (Duke Power Company 2000)

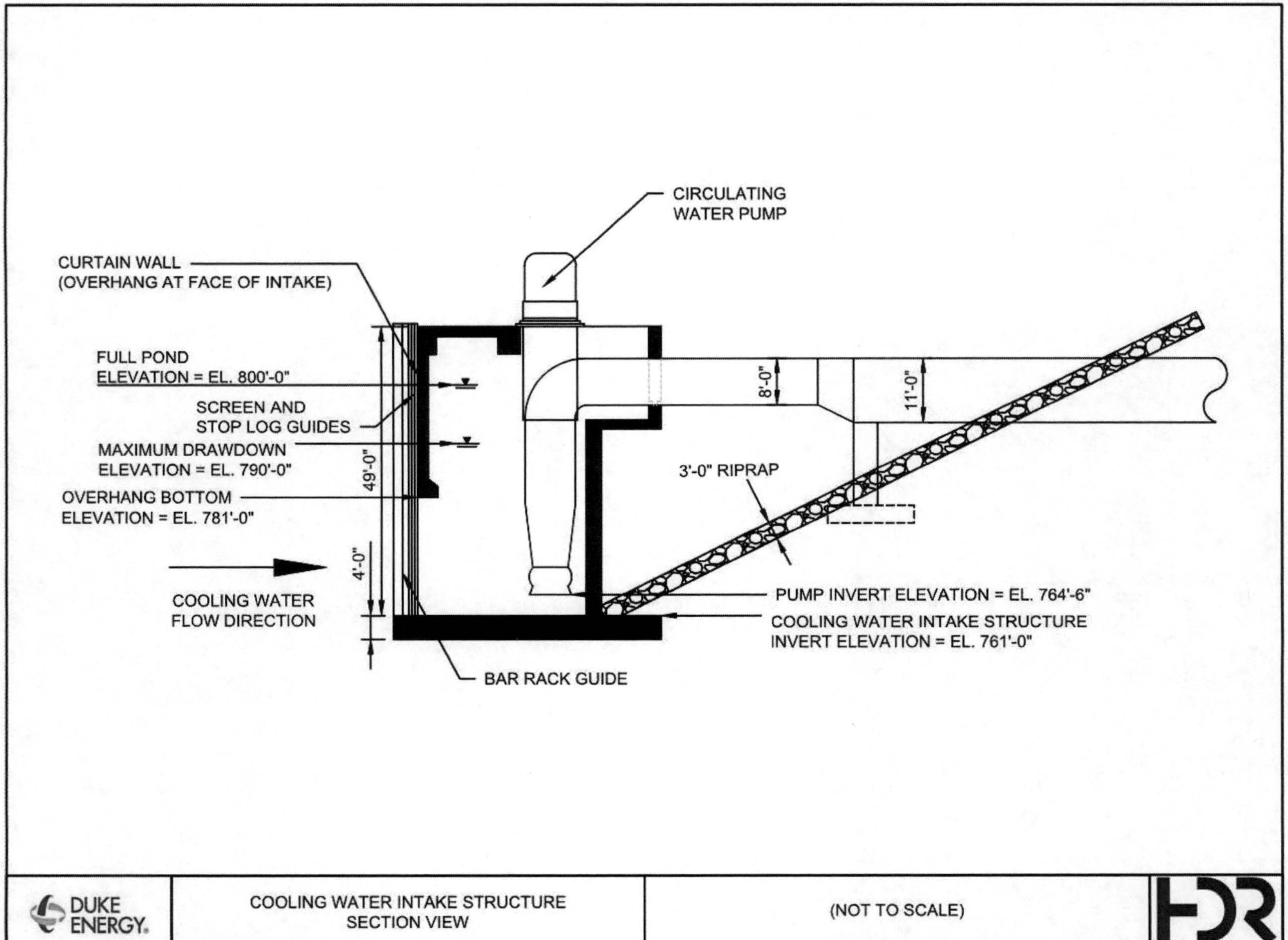


Figure 3-4. Oconee Nuclear Station Cooling Water Intake Structure Section View (Duke Power Company 2000; EPRI 2008; USACE 2014)

3.2 Latitude and Longitude of Cooling Water Intake Structure [§122.21(r)(3)(ii)]

Oconee withdraws cooling water from Lower Lake Keowee via a CWIS at latitude 34° 47' 29" N and longitude 82° 53' 55" W (Google 2019).

3.3 Cooling Water Intake Structure Operations and Intake Flows [§122.21(r)(3)(iii)]

Per the Rule, DIF is defined as "the maximum instantaneous rate of flow of water the intake structure is capable of withdrawing from a source waterbody". Cooling water for Oconee is withdrawn from Lower Lake Keowee using 12 CCW pumps. Each CCW pump has a rated capacity of 246,000 gallons per minute (gpm) (354.2 MGD), for a total cooling system pumping capacity of 2,952,000 gpm (4,251 MGD) (Duke Energy 2002). However, there is a condenser piping restriction in the 8-ft-diameter header pipes on the downstream side of the CCW pumps that limits the capacity of each unit to 708,000 gpm (1,019.5 MGD), for a total DIF of 2,124,000 gpm (3,059 MGD), as summarized in Table 3-1 (Duke Energy 2002). A breakdown of flow per unit based on the number of CCW pumps in operation is provided in Table 3-2.

Table 3-1. Oconee Nuclear Station Design Intake Flow

Generating Unit	Pumps	Pump Capacity (gpm)[1]	Pump Capacity (MGD)
1	1	246,000	354.2
	2	246,000	354.2
	3	246,000	354.2
	4	246,000	354.2
2	1	246,000	354.2
	2	246,000	354.2
	3	246,000	354.2
	4	246,000	354.2
3	1	246,000	354.2
	2	246,000	354.2
	3	246,000	354.2
	4	246,000	354.2
Station DIF		**2,124,000[2]**	**3,059**

[1] While the individual CCW pump design capacity is 246,000 gpm (354.2 MGD), when multiple pumps are operating for a given unit, a piping restriction limits the cooling system capacity to 708,000 gpm (1,019 MGD) per unit.
[2] Due to the piping restriction, the total water withdrawal through the CWIS (all three units combined) is limited to 2,124,000 gpm (3,059 MGD).
Source: Duke Energy 2002, 2019

Table 3-2. Oconee Nuclear Station Flow per Unit Based on Number of Pumps Operating

Number of Pumps Operating	Flow (gpm)	Flow (MGD)
1	246,000	354.2
2	465,000	669.6
3	609,000	877.0
4	708,000	1,019.5

Source: Duke Energy 2019

The AIF based on daily pump operation data for Oconee from July 1, 2014 through June 30, 2019 is presented in Table 3-3. Oconee's AIF during this 5-year period was 2,625 MGD, or approximately 86 percent of the facility's DIF. Average withdrawal rates for this period for each unit were 865 MGD for Unit 1, 881 MGD for Unit 2, and 879 MGD for Unit 3 (Duke Energy 2019). See Table 5-2 in Section 5.1.2 for number of days per year and month when Oconee CCW pumps operated.

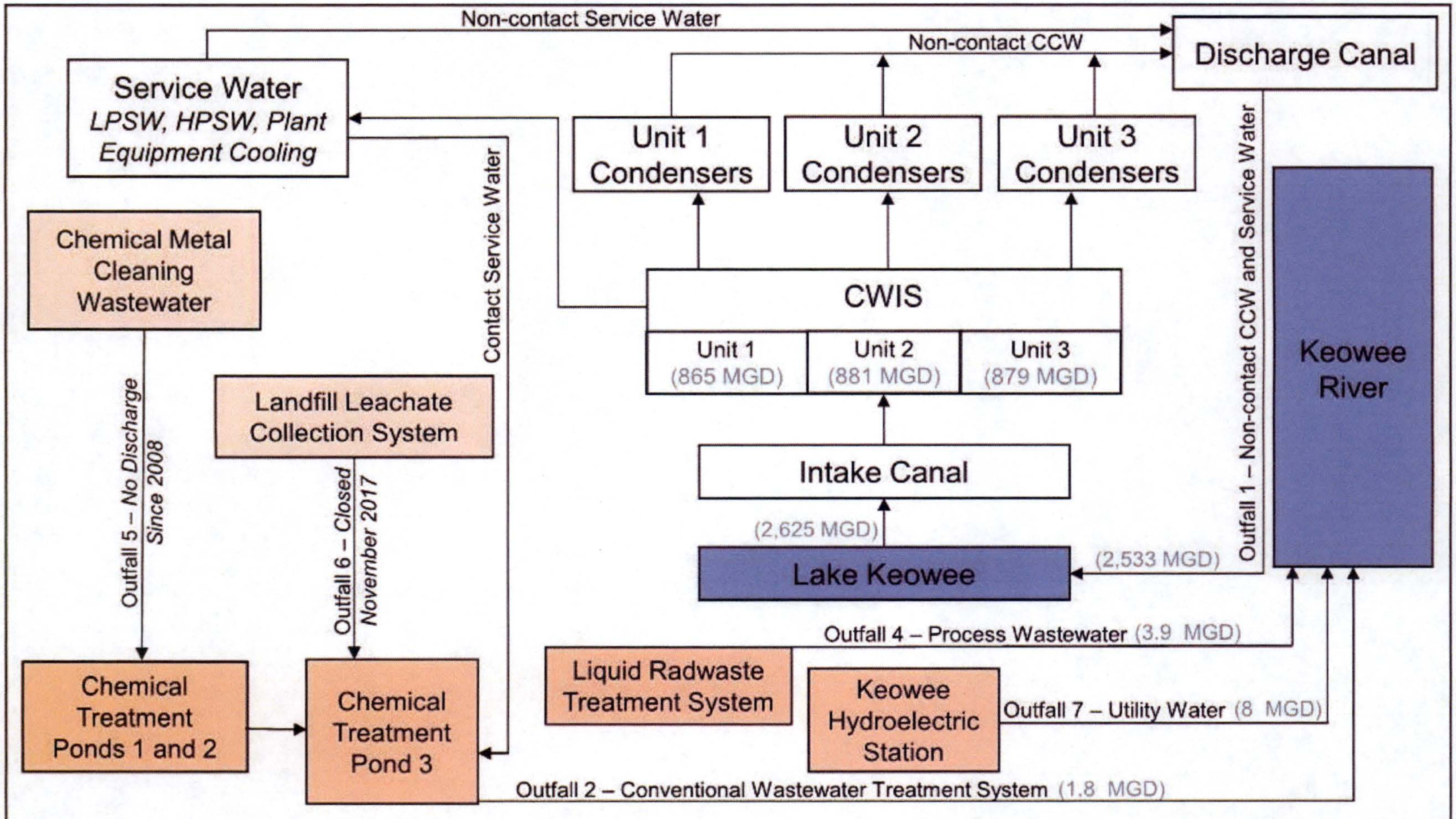
Table 3-3. Actual Intake Flow at Oconee Nuclear Station

Month	Average Monthly Withdrawals from Lake Keowee from July 1, 2014 through June 30, 2019 (MGD)					
	2014	2015	2016	2017	2018	2019
January		2,227	2,492	2,477	2,330	2,591
February		2,047	2,243	2,339	2,023	2,009
March		2,060	2,371	2,588	2,015	2,016
April		2,351	2,397	2,635	2,326	2,284
May		2,631	2,328	2,363	2,283	2,635
June		2,775	2,807	2,992	2,649	2,807
July	3,006	3,059	3,059	3,059	3,036	
August	3,059	3,059	3,059	3,059	3,059	
September	3,059	3,038	3,059	3,055	3,059	
October	3,037	2,467	3,007	2,871	2,683	
November	2,267	2,700	2,345	2,182	2,539	
December	2,561	2,634	2,634	2,631	2,583	
					AIF during Period of Record	**2,625**

Note: Gray shaded cells are not included in the five-year period of record used to evaluate average monthly flows.
Source: Duke Energy 2019

3.4 Flow Distribution and Water Balance [§122.21(r)(3)(iv)]

Oconee employs a once-through cooling system, utilizing Lake Keowee for cooling water needs. Water use based on typical station operations is provided in Oconee's water balance diagram (Figure 3-5).



Notes:
1. Acronyms: CWIS – cooling water intake structure, LPSW – low pressure service water, HPSW – high pressure service water, CCW – condenser cooling water, AIF – actual intake flow.
2. Service water flow is pulled from the Units 1-3 CWIS.
3. The discharge canal receives non-contact cooling water from the Units 1-3 condensers and the service water system.
4. Cooling water withdrawn from Lake Keowee is represented by the AIF for the period from July 1, 2014 – June 30, 2019. All other flow values are annual averages from the 2013 Oconee NPDES Permit Renewal Application.
5. Outfall 3 has been abandoned since February 2010. Sanitary wastewater is now routed to the Seneca Light and Water Facility, and later treated at the Coneross Treatment Plant by the Oconee Joint Regional Sewer Authority.

Figure 3-5. Oconee Nuclear Station Water Flow Schematic

3.5 Determination of Area of Influence

The Oconee CWIS is located on the shores of Lake Keowee immediately southwest of Keowee Dam, which is at Keowee River mile 328.8 (FERC 2016). For this study, the area of influence (AOI) is defined as the portion of the source waterbody where water flow may be hydraulically influenced by the withdrawal of water at the CWIS. This report provides conservative estimates to define the AOI that should not be interpreted as the area of direct impact, or the area for which aquatic organisms have a high probability of being withdrawn by the intake structure. Actual entrainment and impingement at Oconee would be the result of a combination of many dynamic physical and biological factors that vary over space, time, and species.

3.5.1 Regulatory Background

The AOI of a CWIS is not formally defined in the Rule; however, AOI is referenced in several sections of the Federal Register (79 FR 158, 48299[10]):

- 79 FR 158, 48363, §122.21(r)(2) "Source Water Physical Data", states that information on "the methods used to conduct any physical studies to determine the intake's *area of influence* in the waterbody and the results of such studies" is required to be submitted;
- 79 FR 158, 48363, §122.21(r)(4) "Source Water Baseline Biological Characterization Data", states: "The study area should include, at a minimum, the *area of influence* of the cooling water intake structure";
- 79 FR 158, 48367, §122.21(r)(11) "Benefits Valuation Study", states: "The study must also include discussion of recent mitigation efforts already completed and how these have affected fish abundance and ecosystem viability in the intake structure's *area of influence*";
- 79 FR 158, 48363, §122.21(r)(2)(ii) states: "Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's *area of influence* within the waterbody and the results of such studies"; and
- 79 FR 158, 48363, §122.21(r)(4)(viii) states: "The study area should include, at a minimum, the area of influence of the cooling water intake structure".

While neither a formal definition of the AOI nor guidance for its estimation are provided in the Rule, it is assumed that the AOI is that area of the source waterbody from which aquatic organisms would be expected to have a high probability of being drawn into the CWIS and either impinged or entrained.

3.5.2 Impingement Area of Influence

3.5.2.1 Description

For impingeable-sized aquatic organisms (i.e., juvenile and adult fish and shellfish), the AOI can be defined as the region extending outwards from the intake screens in which aquatic organisms would not be capable of overcoming the velocities created by water withdrawals at the CWIS, and thus

[10] National Pollutant Discharge Elimination System – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, 79 FR 158, 48299 (August 15, 2014) (USEPA 2014).

would have a higher probability of becoming impinged upon an intake screen (EPRI 2007). A conservative definition of the AOI[11] for impingement is the area encompassed by the velocity contour created by the 0.5 feet per second (fps)[12] through-screen velocity (TSV) threshold identified at §125.94(c). At this boundary and beyond it, the potential for impingement would be expected to be minimal. Within the 0.5-fps boundary, the potential for impingement would increase. However, because juvenile and adult fish have varying swimming abilities and preferred habitats, including those that involve velocities above 0.5 fps (Leonard and Orth 1988), aquatic organisms located within the impingement AOI would not necessarily become impinged.

3.5.2.2 Estimation Method

The calculation for the AOI of a CWIS is based on the principles of conservation of mass and continuity. The boundary of the AOI is the location where the velocity induced by the CWIS is equal to a specified threshold velocity. For this evaluation, 0.5 fps was selected as the threshold velocity for the impingement AOI. The AOI is estimated from the continuity equation for conservation of mass (Eq. 3-1).

$$Q = v\,A \qquad \text{Eq. 3-1}$$

Where,

Q = Intake flow rate (cfs)
A = Cross-sectional area (square ft)
v = Threshold velocity (fps)

The equation is then rearranged to solve for the cross-sectional area (Eq. 3-2).

$$A = \frac{Q}{v} \qquad \text{Eq. 3-2}$$

Once area is solved for, the length of the cross section can be calculated (Eq. 3-3).

$$L = \frac{A}{d} \qquad \text{Eq. 3-3}$$

Where,

L = Length of the cross-sectional area (ft)
d = Water depth (ft)

The intake flow rate and threshold velocity are known values, while the cross-sectional area that would be required to convey the intake flow rate at the threshold velocity is a calculated value. The cross-sectional area is equal to the water depth at the Oconee CWIS (a known value) multiplied by the length of the AOI boundary. Once the length of the AOI is calculated using Eq. 3-3, it is compared to the length of the face of the CWIS. If the length of the AOI is less than the total length of the face of the CWIS, then the AOI is fully contained within the CWIS and does not extend into the waterbody (see Figure 3-6).

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[11] This approach was proposed to the Ohio Environmental Protection Agency by Dayton Power & Light in their Proposal for Information Collection for the Stuart Generating Station on the Ohio River. Their approach was accepted and also recommended as a model for other facilities on the Ohio River (EPRI 2007).

[12] Per the Rule, a TSV of less than 0.5 fps meets the impingement mortality reduction standards through Compliance Alternatives 2 and 3 (§125.94(c)(2)-(3)) for design and actual intake flows, respectively.

If the length of the AOI is greater than the total length of the face of the CWIS, then the AOI extends into the waterbody and is approximated as an arc. In the case of the AOI extending into the waterbody as an arc, it is assumed that the intake flow would be uniform through the arc's cross-section.

To develop a conservative estimate of AOI, the results presented in the following section are based on the station DIF and water depth at the maximum drawdown water elevation in Lake Keowee. See Figure 3-1 for an overview of the Oconee cooling water intake and discharge system. Detailed impingement AOI calculations are provided in Appendix 3-A.

3.5.2.3 Results

The impingement AOI was calculated based on the DIF at Oconee using the full pond and maximum drawdown water elevations. The maximum drawdown water elevation provides a conservative estimate of the impingement AOI. As shown in Appendix 3-A, the required cross-sectional length within the intake canal to achieve the impingement threshold velocity of 0.5 fps at the full pond elevation is equal to 237 ft, while this length at the maximum drawdown elevation is equal to 315 ft. The face of the Oconee CWIS is approximately 328 ft in length, therefore impingeable-sized organisms within the intake canal in the vicinity of the CWIS would be subject to velocities less than 0.5 fps, and the impingement AOI does not extend out into the waterbody. The impingement AOI at Oconee is presented on Figure 3-6.

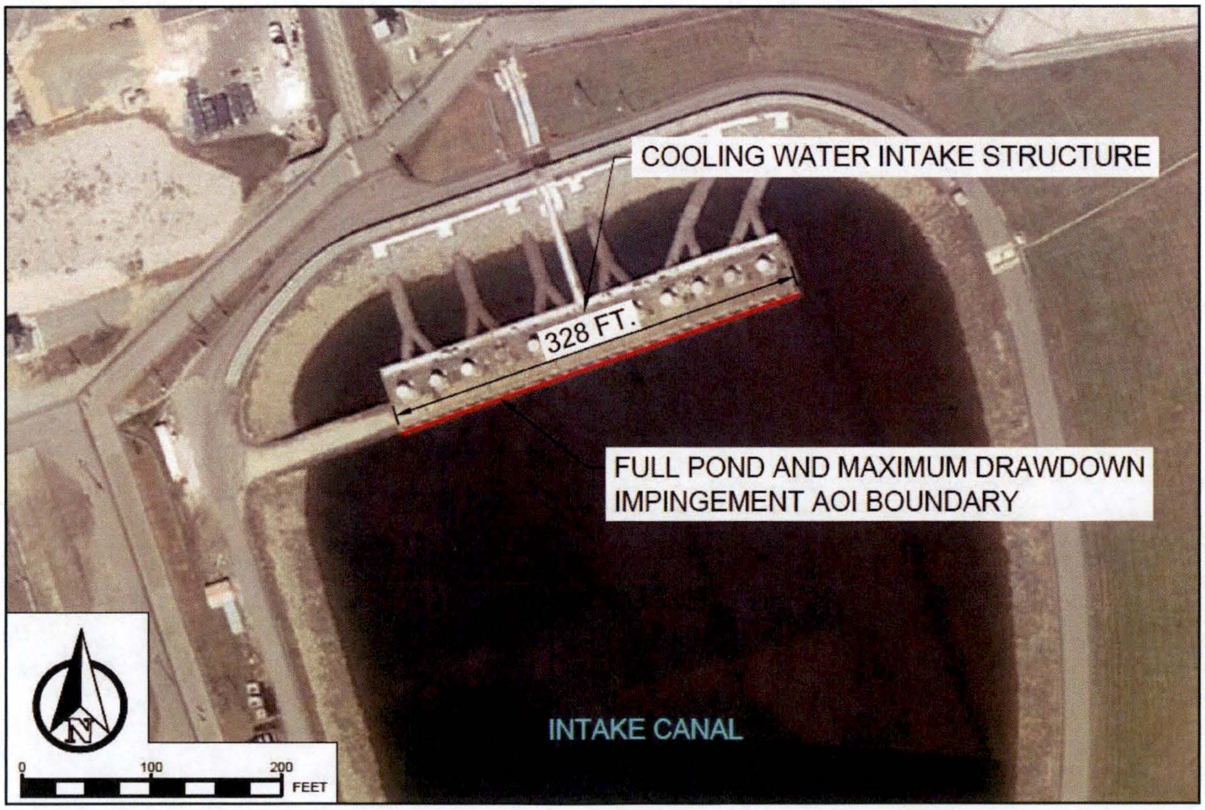

Figure 3-6. Impingement Area of Influence at 0.5-fps Rule Threshold Velocity

3.5.3 Entrainment Area of Influence

3.5.3.1 Description

The majority of aquatic organisms that are considered susceptible to entrainment are in early life stages, unable to swim, and/or float on the water surface. These organisms would be subject to ambient flows and currents within the source waterbody, which can be highly variable. Physical and temporal factors that influence the entrainment AOI of a CWIS include (EPRI 2004):

1. Speed, direction, and distribution of flow in the waters that surround the CWIS;
2. Localized wind speeds and directions in the vicinity of the CWIS;
3. Bathymetry of the waterbody in the vicinity of the CWIS;
4. CWIS flow rate and variability of flow to the CWIS; and
5. CWIS design.

Due to the variability associated with these factors, an entrainment AOI at Oconee has not been quantified, but is discussed qualitatively.

3.5.3.2 Results

Aquatic organisms that are considered susceptible to entrainment would be subject to ambient flows and currents within Lake Keowee and the intake canal at Oconee. The potential exists for entrainment of aquatic organisms within the intake canal at Oconee, and the likelihood of entrainment would increase as an organism's proximity to the Oconee CWIS increases. However, a curtain wall is located at the entrance of the intake canal, which facilitates water withdrawal from the lower portion of the water column, thereby reducing the number of ichthyoplankton in the upper water column from entering the intake canal. A study conducted by Duke Energy from March through October of 2017 was performed on the intake and lake sides of the curtain wall at Oconee to characterize the ichthyoplankton communities and evaluate the efficacy of the curtain wall at reducing entrainment at the Oconee CWIS. Over the eight-month sampling period, densities of ichthyoplankton on the intake side of the curtain wall were 76.6 percent lower than ichthyoplankton densities on the lake side, indicating that the curtain wall is effective at limiting the number of organisms susceptible to entrainment at the CWIS (see Section 7.1.1).

3.6 Engineering Drawings of the CWIS [§122.21(r)(3)(v)]

The following engineering drawings of the CWIS at Oconee are provided in Appendix 3-B:

- Oconee Nuclear Station - Intake Structure General Arrangement Plans and Sections, Drawing No. O-339, 16 Nov 2000, Revision 7 (Duke Power Company 2000);
- Oconee Nuclear Station Units 1, 2 & 3 – Intake Structure Sections and Details Concrete, Drawing No. O-341B, 2 May 1994, Revision 4 (Duke Power Company 1994a);
- Oconee Nuclear Station Units 1, 2 & 3 – Intake Structure Bulkhead Gates & Screens, Drawing No. O-346, 13 Sep 2004, Revision 2 (Duke Power Company 2004);
- Oconee Nuclear Station Units 1, 2, & 3 – Intake Structure Trash Rack Details, Drawing No. O-347, 2 May 1994, Revision 3 (Duke Power Company 1994b);

- Condenser Circulating Water System – Submerged Weir and Skimmer Wall, Drawing No. CCW-3, 28 Nov 1984 (Duke Power Company 1984); and
- Oconee Nuclear Station Site Facilities Map – Sheet 1, 3, and 4 of 4 Site Plan, 28 Apr 2018 (Duke Energy 2018).

3.7 Section 3 References

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__________. 2019. Oconee Nuclear Station Actual Intake Flow Rates: 7/1/2014 – 6/30/2019. Received: 3 Jul 2019.

Duke Power Company. 1984. Condenser Circulating Water System – Submerged Weir and Skimmer Wall. Drawing No. CCW-3. 28 Nov 1984.

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4 Source Water Baseline Biological Characterization Data [§122.21(r)(4)]

The information required to be submitted per §122.21(r)(4), *Source Water Baseline Biological Characterization Data,* is outlined as follows:

(i) *A list of the data in paragraphs (r)(4)(ii) through (vi) of this section that are not available and efforts made to identify sources of the data;*

(ii) *A list of species (or relevant taxa) for all life stages and their relative abundance in the vicinity of the cooling water intake structure;*

(iii) *Identification of the species and life stages that would be most susceptible to impingement and entrainment. Species evaluated should include the forage base as well as those most important in terms of significance to commercial and recreational fisheries;*

(iv) *Identification and evaluation of the primary period of reproduction, larval recruitment, and period of peak abundance for relevant taxa;*

(v) *Data representative of the seasonal and daily activities (e.g., feeding and water column migration) of biological organisms in the vicinity of the cooling water intake structure;*

(vi) *Identification of all threatened, endangered, and other protected species that might be susceptible to impingement and entrainment at your cooling water intake structures;*

(vii) *Documentation of any public participation or consultation with Federal or State agencies undertaken in development of the plan; and*

(viii) *If you supplement the information requested in paragraph (r)(4)(i) of this section with data collected using field studies, supporting documentation for the Source Water Baseline Biological Characterization must include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods you use must be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source waterbody. The study area should include, at a minimum, the area of influence of the cooling water intake structure.*

(ix) *In the case of the owner or operator of an existing facility or new unit at an existing facility, the Source Water Baseline Biological Characterization Data is the information in paragraphs (r)(4)(i) through (xii) of this section.*

(x) *For the owner or operator of an existing facility, identification of protective measures and stabilization activities that have been implemented, and a description of how these measures and activities affected the baseline water condition in the vicinity of the intake.*

(xi) *For the owner or operator of an existing facility, a list of fragile species, as defined at 40 CFR §125.92(m), at the facility. The applicant need only identify those species not already identified as fragile at 40 CFR §125.92(m). New units at an existing facility are not required to resubmit this information if the cooling water withdrawals for the operation of the new unit are from an existing intake.*

(xii) *For the owner or operator of an existing facility that has obtained incidental take exemption or authorization for its cooling water intake structure(s) from the United States Fish and Wildlife Service or the National Marine Fisheries Service, any information submitted in order to obtain that exemption or authorization may be used to satisfy the permit application information requirement of paragraph 40 CFR §125.95(f) if included in the application.*

Each of these requirements is addressed in the following subsections.

4.1 List of Unavailable Biological Data [§122.21(r)(4)(i)]

The biological data needed to prepare the information required for compliance with §122.21(r)(4) are available. Resources reviewed for this report includes:

- 1973-1976 Fish Impingement and Entrainment Studies (ASA 2008);
- 2006-2007 Impingement Mortality Characterization Study (ASA 2008);
- 2008, 2010, 2011 Electrofishing, Hydroacoustic, and Purse Seine Surveys (Duke Energy 2013);
- 2016-2017 Entrainment Characterization Study Report (HDR 2018b); and
- 2017 Oconee Nuclear Station Curtain Wall Entrainment Reduction Performance Study Report (HDR 2018a).
- 2013-2018 Electrofishing Surveys (Duke Energy 2018)

The data were compiled and analyzed and are summarized below. The biological characterization of the source waterbody presented in this section primarily consists of existing, available data collected on Lake Keowee. In the absence of existing entrainment data at Oconee, Duke Energy developed an Entrainment Characterization Study Plan (Appendix 9-A). This plan was reviewed and approved by the South Carolina Department of Health and Environmental Control prior to field data collection. The 2016-2017 Entrainment Characterization Study (Study), which collected entrainment data at the Oconee CWIS, was carried out from March through October in 2016 and 2017. The Study is summarized in Section 4.5.2, is described in greater detail in Section 9, and the full Study report is included in Appendix 9-A.

A Curtain Wall Entrainment Reduction Performance Study was also performed at Oconee from March through October of 2017. The curtain wall study was developed to determine how the existing curtain wall may influence entrainment rates at the CWIS and is summarized in Section 7.1.2.

4.2 List of Species and Relative Abundance in the Vicinity of the CWIS [§122.21(r)(4)(ii)]

Historical sampling of the Lake Keowee fish community was conducted by the South Carolina Wildlife and Marine Resources Division (SCWMRD) from 1968 to 1971 as the newly created reservoir was filled and transitioned from a riverine to lacustrine fish community (ASA 2008). The

SCWMRD annually sampled three, one-acre coves using rotenone and block nets. From 1971 to 1973, the U.S. Fish and Wildlife Service (USFWS) established the Southeast Reservoir Investigations which used several types of sampling gear, including cove rotenone, gill nets, electrofishing, trap nets, and seines. Beginning in 1993, annual sampling consisted of electrofishing and purse seines.

In the early years of reservoir filling, many species of the fish community were associated with riverine environments, such as Quillback (*Carpiodes cyprinus*) and Creek Chub (*Semotilus atromaculatus*) (ASA 2008). As a lake environment became established, the species that became most prevalent were Whitefin Shiner (*Cyprinella nivea)*, Flat Bullhead (*Ameiurus platycephalus)*, Redbreast Sunfish (*Lepomis auritus)*, Green Sunfish (*L. cyanellus*), Warmouth (*L. gulosus)*, Bluegill (*L. macrochirus*), Largemouth Bass (*Micropterus salmoides)*, Black Crappie (*Pomoxis nigromaculatus)*, and Yellow Perch (*Perca flavescens*) (Table 4-1). An apparent shift in the fish community can be observed between the 1968 to 1973 time period and the more recent time periods beginning in 1993 (fifteen taxa collected between 1968 and 1973 were not collected in any subsequent sampling periods). While this may be due to gear selectivity or efficacy, this could also be indicative of a shift in the aquatic habitat from riverine conditions to a lacustrine environment. Additional changes to the fish community also occurred during this transition period due to the stocking of Threadfin Shad (*Dorosoma petenense*) and the unintentional introduction of Blueback Herring (*Alosa aestivalis*) (ASA 2008).

Since 1993, lake-wide electrofishing and purse seine surveys were conducted to assess the diversity and abundance of the fish community in Lake Keowee. The species composition and abundance data from these studies, summarized in the following sections, indicate that Lake Keowee supports a balanced and diverse, indigenous fish community.

Table 4-1. Species Collected in Lake Keowee Historical and Recent Fish Surveys

Family	Common Name	Scientific Name	Multiple Gear Types[1, 2]	Electrofishing and Purse Seines[2]		
			1968-1973	1993-2005	2008-2011	2013-2018
Clupeidae	Threadfin Shad	*Dorosoma petenense*	X	X	X	X
	Blueback Herring	*Alosa aestivalis*		X	X	X
Cyprinidae	Whitefin Shiner	*Cyprinella nivea*	X	X	X	X
	Common Carp	*Cyprinus carpio*	X	X	X	X
	Chub sp.	*Nocomis* sp.	X			
	Golden Shiner	*Notemigonus crysoleucas*	X	X	X	X
	Spottail Shiner	*Notropis hudsonius*	X	X	X	X
	Sandbar Shiner	*Notropis scepticus*	X			
	White Shiner	*Luxilus albeolus*				X
	Creek Chub	*Semotilus atromaculatus*	X			
Catostomidae	Quillback	*Carpiodes cyprinus*	X			
	Spotted Sucker	*Minytrema melanops*	X	X		
	Northern Hog Sucker	*Hypentelium nigricans*	X	X	X	X
	Silver Redhorse	*Moxostoma anisurum*	X			
	Smallfin Redhorse	*Moxostoma robustum*	X			

Family	Common Name	Scientific Name	Multiple Gear Types[1, 2]	Electrofishing and Purse Seines[2]		
			1968-1973	1993-2005	2008-2011	2013-2018
	Striped Jumprock	*Moxostoma rupiscartes*	X		X	
	Notchlip Redhorse	*Moxostoma collapsum*		X	X	X
	Brassy Jumprock	*Moxostoma* sp.			X	X
Ictaluridae	Channel Catfish	*Ictalurus punctatus*	X	X	X	X
	Brown Bullhead	*Ameiurus nebulosus*	X			
	Snail Bullhead	*Ameiurus brunneus*	X	X	X	X
	Yellow Bullhead	*Ameiurus natalis*	X			
	Madtom	*Noturus* sp.	X			
	Flat Bullhead	*Ameiurus platycephalus*	X	X	X	X
	White Catfish	*Ameiurus catus*	X	X		
	Flathead Catfish	*Pylodictis olivaris*			X	X
Esocidae	Chain Pickerel	*Esox niger*	X			
Poeciliidae	Eastern Mosquitofish	*Gambusia holbrooki*	X	X	X	X
Centrarchidae	Warmouth	*Lepomis gulosus*	X	X		X
	Pumpkinseed	*Lepomis gibbosus*	X			
	Redbreast Sunfish	*Lepomis auritus*	X	X	X	X
	Bluegill	*Lepomis macrochirus*	X	X	X	X
	Largemouth Bass	*Micropterus salmoides*	X	X	X	X
	Smallmouth Bass	*Micropterus dolomieu*		X	X	X
	Alabama Bass	*Micropterus henshalli*		X	X	X
	White Crappie	*Pomoxis annularis*	X			
	Black Crappie	*Pomoxis nigromaculatus*	X	X	X	X
	Green Sunfish	*Lepomis cyanellus*	X	X	X	X
	Longear Sunfish	*Lepomis megalotis*	X			
	Redear Sunfish	*Lepomis microlophus*	X	X	X	X
	Spotted Sunfish	*Lepomis punctatus*	X			
	Rock Bass	*Ambloplites rupestris*	X			
	Redeye Bass	*Micropterus coosae*	X	X	X	X
	Hybrid Black Bass	*Micropterus* sp. hybrid			X	X
	Alabama Bass	*Micropterus henshalli*				X
	Hybrid Sunfish	*Lepomis* sp. hybrid		X	X	X
Percidae	Yellow Perch	*Perca flavescens*	X	X		
	Blackbanded Darter	*Percina nigrofasciata*	X	X	X	X
	Walleye	*Sander vitreum*	X			
Salmonidae	Brown Trout	*Salmo trutta*	X	X	X	
	Rainbow Trout	*Oncorhynchus mykiss*		X	X	X
	Number of Distinct Species		**40**	**28**	**26**	**27**

[1]Multiple gear types included cove rotenone, gill nets, electrofishing, trap nets, and seines.
[2] Sources: ASA 2008; Duke Energy 2007, 2013, 2018

4.2.1 Spring Electrofishing (2013-2018)

While spring electrofishing has been performed in littoral areas of Lake Keowee since 1993, the most recent five years of data (2013, 2014, 2015, 2016, and 2018) are presented here to represent current conditions. Ten, 300-meter (m) transects (total sampled shoreline length of 3,000 m) were electrofished during daylight hours when temperatures ranged from 15°C to 20°C. Transects include habitats representative of those found in Lake Keowee and were established in three areas: one outside of the thermal influence of the discharge (Zone 1), one near the thermal discharge in Upper Lake Keowee (Zone 2), one outside of the influence of the discharge in Upper Lake Keowee and within influence of the Jocassee Pumped Storage Station (Zone 3) (Figure 4-1). Fish were identified to species, total numbers and total weights were obtained, and surface water temperatures were measured. Data for the ten transects located in Lower Lake Keowee were used to characterize species diversity and relative abundance near the Oconee CWIS.

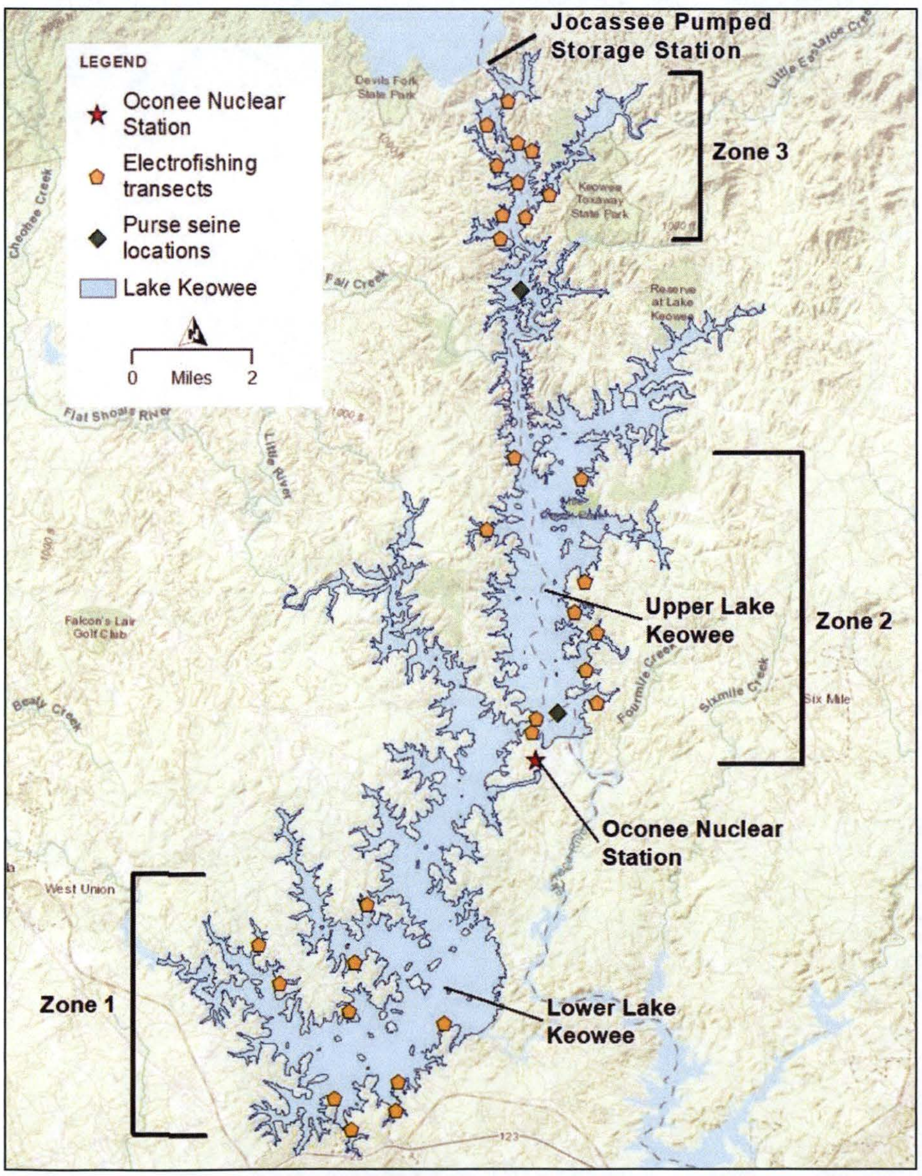


Figure 4-1. Fish Sampling Locations

A summary of the species collected in the electrofishing surveys from Lower Lake Keowee from 1993 to 2018 are presented in Table 4-2. This survey area was selected as the best representation of the fish community that may be in the vicinity of the CWIS, as opposed to the thermally-influenced area (near the discharge) or Upper Lake Keowee within the influence of the Jocassee Pumped Storage Station.

Table 4-2. Total Number Collected and Percent of Total of Fish Collected during Recent Electrofishing Surveys in Lower Lake Keowee

Common Name	Scientific Name	2013		2014		2015		2016		2018	
		Total No.	Percent of Total	Total No.	Percent of Total	Total No.	Percent of Total	Total No.	Percent of Total	Total No.	Percent of Total
Centrarchidae											
Alabama Bass	*Micropterus henshalli*	53	5.8	76	4.9	28	2.7	52	3.9	57	1.9
Bluegill	*Lepomis macrochirus*	441	48.7	770	49.1	526	51.3	937	69.7	1,681	55.7
Green Sunfish	*Lepomis cyanellus*	129	14.2	262	16.7	115	11.2	93	6.9	242	8.0
Hybrid Black Bass	*Micropterus salmoides* x *M. punctulatus*	--	--	1	0.1	4	0.4	4	0.3	--	--
Hybrid Sunfish	*Lepomis* spp.	15	1.7	51	3.3	15	1.5	36	2.7	74	2.5
Largemouth Bass	*Micropterus salmoides*	6	0.7	10	0.6	3	0.3	6	0.4	26	0.9
Redbreast Sunfish	*Lepomis auritus*	102	11.3	145	9.3	72	7.0	68	5.1	373	12.4
Redear Sunfish	*Lepomis microlophus*	10	1.1	12	0.8	8	0.8	26	1.9	187	6.2
Redeye Bass	*Micropterus coosae*	--	--	--	--	3	0.3	1	0.1	13	0.4
Warmouth	*Lepomis gulosus*	21	2.3	67	4.3	36	3.5	43	3.2	115	3.8
Clupeidae											
Blueback Herring	*Alosa aestivalis*	63	7.0	94	6.0	166	16.2	1	0.1	108	3.6
Threadfin Shad	*Dorosoma petenense*	--	--	2	0.1	--	--	--	--	--	--
Cyprinidae											
Common Carp	*Cyprinus carpio*	3	0.3	4	0.3	--	--	5	0.4	1	0.03
Golden Shiner	*Notemigonus crysoleucas*	--	--	--	--	--	--	--	--	1	0.03
Spottail Shiner	*Notropis hudsonius*	1	0.1	15	1.0	3	0.3	7	0.5	70	2.32
Whitefin Shiner	*Cyprinella nivea*	60	6.6	52	3.3	45	4.4	61	4.5	59	2.0

Common Name	Scientific Name	2013		2014		2015		2016		2018	
		Total No.	Percent of Total	Total No.	Percent of Total	Total No.	Percent of Total	Total No.	Percent of Total	Total No.	Percent of Total
Ictaluridae											
Channel Catfish	*Ictalurus punctatus*	2	0.2	5	0.3	--	--	4	0.3	4	0.1
Flathead Catfish	*Pylodictis olivaris*	--	--	1	0.1	1	0.1	1	0.1	--	--
Snail Bullhead	*Ameiurus brunneus*	--	--	--	--	--	--	--	--	2	0.07
Percidae											
Blackbanded Darter	*Percina nigrofasciata*	--	--	--	--	--	--	--	--	1	0.03
Salmonidae											
Rainbow Trout	*Oncorhynchus mykiss*	--	--	--	--	--	--	--	--	2	0.07
	Total Number	**906**	**100**	**1,567**	**100**	**1,025**	**100**	**1,345**	**100**	**3,016**	**100**
	Total Number Species	**12**		**14**		**12**		**14**		**18**	

Source: Duke Energy 2018

First stocked into Lake Keowee as fingerlings in 1968 (ASA 2008), Bluegill are consistently the most abundant species collected in monitoring studies, representing 48.7 percent to 69.7 percent of the fish collected per year (Table 4-2) (Duke Energy 2018). Overall, the five most abundant species collected in electrofishing surveys from 2013-2018 were Bluegill, Green Sunfish, Redbreast Sunfish, Blueback Herring, and Whitefin Shiner; with the remaining taxa combining for The remainder of fish collected during electrofishing surveys between 2013 and 2018 accounted for approximately fifteen percent or less of the total fish collected, combined.

4.2.2 Purse Seine Sampling

Purse seine surveys have historically been performed annually or semi-annually on Lake Keowee to evaluate the seasonal abundance and distribution of small (150 millimeters [mm] or smaller) pelagic fish species such as Threadfin Shad and Blueback Herring (ASA 2008; Duke Energy 2007, 2013). Samples were collected using a 122-m by 9.1-m purse seine with 4.8-mm mesh from two locations in Upper Lake Keowee (Figure 4-1). The species composition and size distribution were estimated each year using a subsample of fish collected from each area sampled with the seine.

Threadfin Shad and Blueback Herring were the only forage species collected in purse seines with the exception of a single Gizzard Shad (*Dorosoma cepedianum*) collected during the 2009 survey in southern Upper Lake Keowee (Figure 4-2). The purse seine sampling shows the ratio of Threadfin Shad to Blueback Herring to vary between the lake regions: Blueback Herring generally dominate the northern Upper Lake Keowee samples, while Threadfin Shad dominate the southern Upper Lake Keowee region nearest to the Oconee discharge, which may indicate a requirement for warmer water temperatures (Griffith 1978; Loar et al. 1978) and therefore an association with the thermal plume. Most fish collected were young-of-year. Threadfin Shad and Blueback Herring have historically been collected via purse seines in Lake Jocassee, upstream of Lake Keowee, and largely dominate the limnetic forage fish community on Lake Keowee and downstream reservoirs (FERC 2013, 2016).

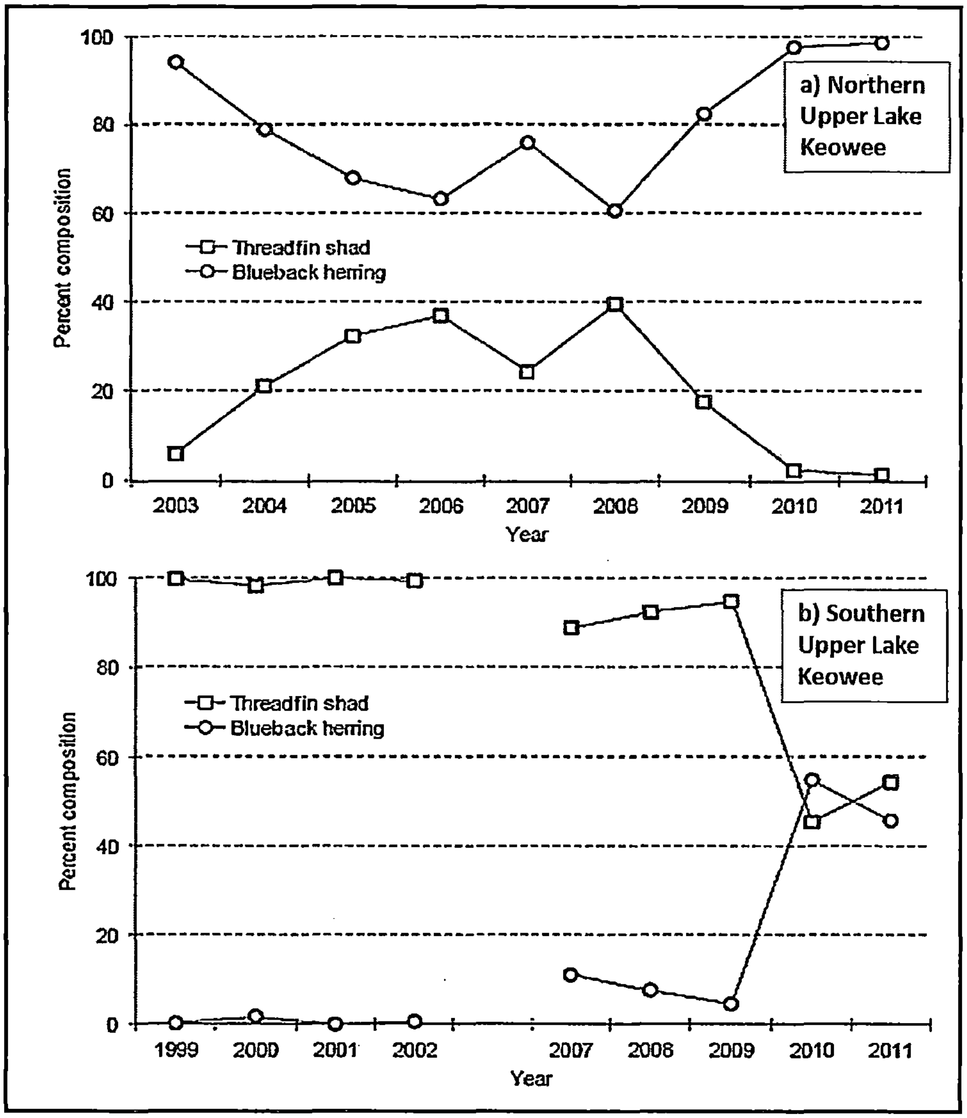


Figure 4-2. Percent Composition of Forage Fish in Purse Seine Surveys in (a) Northern Upper Lake Keowee and (b) Southern Upper Lake Keowee (Duke Energy 2013)

4.2.3 Hydroacoustic Surveys

Hydroacoustic surveys were performed annually in conjunction with purse seine surveys in Upper and Lower Lake Keowee (Duke Energy 2007, 2013; ASA 2008). Surveys were conducted with multiplexing, side- and down-looking transducers to detect surface-oriented fish and deeper fish (from 2.0 m depth to the bottom), respectively.

Forage fish populations (i.e., mainly Threadfin Shad and Blueback Herring) fluctuated annually between 1999 and 2005 (Duke Energy 2007) with the lowest estimate at 6.4 million in 1999 to the highest at 16.9 million in 2000 (Figure 4-3). Forage fish populations appeared to stabilize from 2006 to 2011 with the exception of a dip in 2010. During this time period, total population estimates ranged from approximately 2.1 to 7.2 million fish, with annual variability primarily attributed to the influence of natural variability in concentrations of chlorophyll *a*, phytoplankton standing crops, and zooplankton density (Duke Energy 2013).

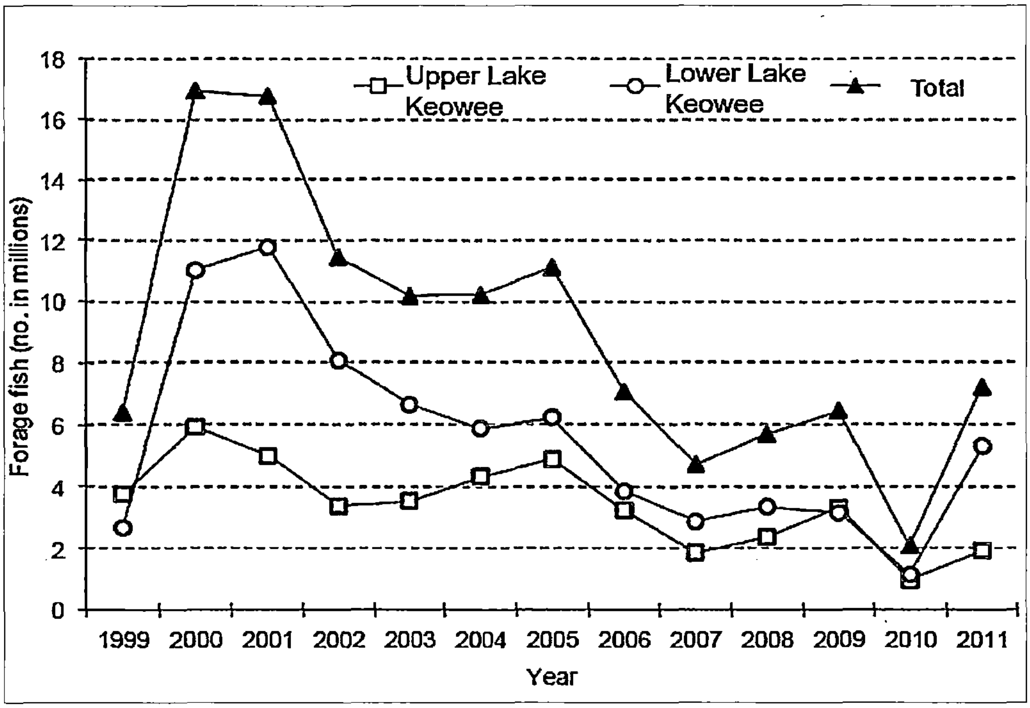


Figure 4-3. Total Population Estimates of Pelagic Forage Fish in Upper and Lower Lake Keowee (Duke Energy 2013)

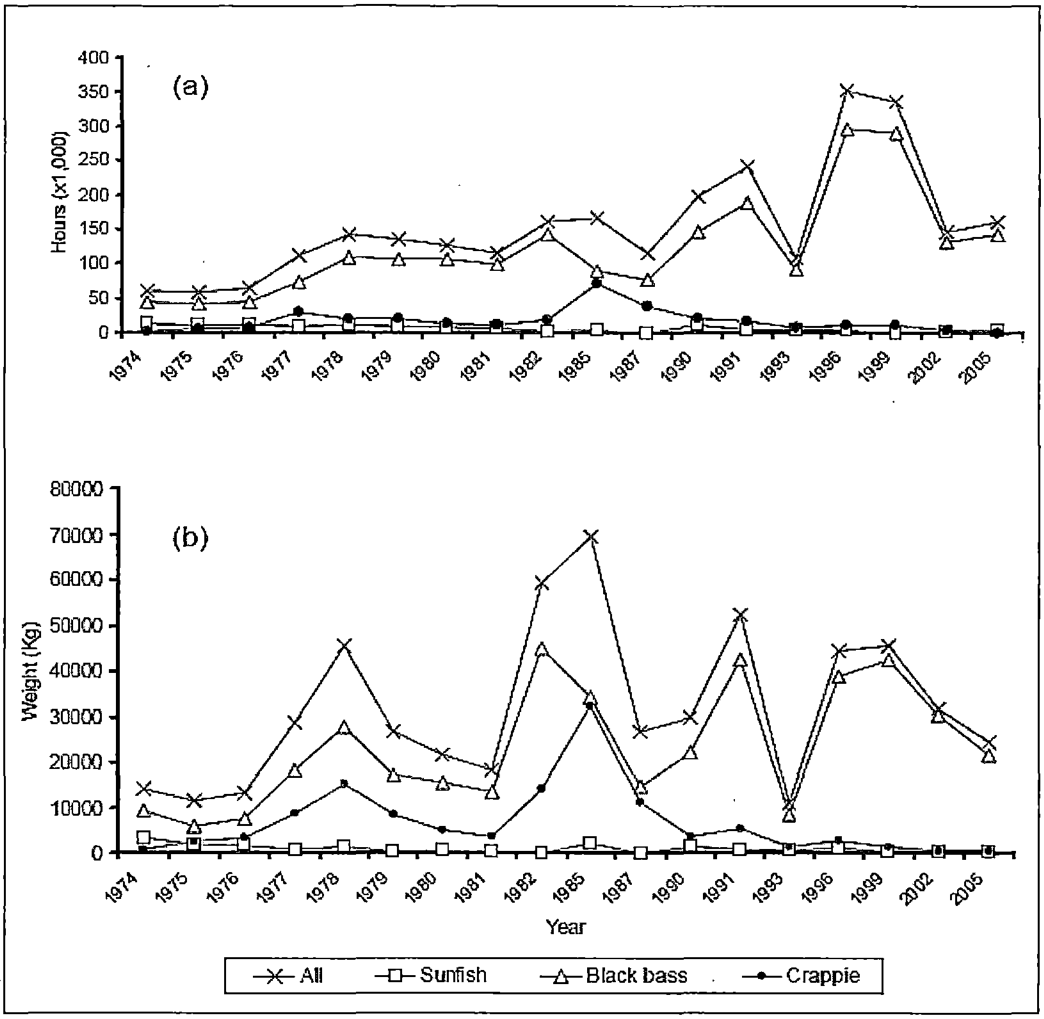
4.2.4 Creel Surveys

The SCWMRD has performed creel surveys since the 1970's to estimate angling effort, catch, and harvest on Lake Keowee (Duke Energy 2007). A roving creel survey to sample fishing effort and harvest in Lake Keowee was conducted by Clemson University using a two-stage design (Duke Energy 2007). Creel surveys were conducted in 1996, 1999, 2002, and 2005 to compare angler pressure and harvest throughout Lake Keowee, including Lower Lake Keowee, the thermally-influenced discharge area, and Upper Lake Keowee (Figure 4-1).

According to these surveys, angler pressure and harvest is elevated within the thermally-influenced discharge zone, however it is not statistically significant. Targeted species primarily include black basses such as Alabama Bass (Micropterus henshalli), Largemouth Bass, and Redeye Bass, as well as sunfish and crappies. Based on the data available through 2005 (Figure 4-4)

fishing pressure and harvest of the sport fishery (primarily black bass) were variable between surveys, becoming more pronounced in surveys completed after 1988. As awareness of the resource has grown since impoundment of Lake Keowee, fishing pressure and harvest have shown an overall slight increase over time, a pattern that is expected to continue as population growth in the region continues.

More recent Oconee-specific creel survey data were not available; however, based on data collected from 2006 – 2016 for the National Survey of Fishing, Hunting and Wildlife-Associated Recreation (NSFHWA 2016), there was a 19 percent increase nationally in the total number of anglers, but a simultaneous reduction in the total numbers of trips taken, and thus a reduction in the total economic impact to the economy. Fishing pressure on Lake Keowee could be expected to continue to exhibit annual variability but should align with overall trends indicated by national survey data.



(Note: weight is in kilograms [kg])

Figure 4-4. Creel Survey Data for Angler (a) Fishing Pressure and (b) Harvest in Lake Keowee (Duke Energy 2007); surveys conducted annually through 1982 and every third year after 1982

4.2.5 Summary

Historical sampling data demonstrated a shift in fish species composition that occurred when the impoundment was created and transitioned from a riverine system to a lacustrine system. Lake Keowee currently supports a fishery that is typical of the Piedmont region of the southeastern U.S., with a littoral zone community largely dominated by centrarchids and a pelagic community dominated by clupeids (ASA 2008; Duke Energy 2007, 2013). Largemouth Bass and Redeye Bass (*Micropterus coosae*) have both decreased in abundance since 1996 while the abundance of introduced species such as Alabama Bass and Flathead Catfish has increased. Blueback Herring and Threadfin Shad dominated the forage fish populations, influenced spatially and temporally by water temperature. The abundant littoral zone and pelagic forage fish species continue to provide a consistent and diverse prey base for predators. Continued lake monitoring studies suggest that Lake Keowee supports a balanced fish community (Duke Energy 2007, 2013).

4.3 Identification of Species and Life Stages Susceptible to Impingement and Entrainment [§122.21(r)(4)(iii)]

The following sections summarize the species and life stages that may be susceptible to impingement and entrainment at the Oconee CWIS, as indicated by ongoing monitoring data, historical impingement data, and entrainment studies performed at the facility.

4.3.1 Impingement

The degree of vulnerability to impingement exhibited by adult and juvenile or young-of-year (YOY) fish varies by species and life stage and depends upon biological and behavioral factors including seasonal fish community structure, swimming speed, spawning effects on distribution (proximity of spawning, nursery, and foraging habitat to the CWIS), habitat surrounding intake structures, high flow events, fish health, water withdrawal rate, and attraction to the flow associated with the intakes themselves. In addition, intake velocity, screen mesh size, bar rack spacing, and intake configuration can also affect the susceptibility of aquatic organisms to impingement. For example, clupeids have high susceptibility to impingement based on multiple factors such as schooling behavior, distribution in the water column, rheotactic response to intake flows, and poor swimming performance in winter months due to lower water temperatures (Loar et al. 1978).

4.3.1.1 1974-1975 Impingement Study (Duke Power Company 1976)

An impingement study was conducted on a bi-weekly basis at the Oconee CWIS from May 1974 through May 1975 (Duke Power Company 1976). Every two weeks during the sampling year, two fixed screens were removed, inspected, cleaned thoroughly, and replaced. All impinged fish were identified, measured, enumerated, and provided a condition assessment.

Threadfin Shad were first stocked in Lake Keowee in February 1974 and were first observed in the impingement study beginning in November 1974. Prior to November 1974, Bluegill (72.6 percent) and Yellow Perch (22.2 percent) dominated impingement collections. By December, Threadfin Shad were the most prevalent species impinged and accounted for 98 percent of impingement from January to May 1975, and 49.3 percent of the year overall. Estimates of number of fish identified by condition, or total number of fish impinged annually excluding those that may have died prior to impingement (i.e., "dead and drifted in") were not provided.

4.3.1.2 1990 Impingement Study (Barwick 1990)

An impingement study was also performed monthly from January through March 1990 (Barwick 1990). Two screens on each of three pumps were cleaned and replaced. After seven days, the screens were removed and rinsed and all impinged fish were collected and quantified.

A total of 543,605 fish (758.5 kg biomass) were estimated to be impinged over the three month period (Barwick 1990). Threadfin Shad was the most prevalent taxon collected (91.5 percent), likely a result of thermal stress resulting from the cool temperatures documented during the study period (NOAA 2019). Blueback Herring (8.4 percent) and Yellow Perch (0.1 percent) were the only additional species impinged during the study. Threadfin Shad and Blueback Herring are both sensitive to water temperatures below 10-15°C (Pardue 1983), which can contribute to episodic increases in impingement rates. Decreasing temperatures stress the fish and impairs swimming ability, leaving the fish unable to avoid the current associated with water withdrawals.

4.3.1.3 2006-2007 Impingement Mortality Characterization Study (ASA 2008)

Duke Energy conducted a study in 2006-2007 to assess the level of "adverse environmental impact" from impingement losses, applying the USEPA's Framework for Ecological Risk Assessment (ASA 2008). Adverse environmental impacts were defined as an unacceptable reduction in biological integrity (measured in terms of aquatic community species composition, diversity, and function) or human use of the aquatic resources of Lake Keowee (particularly, fishing opportunity or quantity/quality of catch). The 2006-2007 study was performed to document levels of impingement at the facility's CWIS and compare those results to data collected during sampling programs conducted in 1973-1976 and 1990 (Barwick 1990), and assess any possible adverse environmental impacts to the fishery (ASA 2008). The study concluded that there was no evidence to support that impingement at Oconee was causing an adverse environmental impact, as defined above, in Lake Keowee. Details of the study and results are summarized below.

Impingement sampling was performed on a biweekly basis at the CWIS from September 2006 to August 2007 (ASA 2008). Eight randomly-selected fixed screens were chosen for sampling. The selected screens were allowed to accumulate impinged fish for approximately 24 hours, after which any impinged fish were washed from the screens, sorted, and identified. Fish identified to species were measured for total length and weighed. Surface water temperature was also recorded during each sampling event.

A total of 1,162 fish (2,873 grams biomass) representing 11 species were collected over 26 sampling events (Table 4-3), equating to an estimated annual impingement mortality (IM) of 43,923 fish (109.3 kg) (ASA 2008). The most abundant species was Threadfin Shad (72.2 percent), followed by Blueback Herring (23.4 percent) and Bluegill (2.9 percent). Threadfin Shad and Blueback Herring were more abundant in samples during the fall and early winter (September-December), while Bluegill were impinged throughout the year at relatively low numbers with lower densities in the fall than in the remainder of the year.

Table 4-3. Total Number and Percent Composition of Fish Impinged at Oconee Nuclear Station, September 2006 - August 2007 (Source: ASA 2008)

Species	September 2006 - August 2007	
	Total Number	Percent Composition
Threadfin Shad	849	73.1
Blueback Herring	250	21.5
Bluegill	45	3.9
Alabama Bass	4	0.3
Redbreast Sunfish	6	0.5
Redeye Bass	2	0.2
Warmouth	1	0.1
Blackbanded Darter	2	0.2
White Catfish	1	0.1
Flathead Catfish	1	0.1
Golden Shiner	1	0.1
Total	**1,162**	**100**

Vulnerability to impingement can be dependent on the species, life stage or body size, swimming ability, and habitat preferences of organisms that occur near the CWIS, as indicated by the variability observed in total length and body size values of the species of fish collected during the 2006-2007 impingement study. In general, impinged Blueback Herring ranged in length from 80 to 130 mm, while Threadfin Shad were 41 to 60 mm in length, and based on these data and other distinguishing characteristics, the majority of impinged Blueback Herring were designated as yearlings, while impinged Threadfin Shad were classified primarily as YOY.

Blueback Herring is a fragile species, and Threadfin Shad should be considered fragile at this facility (see Section 4.12); therefore, neither species should be considered as part of the annual IM estimate at Oconee (79 FR 158, 48364). Excluding fragile species from the annual impingement estimated at Oconee (based on the 2006-2007 study) results in a 95.6 percent reduction in estimated annual IM (1,944 fish per year).

Peak impingement rates for all species occurred from September to December (ASA 2008). There were no anomalous water quality events during this time period; therefore, the increased impingement is most likely related to the high abundance and distribution of YOY Threadfin Shad in the vicinity of the intake (ASA 2008). The TSV at the Oconee CWIS at the time the peak impingement rates were observed may have been as high as 2.6 fps[13], depending on the number of pumps that were operating (i.e., the facility was operating at maximum capacity in September when impingement rates were greatest). Therefore, YOY Threadfin Shad may be more susceptible to impingement if in the AOI of the CWIS.

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[13] TSV estimates for the 2006 – 2007 Impingement Mortality Characterization Study were provided by ASA Analysis & Communication, Inc. (ASA).

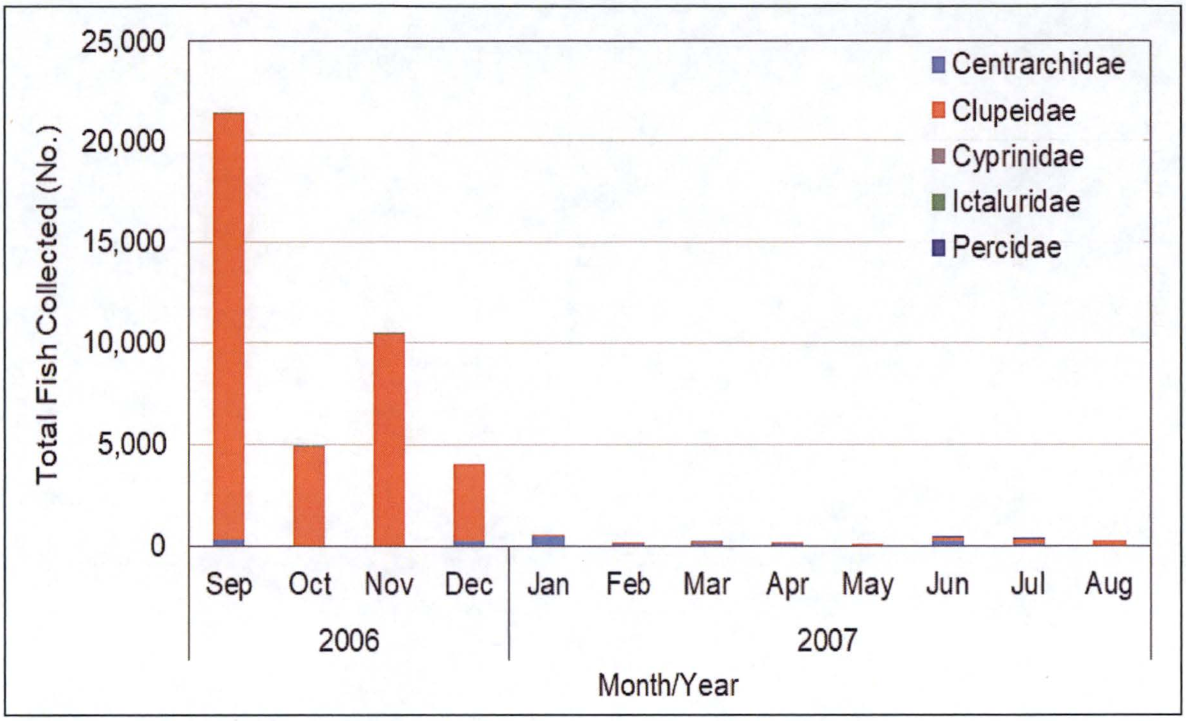

Figure 4-5. Monthly Impingement by Family during the 2006-2007 Impingement Study (ASA 2008)

4.3.2 Entrainment

Ichthyoplankton (the egg and larval life stage of fishes) exhibit the highest degrees of susceptibility to entrainment based on size and little or no swimming ability. Therefore, an organism is only susceptible to entrainment for a portion of its life cycle. Larger juvenile and adult life stages have the swimming ability to avoid entrainment or are often size-excluded by the mesh screen. Additionally, life history characteristics such as spawning behavior can also influence the vulnerability of a fish species to entrainment. For example, broadcast spawners with non-adhesive, free-floating eggs can drift with water currents and may become entrained in a CWIS, while nest-building species with adhesive eggs are less susceptible to entrainment during early life stages (King et al. 2010).

4.3.2.1 2016-2017 Entrainment Characterization Study

A two-year Entrainment Characterization Study was performed at Oconee from 2016 to 2017 (see Section 9 and Appendix 9-A). A total of 176 organisms representing 3 distinct taxa including two families were collected in ichthyoplankton samples during the Study. The total number of ichthyoplankton collected during the two years did not exhibit significant inter-annual variation, with 82 organisms collected in 2016 and 94 organisms in 2017. Blueback Herring eggs dominated the ichthyoplankton collection in 2016 (92.7 percent) and 2017 (78.7 percent). Combined with other unidentified shads (Gizzard or Threadfin shads) and herrings (Blueback Herring or Alewife [*Alosa pseudoharengus*]), clupeids dominated collections for both years (greater than 98 percent), with the exception of a single sunfish post yolk-sac larvae collected in 2016 and several unidentifiable ichthyoplankton collected in 2017. The two years of sampling exhibited similar seasonal trends with the highest ichthyoplankton densities in June and July of both years. Blueback Herring was the most abundant taxon, exhibiting the highest rates of entrainment (i.e., average of daily densities by month;

see Appendix 9-C), and accounting for the increased entrainment rates documented in June and July for both years of the study.

Eggs accounted for nearly the entire ichthyoplankton collection in 2016 (92.7 percent) and 2017 (86.2 percent); few yolk-sac or post yolk-sac larvae and no young-of-year or yearling life stages were collected during the two year study. Ichthyoplankton density was lowest during daytime hours and substantially higher during morning hours for both years of sampling, a pattern resulting from the timing and proximity of spawning activity to the Oconee CWIS. Details of the Study methods, analysis, and results are presented in Section 9 and in Appendix 9-B.

4.3.2.2 2017 Curtain Wall Entrainment Reduction Performance Study

A Curtain Wall Entrainment Reduction Performance Study was conducted by Duke Energy from March through October of 2017 to characterize the ichthyoplankton communities on the intake and lake sides of the curtain wall at Oconee to evaluate the efficacy of the curtain wall at reducing entrainment at the CWIS (HDR 2018a; Appendix 7-A). Details of the study methods, analysis, and results are presented in Section 7.

4.3.3 Summary

All species in Lake Keowee have the potential to be impinged or entrained at the CWIS; however, as demonstrated by recent studies summarized above, clupeids (such as Threadfin Shad and Blueback Herring) have the greatest likelihood of impingement and entrainment at Oconee. These taxa accounted for 94.2 percent of impinged fish during the 2006-2007 impingement study and 98.3 percent of organisms collected during the 2016 and 2017 entrainment Study. Clupeids exhibit an increased susceptibility to entrainment and impingement at the Lake Oconee CWIS, likely attributable to their reproductive and life history strategies as pelagic, schooling broadcast spawners with high fecundity. However, purse seine and hydroacoustic sampling demonstrate that forage fish in Lake Keowee maintain healthy and abundant communities of Threadfin Shad and Blueback Herring. These species provide ample prey resources to recreational predators such as black basses and Black Crappie, which are targeted by anglers in Lake Keowee.

4.4 Identification and Evaluation of Primary Growth Period [§122.21(r)(4)(iv)]

The primary growth period for fishes in Lake Keowee immediately follows the spring hatch, with rapid growth occurring in the spring through early summer. Growth rates begin to slow in the late summer and fall, and virtually stop during the winter (Gebhart and Summerfelt 1978). The majority of taxa in Lake Keowee have the highest densities shortly after the hatch occurs when larvae are concentrated. Feeding competition is especially important during late spring through early summer when the bulk of fish are in their early life stages. During this time, they are more susceptible to starvation (May 1974). This is a critical stage in development, where larval fish have a short time period to initiate exogenous feeding before starving (Ehrlich 1974; Miller et al. 1988).

4.4.1 Reproduction and Recruitment

Fish species present in Lake Keowee consist of nest builders (such as centrarchids) or broadcast spawners (such as clupeids). Nest builders usually exhibit parental care until hatching and the swim-up stage, whereas broadcast spawners do not construct nests and provide no parental care. Eggs for both types of spawners are usually demersal and/or adhesive. Nest-building species with adhesive eggs are less susceptible to entrainment.

Fish spawning is typically triggered when water temperatures reach the species-specific temperature threshold (Etnier and Starnes 1993). Fish reproduction has the potential to produce high yields; however, mortality rates are typically higher compared to other organisms such as mammals or birds (McCoy and Gillooly 2008). Additionally, many fish spawn only once per year, regardless of prior success. The number of eggs a female produces (fecundity) can vary depending on the life history of the species and individual body size. Species-specific spawning information is summarized in Appendix 4-A.

For most species, peak larval recruitment is expected to occur near the end of the spawning season, after eggs hatch. Young of year for the majority of fishes are most abundant shortly after the spring and summer spawning period (Page and Burr 2011).

4.4.2 Period of Peak Abundance for Relevant Taxa

Fish spawning is a direct function of water temperature and most activity is constrained to the spring and summer months. As a result, an influx of egg, larval, and juvenile fishes occurs in Lake Keowee in the spring and summer of each year when water temperatures rise. Based on a literature review, peak abundance for early life stages and juvenile fishes of the most abundant species in Lake Keowee would occur between April and June (Table 4-4). Generally, recruitment to the juvenile life stage follows the peak spawning window and continues until April or May of the succeeding year, depending on the life history strategy of individual species (Page and Burr 2011).

Table 4-4. Period of Reproduction for the Species Present in Lake Keowee, South Carolina near Oconee [1]

Family	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Centrarchidae	Bluegill												
	Green Sunfish												
	Largemouth Bass												
	Redbreast Sunfish												
	Redear Sunfish												
	Warmouth												
Clupeidae	Blueback Herring												
	Threadfin Shad[2]												
Cyprinidae	Common Carp												
	Spottail Shiner												
	Whitefin Shiner												
Ictaluridae	Channel Catfish												
	Flathead Catfish												

Sources: Rohde et al. 1994, 2009.
Note: The species presented in this table were identified from a review of biological survey data (Environmental Monitoring Reports summarized in Section 4.2), historical impingement data (Section 4.5.1), and recent entrainment data (Section 4.5.2).
[1]This table illustrates the potential spawning window and potential peak spawning period in Lake Keowee based on a review of available literature on Lake Keowee and comparable southeastern reservoirs. Lighter shade indicates the spawning window and darker shading indicates the peak spawning period.
[2]Spawning period adjusted as indicated by data collected in the entrainment characterization study (see Section 9).

4.5 Data Representative of Seasonal and Daily Activities of Organisms in the Vicinity of the Cooling Water Intake Structure [§122.21(r)(4)(v)]

The typical habitat preferred by littoral zone species includes submerged woody debris, boulders, rocks, riprap shorelines, artificial structures (i.e., docks or piers), and vegetated areas. Pelagic species, such as clupeids, form large schools mid-water column in open water. Some predators, such as Largemouth Bass, utilize both the littoral and pelagic zones (Matthias et al. 2014). Appendix 4-A provides a summary of species-specific preferred daily habitat and diet information.

Some fish species in Lake Keowee may exhibit daily migrations, such as diel vertical migration (or water column migration). During a daily cycle, zooplankton and fish exhibit synchronized movements up and down in the water column (Brierley 2014). The primary trigger for diel vertical migration in freshwater fish is the daily change in light intensity; declining light at dusk triggers the ascent to the surface while increasing light at dawn triggers some fish to return to deeper water (Mehner 2012). This is the typical pattern for many species although reverse migrations do occur. Additional triggers for vertical migration include hydrostatic pressure and water temperature, which may guide fish into particular limnological zones at night, particularly during stratification (Mehner 2012). Most fish species that perform diel vertical migration are planktivorous, and primarily inhabit the pelagic zone of thermally stratified lakes (Mehner 2012).

Variation in seasonal behavior of fishes is primarily associated with the timing of spawning and recruitment. Most species undergo short or local migrations for spawning and/or overwintering, such as pelagic species moving to the shoreline or upstream (e.g., Blueback Herring), while others may make long migrations to natal spawning grounds located upstream in inland rivers (Rohde et al. 2009). Lake Keowee is an impoundment of an inland river with multiple impassable downstream barriers (i.e., non-navigable dams) preventing further inland movement from the coastal zone, thus no diadromous species have been document and none are expected to occur Lake Keowee.

4.6 Identification of Threatened, Endangered, and Other Protected Species Susceptible to Impingement and Entrainment at the Cooling Water Intake Structure [§122.21(r)(4)(vi)]

The Rule requires the permittee to document federally listed species and designated critical habitat in the Action Area (see §125.98[f]). For the purpose of defining listed species, the Action Area for Oconee consists of Lake Keowee and the area encompassed by a 1-mile radius of the Lake Keowee shoreline (Figure 4-6).

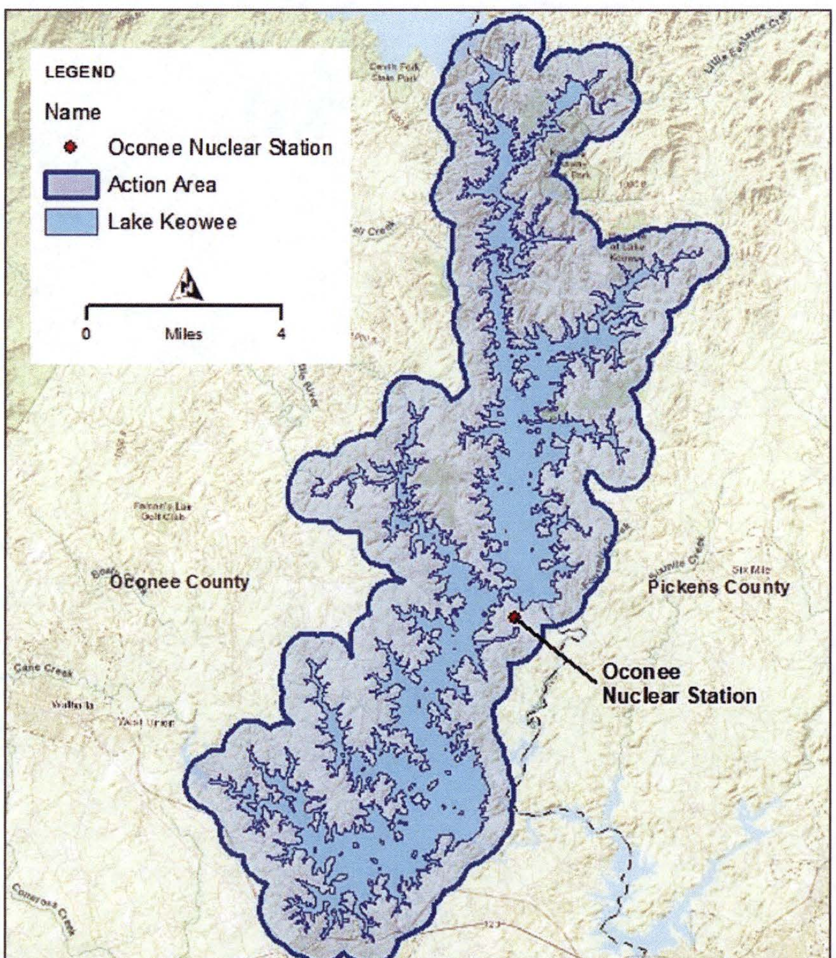

Figure 4-6. Defined 1-mile Radius Action Area for Oconee Nuclear Station CWIS

A desktop review of available resources was performed to develop a list of species with protected, endangered, or threatened status with the potential to be impacted by the continued operation of Oconee, including those that might be susceptible to impingement and entrainment at Oconee's CWIS on Lake Keowee. The USFWS map-based search tool (Information for Planning and Consultation [IPaC]) was used to identify state or federally listed rare, threatened, or endangered species or critical habitat designations within the Action Area (USFWS 2019). Additionally, the South Carolina Department of Natural Resources (SCDNR) was consulted to identify rare, threatened, or endangered species that occur or potentially occur within the vicinity of the Oconee CWIS (SCDNR 2015a).

A summary of state and federally listed rare, threatened, or endangered species and designated critical habitat (including potential fish hosts of mussel glochidia) with the potential to occur in the vicinity of the Oconee CWIS, as well as species of concern that have legal protection in the state of South Carolina, is provided in Table 4-5 (USFWS 2019; SCDNR 2015a). Federal species of concern and candidate species were omitted from the list (unless they were also state threatened or endangered), as there are no requirements to address those species under the Rule or Section 7 of the Endangered Species Act (USFWS 2003).

Table 4-5. Summary of Rare, Threatened, or Endangered Species with the Potential to Occur near the Oconee CWIS

Species Common and Scientific Name	Protected Status[1]	Preferred Habitat	Potential to Occur Near the CWIS	Impingement/ Entrainment Potential
Reptiles				
Bog Turtle (*Clemmys muhlenbergii*)	FT[2], ST	Semi-aquatic; prefer muddy habitats in bogs, swamps, and marshy meadows typically fed by cool springs[3]	No–suitable habitat type not available	No
Southern Coal Skink (*Eumeces anthracinus pluvialis*)	ST	Terrestrial	No	No
Mammals				
Eastern Small-Footed Myotis (Myotis leibii)	ST	Terrestrial	No	No
Indian Myotis (Myotis sodalis)	FE, SE	Terrestrial	No	No
Northern Long-Eared Bat (Myotis septentrionalis)	FT	Terrestrial	No	No
Rafinque's Big-Eared Bat (Corynorhinus rafinesquii)	SE	Terrestrial	No	No
Birds				
American Peregrine Falcon (Falco peregrinus anatum)	ST	Terrestrial	No	No
Bewick's Wren (Thryomanes bewickii)	ST	Terrestrial	No	No
Bald Eagle (Haliaeetus leucocephalus)	BGEPA[4], ST	Terrestrial	No	No

Species Common and Scientific Name	Protected Status[1]	Preferred Habitat	Potential to Occur Near the CWIS	Impingement/ Entrainment Potential
Vascular Plants				
Black-Spored Quillwort (Isoetes melanospora)	FE	Semi-aquatic; grow in shallow, temporarily flooded pools in granite outcrops[5]	No–suitable habitat type not available	No
Dwarf-Flowered Heartleaf (Hexastylis naniflora)	FT	Terrestrial	No	No
Mountain Sweet Pitcher Plant (Sarreacenia rubra ssp. jonesii)	FE	Semi-aquatic; grow in mountain bogs[6]	No–suitable habitat type not available	No
Persistent Trillium (Trillium persistens)	FT	Terrestrial	No	No
Small Whorled Pogonia (Isotria medeoloides)	FT	Terrestrial	No	No
Smooth Coneflower (Echinacea laevigata)	FE	Terrestrial	No	No

Sources: USFWS 2019; SCDNR 2015b, 2015c
[1]Includes federally listed endangered (FE), threatened (FT), and species of concern (FSOC), as well as those identified from the IPaC search (USFWS 2019), or species identified in the USFWS (2016) 7-year Workplan for national listing. Protected status listings also includes state listed endangered (SE) and threatened (ST) species, which have legal protection status in South Carolina as presented by the South Carolina Department of Natural Resources (SCDNR) (SCDNR 2015a; 2015b; 2015c; SCLSA 2019).
[2]Threatened based on similarity of appearance to other protected species;
[3]USFWS 2011a; [4]Protected under the Bald and Golden Eagle Protection Act (BGEPA) (USFWS 2007);
[5]Chafin and Brunton 2008; [6]USFWS 2011b.

Three federally listed species, including one state listed aquatic species, have the potential to occur in the Action Area based on protected species listings for Oconee and/or Pickens counties (USFWS 2019; SCDNR 2015b; 2015c). The remaining species listed in Table 4-5 are terrestrial and would not be present in Lake Keowee or near the CWIS; therefore they are not discussed further. No federally-designated critical habitat was identified within the Action Area (USFWS 2019).

The Bog Turtle (*Clemmys muhlenbergii*) is a small, semi-aquatic reptile that is federally listed as threatened wherever it is found except for southern states, including South Carolina (USFWS 2019). The southern portion of the Bog Turtles range is listed as threatened based on Similarity of Appearance to the federally threatened northern population of Bog Turtle. The Bog Turtle is also state listed as threatened in South Carolina. The Bog Turtle typically inhabits wetland environments with muddy soils, such as bogs, swamps, and meadow marshes (USFWS 2011a). Based on a comparison of available habitat, the Action Area does not provide suitable habitat for the Bog Turtle; therefore, it is not susceptible to entrainment or impingement at the Oconee CWIS.

Two semi-aquatic vascular plants were identified during the desktop species review, including the Black-spored Quillwort (*Isoetes melanospora*) and the Mountain Sweet Pitcher Plant (*Sarreacenia rubra ssp. jonesii*). Black-spored Quillwort are described as growing in flood pools within granite outcrops (Chafin and Brunton 2008) and Mountain Sweet Pitcher Plant are typically found in mountain bogs (USFWS 2011b). These habitat types do not exist within the Action Area; therefore, neither the Black-spored Quillwort nor the Mountain Sweet Pitcher Plant would be impacted by ongoing or future plant operations at Oconee.

4.7 Documentation of Consultation with Services [§122.21(r)(4)(vii)]

In preparing this response package for compliance with the Rule, there has been neither public participation, nor formal coordination undertaken with USEPA, USFWS, or the National Marine Fisheries Service, collectively known as the Services.

As part of the Oconee license renewal process in 1998, U.S. Nuclear Regulatory Commission (USNRC) prepared a list of all consultations with federal, state, and regional agencies (USNRC 1999), including the following coordination with USFWS:

- On 23 June 1998, USNRC provided a survey report to USFWS regarding rare or endangered species. By correspondence dated 26 June 1998, the USFWS concurred with determination of no effect on listed or proposed endangered or threatened species.
- On 30 June 1999, USNRC provided a biological assessment to USFWS regarding impacts to threatened and engendered species from 330 miles of transmission lines associated with Oconee. By correspondence dated 4 November 1999, USFWS provided concurrence with the not likely to adversely affect finding.

4.8 Information Submitted to Obtain Incidental Take Exemption or Authorization from Services

As noted in Section 4.6, no federally listed fish or aquatic species have been collected in Lake Keowee near the Oconee CWIS, and none are believed to occur near the CWIS. Therefore, an incidental take exemption or authorization for the Oconee CWIS has neither been required by USFWS nor sought by Duke Energy.

4.9 Methods and QA Procedures for Field Efforts [§122.21(r)(4)(viii)]

Data presented in Section 4 were compiled from Duke Energy's historical and ongoing monitoring program, historical impingement studies, and historical and recent entrainment studies on Lake Keowee. The monitoring program collected electrofishing, purse seine, hydroacoustic, and creel survey data to characterize the Lake Keowee fishery. Data obtained through the historical and recent Duke Energy monitoring studies were collected following Duke Energy procedures and quality assurance protocols, as detailed in each of the referenced reports.

Methodology and quality assurance protocols used for the 2016-2017 Entrainment Characterization Study are discussed in Section 9 and associated appendices.

4.10 Definition of Source Water Baseline Biological Characterization Data [§122.21(r)(4)(ix)]

Data were provided to address §122.21(r)(4)(i) – (viii) and (x) – (xii), and there is no required submittal under subsection §122.21(r)(4)(ix) of the Rule.

4.11 Identification of Protective Measures and Stabilization Activities [§122.21(r)(4)(x)]

4.11.1 Protective Measures

On October 17, 2014, an Operating Agreement pertaining to reservoir levels in Lake Keowee was signed by representatives from the Savannah District of the USACE, the Southeastern Power Administration, and Duke Energy (USACE 2014). The Operating Agreement helps Duke Energy meet power and water demands during droughts as well as protect key recreational and environmental resources by:

- Limiting the maximum reservoir drawdown in Lake Keowee to El. 790 ft msl (10 ft drawdown);
- Balancing the percentage of combined remaining usable storage between the Duke Energy and USACE reservoirs in the Savannah River Basin;
- Coordinating drought response between the Duke Energy and USACE reservoirs and downstream flow releases in the Savannah River Basin;
- Developing measures to protect water supply in the Duke Energy and USACE reservoirs in the Savannah River Basin; and
- Implementing a low inflow protocol which provides rules for how Duke Energy reservoirs (i.e., Lake Keowee and Lake Jocassee) are to be operated during periods of drought, including minimum lake elevations and water use conservation for existing and future water intake owners located on these two reservoirs.

4.11.2 Stabilization Activities

As required by the Keowee-Toxaway Project Comprehensive Relicensing Agreement (FERC No. 2503-154), Duke Energy is in the process of stabilizing 6,250 feet of shoreline on islands located in Lake Keowee which are used for recreational purposes (FERC 2016).

4.12 Fragile Species

Fragile species are defined as fish and shellfish that are least likely to survive any form of impingement, with survival rates of 30 percent or less (§125.92(m)). The Rule identifies 14 species representing 7 families as fragile species, but states that this list is not meant to be exhaustive and does not include all potential fragile species. The Rule provides that the Director may accept additional species as "fragile species" when presented with sufficient justification from the applicant (79 FR 158, 48364).

The fragile species, Blueback Herring and Gizzard Shad, have been historically documented in Lake Keowee by Duke Energy (Duke Power Company 1976; ASA 2008; Duke Energy 2007, 2013). The remaining species included in §125.92(m) are marine or coastal anadromous species, with the exception of Rainbow Smelt, which does not occur in Lake Keowee.

Threadfin Shad, although not included on USEPA's "non-exclusive" list of fragile species, is a semi-tropical member of the Clupeidae family and a relative (sharing the same family or genus) to several Rule-identified fragile species and is expected to have low post-impingement survival. Threadfin

Shad are not indigenous to Lake Keowee but were stocked in Lake Keowee in the early 1970s (ASA 2008). Further, Threadfin Shad is provided in the Rule as an example of a species not specifically identified at §125.92(m), but that is prone to die-off events when temperatures drop to low levels in fall and winter months (79 FR 158, 48364). Historical impingement monitoring at Oconee (see Section 4.3.1) found that Threadfin Shad comprise up to 73.1 percent of fish impinged and that the majority of the Threadfin Shad were impinged from September to December.

Threadfin Shad were consistently collected in purse seines during historical monitoring studies of the Lake Keowee fishery (Section 4.2.2). Annual trends in sampling show that of the two dominant clupeids collected on Lake Keowee, Threadfin Shad consistently dominate samples and exhibit stable population trends. As such, despite the fragile nature of Threadfin Shad and temperature-induced seasonal die-offs, Threadfin Shad populations in Lake Keowee are stable. Furthermore, due to their low tolerance of cool temperatures, the long-term success of this species in Lake Keowee may be owed, in part, to the thermal influence of Oconee on Lake Keowee (providing winter refuge habitat) during low temperature events.

Based on these data, Threadfin Shad in Lake Keowee demonstrate low survival that is consistent with the Rule's definition of fragile species. Although Threadfin Shad were collected in entrainment and impingement samples at Oconee, the continued presence of robust Threadfin Shad populations in historical monitoring studies of Lake Keowee indicates that the Oconee CWIS is not having an adverse effect on their populations. Given their low thermal tolerance and challenges this species could present for future technology optimization or technology efficacy demonstration studies, Threadfin Shad should be considered fragile at this facility.

4.13 Section 4 References

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5 Cooling Water System Data [§122.21(r)(5)]

The information required to be submitted per §122.21(r)(5), *Cooling water system data*, is outlined as follows:

(i) *A narrative description of the operation of the cooling water system and its relationship to cooling water intake structures; the proportion of the design intake flow that is used in the system; the number of days of the year the cooling water system is in operation and seasonal changes in the operation of the system, if applicable; the proportion of design intake flow for contact cooling, non-contact cooling, and process uses; a distribution of water reuse to include cooling water reused as process water, process water reused for cooling, and the use of gray water for cooling; a description of reductions in total water withdrawals including cooling water intake flow reductions already achieved through minimized process water withdrawals; a description of any cooling water that is used in a manufacturing process either before or after it is used for cooling, including other recycled process water flows; the proportion of the source waterbody withdrawn (on a monthly basis);*

(ii) *Design and engineering calculations prepared by a qualified professional and supporting data to support the description required by paragraph (r)(5)(i) of this section; and,*

(iii) *Description of existing impingement and entrainment technologies or operational measures and a summary of their performance, including but not limited to reductions in impingement mortality and entrainment due to intake location and reductions in total water withdrawals and usage.*

Each of these requirements is addressed in the following subsections.

5.1 Description of Cooling Water System Operation [§122.21(r)(5)(i)]

5.1.1 Operation of Cooling Water System

Oconee employs a once-through cooling system. Water withdrawn from Lake Keowee via the CWIS is used to provide cooling water to the Unit 1, 2, and 3 condensers (Figure 3-5). Oconee has 12 vertical, wet-pit CCW pumps (4 per unit, 1 for every 2 intake bays). Each CCW pump has a rated capacity of 246,000 gpm (354.2 MGD), for a total cooling system pumping capacity of 2,952,000 gpm (4,251 MGD). As discussed in Section 3.3, the condenser piping restriction in the 8-ft-diameter header pipes on the downstream side of the CCW pumps limits the capacity of each unit to 708,000 gpm (1,019.5 MGD) by combining flow from two CCW pumps per unit into a common header before reaching the condensers (Duke Energy 2002). This piping restriction reduces the cooling water flow to less than the design capacity during multiple pump operation.

The CCW pumps are located in the CWIS, downstream of the fixed panel mesh screens. Cooling water is discharged into Upper Lake Keowee at a discharge structure northeast of the intake canal (EPRI 2008).

5.1.2 Temporal Characteristics of Cooling Water System Operation

As shown in Table 5-1[14], Oconee operates two to four CCW pumps per unit based on lake temperatures. Generally, a minimum number of pumps are used during cooler months, and all four pumps are used during summer when intake water temperatures are higher.

Table 5-1. Design Circulating Water and Operational Pump Configurations

Operating Schedule	Number of CCW Pumps	Effective Pump Capacity per Unit Basis[1]	
		gpm	MGD
Outage Related	1	246,000	354
Lake Temps < 56 °F (December - February)	2	465,000	670
Lake Temps > 56 °F (Spring and Fall)	3	609,000	877
Lake Temps > 69 °F (Summer)	4	708,000	1,020

[1] Withdrawal volume is limited by condenser header pipes on the downstream side of the CCW pumps. The header pipe flow restrictions are based on Oconee calculation number OSC-6535 (Duke Energy 2002).

The number of days (per month) that the Oconee CCW pumps were operated from July 1, 2014 through June 30, 2019 is provided in Table 5-2. Based on these data, CCW pumps operated nearly continuously, with Unit 1 pumps operating 97 percent of the period of record, and Units 2 and 3 pumps operating 98 percent of the period of record (Duke Energy 2019a).

[14] Each of the three operating units is served by four pumps and two headers. At least one pump on each header must be in operation if the unit is online. Each unit can operate with two, three, or four pumps depending on inlet water temperature. The heated water then flows to the discharge canal.

Table 5-2. Number of Days per Year and Month when Oconee Nuclear Station Condenser Cooling Water Pumps Operated July 2014 – June 2019

Month	2014			2015			2016			2017			2018			2019		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
January				31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
February				28	28	28	29	29	29	28	28	28	28	28	28	28	28	28
March				31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
April				30	30	30	30	30	24	30	30	30	30	30	23	30	30	30
May				31	31	31	31	31	22	31	31	31	31	31	22	31	31	31
June				30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
July	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31			
August	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31			
September	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30			
October	31	31	31	31	19	31	31	31	31	31	30	31	21	31	31			
November	10	30	30	30	29	30	14	30	30	30	16	30	26	30	30			
December	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31			
Total	**164**	**184**	**184**	**365**	**352**	**365**	**350**	**366**	**351**	**365**	**350**	**365**	**351**	**365**	**349**			

Note: Gray shaded cells are not included in the 5-year period of record.
Source: Duke Energy 2019a

5.1.3 Proportion of Design Flow Used in the Cooling Water System

Approximately 96 percent (2,929 MGD) of Oconee's DIF (3,059 MGD) is used in the condenser cooling water system (Duke Power Company 1970). The remaining 130 MGD is used for service water purposes, including operation of the low and high pressure service water systems, fire protection water, and cooling of various plant equipment (4 percent of the DIF) (Duke Energy 2019b). Service water is withdrawn from the condenser piping system on the downstream side of the CCW pumps and, after use, is returned to the condenser piping system and combined with once-through heated cooling water prior to being discharged at NPDES Outfall 001. Oconee does not use cooling water for process units (see Section 8.3) or contact-cooling purposes.

5.1.4 Distribution of Water Reuse

Oconee does not currently employ any water reuse strategies (Duke Energy 2018).

5.1.5 Description of Reductions in Total Water Withdrawals

5.1.5.1 Seasonal Reductions

While Oconee does not have planned seasonal reductions in total water withdrawals, one to two CCW pumps per unit are generally turned off based on lake temperatures. Generally, two pumps are operated in colder winter months (December – February), three pumps are operated in cooler spring and fall months, and all four pumps are operated during the hottest summer months (Table 5-1).

Oconee's DIF per unit (including all four CCW pumps) is 1,019.5 MGD (Table 3-2). With two CCW pumps per unit turned off (during colder winter months), the DIF is reduced by approximately 34 percent. With one CCW pump per unit turned off (during cooler spring and fall months), the DIF is reduced by approximately 14 percent.

5.1.5.2 Lake Keowee as a Closed-cycle Recirculating System

Water withdrawal reduction is also achieved by operation of Lake Keowee as a closed-cycle recirculating system (CCRS). Runoff from the watershed (including upstream flow releases from the Jocassee Development) and direct precipitation to the reservoir replace evaporation, seepage, and downstream flow allowing maintenance of the water levels in the reservoir. Therefore, no separate make-up pumping from another source of WOTUS is required to maintain water levels in Lake Keowee. Under the Rule, use of a WOTUS as a CCRS suggests that absence of separate make-up pumping to the CCRS from another WOTUS by reliance on runoff/rainfall is the maximum potential water withdrawal reduction scenario relative to a potential separate source of make-up water.

The preamble to the Rule (at 79 FR 48334) also indicates that recirculation of cooling water within the reservoir (or impoundment), by itself, constitutes water withdrawal reduction as the latent heat of evaporation is used to dissipate heat from the water and the cooling water is reused:

> "*As with cooling towers, impoundments rely on evaporative cooling to dissipate the waste heat; a facility withdraws water from one part of the impoundment and then discharges the heated effluent back to the impoundment, usually in another location to allow the heated water time to cool.*"

As described in Section 2.1, Oconee withdraws cooling water from Lower Lake Keowee and discharges the heated effluent into Upper Lake Keowee. Heated effluent must travel back to Lower Lake Keowee (allowing additional time for heat dissipation) prior to being re-used by the station. Therefore, consistent with the purpose of its creation as a CCRS, Lake Keowee reduces cooling water withdrawals relative to an open-cycle system that does not re-use cooling water.

5.1.5.3 Cooling Water System Configuration

Oconee withdraws cooling water through a CWIS at the end of a 5,860-ft long intake canal. A curtain wall is located at the entrance of the intake canal and facilitates the withdrawal of cooler water from the bottom of Lake Keowee to Oconee's cooling water system. By using cooling water that is significantly colder than ambient surface water, the thermal impacts of the discharge water from the condensers to the surface waters of Lake Keowee are lower than they would be without the curtain wall. Therefore, Oconee is able to exert a larger change in temperature to the discharge water without impacting the lake surface water. If surface water was used as a source of cooling water, a lower change in temperature would be required to mitigate the potential thermal impacts, and a larger quantity of water would be needed to dissipate the same heat load. While this reduction in flow has not been quantified, it is likely to be substantial.

5.1.6 Proportion of Source Waterbody Withdrawn

The total water volume of Lake Keowee is 952,300 acre-ft, or 310.3 billion gallons (Duke Energy 2013). The DIF and the AIF from July 1, 2014 through June 30, 2019, as discussed in Section 3.3, are 3,059 MGD and 2,625 MGD, respectively (Duke Energy 2019a). The monthly Oconee cooling water withdrawal as a percentage of the total Lake Keowee water volume, based on both DIF and AIF, for the five-year period of record is presented in Table 5-3. On average, the proportion of Lake Keowee withdrawn on a monthly basis is approximately 30 percent based on the DIF, and approximately 26 percent based on the AIF.

Table 5-3. Monthly Cooling Water Withdrawal as a Percentage of Lake Keowee Water Volume for the Period of Record, July 1, 2014 through June 30, 2019

Month	AIF (MGD)	DIF (MGD)	AIF as Percent of Lake Keowee Volume	DIF as Percent of Lake Keowee Volume
January	2,423	3,059	24%	31%
February	2,133	3,059	19%	28%
March	2,210	3,059	22%	31%
April	2,399	3,059	23%	30%
May	2,503	3,059	25%	31%
June	2,806	3,059	27%	30%
July	3,043	3,059	30%	31%
August	3,059	3,059	31%	31%
September	3,054	3,059	30%	30%
October	2,813	3,059	28%	31%
November	2,407	3,059	23%	30%
December	2,609	3,059	26%	31%
Overall Average	**2,625**	**3,059**	**26%**	**30%**

Note: The monthly percentages are based on daily data from the period of record July 1, 2014 through June 30, 2019. The overall average percentage may be slightly different than the average of the monthly percentages due to rounding.
Source: Duke Energy 2013; Duke Energy 2019a

5.2 Design and Engineering Calculations [§122.21(r)(5)(ii)]

Table 5-4 provides the estimated CWIS approach velocity and estimated TSV under several pump operating scenarios. Due to a condenser piping restriction (described in Section 3.4), the CCW pump flow per unit is reduced based on number of CCW pumps operating and number of screens utilized (Table 3-2). It is assumed that flow is distributed equally among utilized screens. Screen area available to flow is impacted by the presence of the overhang at the CWIS (Duke Energy 2020). Cooling water is withdrawn from the bottom of the overhang elevation (781.0 ft msl) to the bottom of the CWIS elevation (761.0 ft msl).

The approach velocity is defined as the localized velocity component perpendicular to the screen face measured at a distance from the screen (often three inches), or if the intake does not have a screen, it may be measured at the opening of the intake (USEPA 2014). Parameters used in calculating the approach velocity include the CCW pump design ratings, the maximum drawdown and full pond elevations, and the width of the intake bay channel immediately before the screens. The TSV is the velocity of water passing through the screen mesh openings (USEPA 2014). Parameters used in calculating the TSV include number of screens, screen mesh size and width, screen wire gauge type, number, and diameter, CCW pump design ratings, and maximum drawdown and full pond elevations. The engineering calculations of TSV and approach velocity were prepared by Professional Engineers (Appendix 5-A).

Table 5-4. Estimated Approach Velocity and TSV at Oconee Nuclear Station

Estimated Approach Velocity at Entrance of CWIS	Units	Values		
		Unit 1	Unit 2	Unit 3
One-pump Operation	fps	0.83	0.83	0.83
Estimated TSV	**Units**	**Values**		
		Unit 1	**Unit 2**	**Unit 3**
One-pump Operation[15] (Two Screens)	fps	2.90	2.90	2.90
Two-pump Operation (Four Screens)	fps	2.74	2.74	2.74
Three-pump Operation (Six Screens)	fps	2.39	2.39	2.39
Four-pump Operation (Eight Screens)	fps	2.08	2.08	2.08

5.3 Description of Existing Impingement and Entrainment Reduction Measures [§122.21(r)(5)(iii)]

Oconee employs the following measures to reduce impingement and entrainment at the station:

- A reduction in water withdrawals is achieved at Oconee by operating Lake Keowee as a CCRS. The preamble to the Rule indicates that recirculation of cooling water within a reservoir (or impoundment), by itself, constitutes flow reduction as the latent heat of evaporation is used to dissipate heat from the water and the cooling water is re-used: "As with cooling towers, impoundments rely on evaporative cooling to dissipate the waste heat; a facility withdraws water from one part of the impoundment and then discharges the heated effluent back to the impoundment, usually in another location to allow the heated water time to cool."[16] Oconee withdraws cooling water from Lower Lake Keowee and discharges the heated effluent into Upper Lake Keowee. Heated effluent must travel back to Lower Lake Keowee (allowing additional time for heat dissipation) prior to being re-used by the station.
- A reduction in water withdrawals is also achieved as runoff from the watershed (including upstream flow releases from the Jocassee Development) and direct precipitation to the reservoir replace water lost through evaporation, seepage, and downstream flow, helping to maintain water levels in the reservoir; therefore, no make-up water source (from a separate WOTUS) is required to maintain water levels in Lake Keowee. Use of WOTUS as a CCRS under the Rule suggests that (1) absence of a make-up source pumped from a separate WOTUS to the CCRS and (2) reliance on runoff and rainfall are indicative of the maximum potential flow reduction scenario relative to a potential separate source of make-up water.
- Further, Oconee's cooling water intake system employs a curtain wall at the entrance to the intake canal that extends from El. 800.5 ft msl (i.e., 0.5 ft above full pond) down to El.

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[15] One-pump operation occurs on less than 10 days during the five-year period of record from July 1, 2014 through June 30, 2019 (Duke Energy 2019a).

[16] 79 FR 48,334 (August 15, 2014).

733 ft msl in the water column. The curtain wall was specifically designed to allow access to the cooler hypolimnetic water in the bottom 23 ft of the water column (the curtain wall opening extends from El. 733 ft msl down to approximately El. 710 ft msl). As a result, less cooling water is needed by the station's condenser cooling system to dissipate heat. While this reduction in flow has not been quantified, it is likely to be substantial, and it is expected that any reduction in flow proportionately reduces impingement and entrainment.

- The curtain wall at the entrance to the intake canal also provides entrainment reduction benefits. A study was performed by Duke Energy from March through October of 2017 to characterize the ichthyoplankton communities on the intake and lake sides of the curtain wall at Oconee and to evaluate the efficacy of the curtain wall at reducing ichthyoplankton passage under the curtain wall and thus their susceptibility to entrainment at the Oconee CWIS. Over the eight-month sampling period, densities of ichthyoplankton on the intake side of the curtain wall were 76.6 percent lower than ichthyoplankton densities on the lake side, indicating that the curtain wall is effective at limiting the number of organisms susceptible to entrainment at the CWIS (see Section 7.1.2).
- The face of the Oconee CWIS also includes an overhang that extends below the full pond elevation by 19 feet, thus restricting water withdrawal at the intake structure to the bottom 20 feet of the water column near the entrance to the CWIS (see Figure 3-4). As a result, the CWIS overhang functions like a curtain wall structure (see Section 4.3.2 for additional discussion).
- Oconee employs seasonal flow reductions which effectively reduce impingement and entrainment compared to operating at full capacity. Two to four CCW pumps per unit are operated based on lake temperatures; generally, two pumps are operated in colder winter months (December – February), three pumps are operated in cooler spring and fall months, and all four pumps are operated during the hottest summer months.

5.4 Section 5 References

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6 Chosen Method(s) of Compliance with Impingement Mortality Standard [§122.21(r)(6)]

The information required to be submitted per §122.21(r)(6), *Chosen Method(s) of Compliance with Impingement Mortality Standard,* is outlined as follows:

> *The owner or operator of the facility must identify the chosen compliance method for the entire facility; alternatively, the applicant must identify the chosen compliance method for each cooling water intake structure at its facility. The applicant must identify any intake structure for which a BTA determination for Impingement Mortality under 40 CFR §125.94 (c)(11) or (12) is requested.*

The Rule at §125.94(c) requires that existing facilities employ one of seven IM BTA compliance options (IM Options) or alternatives[17]:

1. Operate a CCRS as defined by the Rule (this includes cooling towers and certain impoundments);
2. Operate a cooling water intake structure that has a maximum design through screen velocity of 0.5 fps or less;
3. Operate a cooling water intake structure that has a maximum actual through screen velocity of 0.5 fps or less;
4. Operate an existing offshore velocity cap that is a minimum of 800-ft offshore and has bar screens or otherwise excludes marine mammals, sea turtles, and other large aquatic organisms;
5. Operate a modified traveling screen system such as modified-Ristroph screens with a fish handling and return system, dual-flow screens with smooth mesh, or rotary screens with fish returns. Demonstrate that the technology is or will be optimized to minimize IM of all non-fragile species;
6. Operate any combination of technologies, management practices, and operational measures that the Director determines is BTA for reducing impingement. As appropriate to the system of protective measures implemented, demonstrate the system of technologies has been optimized to minimize IM of all non-fragile species; or
7. Achieve a 12-month performance standard of no more than 24 percent mortality including latent mortality for all non-fragile species.

IM Options 1, 2, and 4 are essentially pre-approved technologies that require minimal additional monitoring after their installation and proper operation. IM Options 3, 5, and 6 require that more detailed information be submitted to the Director before they can be considered the BTA for reducing

[17] Or under specific circumstances, one of nine alternatives, which includes §125.94(c)(11) and (12) in addition to §125.94(c)(1)-(7).

IM at the facility. Options 5, 6, and 7 require demonstrations with field studies that the technologies have been optimized to minimize IM of non-fragile species. The remaining options for which the Director may consider little or no additional controls for IM compliance apply under very specific circumstances:

i. *De minimis* rate of impingement – if the rates of impingement at a facility are so low that additional impingement controls may not be justified (§125.94(c)(11)); and

ii. Low capacity utilization of generating units – if the annual average capacity utilization rate (CUR) of a 24-month contiguous period is less than 8 percent (§125.94(c)(12)).

The information presented below is provided to support a request for a regulatory determination for IM BTA under *40 CFR §125.94 (c)(11)*. **Based on existing data, Duke Energy is seeking a regulatory determination for IM BTA Option 1 wherein Lake Keowee would be classified as a CCRS,** as discussed in Section 6.1.

A comparative evaluation of IM reduction options (i.e., technologies and operational scenarios) was performed for the CWIS at Oconee based on the Rule. The potential compliance options were evaluated based on technology efficacy, site-specific applicability, regulatory acceptability, order of magnitude costs, operational experience at similar facilities, and anticipated station downtime, to identify those technologies or operational scenarios that are feasible and practicable. Based on the existing design, operational data, rates of impingement demonstrated by historical impingement monitoring, and results of the comparative evaluation of IM reduction options, three technologies were advanced for further consideration: (1) regulatory determination that Oconee's use of Lake Keowee for cooling purposes meets the definition of a CCRS [IM Option 1]; (2) implementing a combination of technologies, management practices, and operational measures that would be considered BTA for reducing impingement [IM Option 6]; and (3) obtaining a regulatory determination of *de minimis* rate of impingement. The additional technologies and operational measures evaluated are summarized in Appendix 6-A.

6.1 CCRS Regulatory Determination

The Rule provides two criteria that impounded WOTUS must meet to be considered a CCRS:

- Criterion #1: The impoundment was constructed prior to October 14, 2014; and
- Criterion #2: The impoundment was "created for the purpose of serving as part of the cooling water system" as documented in the CWA Section 404 permit or otherwise demonstrated to the satisfaction of the NPDES Director (i.e., SCDHEC).

The preamble to the Rule provides perspective on USEPA's decision to include certain WOTUS as CCRS, dependent on their adherence to the definition of CCRS at §125.92(c), clarifying that the USEPA intended to allow "use of such lawfully created impoundments for their intended purpose" and to avoid "a large number of stranded assets"[18].

[18] 79 FR 48345. VI. Basis for the Final Regulation. Final Rule BTA Performance Standards. Impingement Mortality Controls for Existing Units at Existing Facilities for the Final Rule - Closed-cycle Recirculating Systems.

Lake Keowee was lawfully created for the purpose of serving as part of the cooling water system for Oconee, and Duke Energy requests designation by SCDHEC of the cooling water system at Oconee as CCRS (see Appendix 6-A).

The preamble's discussion of impounded WOTUS as CCRS[19] is consistent with the construction and operation of Lake Keowee:

> *"Impoundments are surface waterbodies that serve as both a source of cooling water and a heat sink. As with cooling towers, impoundments rely on evaporative cooling to dissipate the waste heat; a facility withdraws water from one part of the impoundment and then discharges the heated effluent back to the impoundment, usually in another location to allow the heated water time to cool. Depending on local hydrology, impoundments may also require makeup water from another waterbody. Impoundments can be man-made or natural, and can be offset from other water bodies or as part of a "run of the river" system (the latter are sometimes referred to as cooling lakes)."*

Water withdrawal reduction at Oconee is achieved by operating Lake Keowee as a CCRS. Runoff from the watershed (including upstream flow releases from the Jocassee Development) and direct precipitation to the reservoir replace water lost through evaporation, seepage, and downstream flow, helping to maintain water levels in the reservoir; therefore, no make-up water source (from a separate WOTUS) is required to maintain water levels in Lake Keowee. Use of WOTUS as a CCRS under the Rule suggests that (1) absence of a make-up source pumped from a separate WOTUS to the CCRS and (2) reliance on runoff and rainfall are indicative of the maximum potential flow reduction scenario relative to a potential separate source of make-up water.

The preamble to the Rule also indicates that recirculation of cooling water within the reservoir (or impoundment) constitutes flow reduction as the latent heat of evaporation is used to dissipate heat from the water and the cooling water is re-used:

> *"As with cooling towers, impoundments rely on evaporative cooling to dissipate the waste heat; a facility withdraws water from one part of the impoundment and then discharges the heated effluent back to the impoundment, usually in another location to allow the heated water time to cool."*

Oconee withdraws cooling water from Lower Lake Keowee and discharges the heated effluent into Upper Lake Keowee. Heated effluent must travel back to Lower Lake Keowee (allowing additional time for heat dissipation) prior to being re-used by the station. Therefore, consistent with the purpose of its creation as a CCRS, Lake Keowee reduces cooling water withdrawals relative to an open-cycle system that does not re-use cooling water.

All three units at Oconee withdraw cooling water from Lake Keowee under a 67-foot deep curtain wall located at the head of the intake canal. Withdrawal of bottom waters from beneath the curtain wall facilitates a reduction in the density of ichthyoplankton entrained under the wall relative to withdrawing from surface waters. The use of cooler bottom waters also improves condenser cooling efficiency and helps the station achieve compliance with temperature criteria, while also mitigating

[19] 79 FR 48333 48334. VI. Basis of the Final Regulation. C. Technologies Considered To Minimize Impingement and Entrainment. f. Closed-Cycle Cooling Systems. iv. Impoundments

the potential impact of the heated discharge from the condensers to the surface waters of Lake Keowee. By using intake water that is substantially colder than the ambient surface water, Oconee is able to reduce the volume of cooling water required to dissipate the same quantity of waste heat, thus more efficiently achieving compliance with effluent temperature criteria. While this reduction in flow has not been quantified, it is likely to be substantial.

6.2 System of Technologies

The System of Technologies IM Option includes operation of any combination of technologies, management practices, and operational measures that the Director determines is BTA for reducing impingement. Technologies implemented at Oconee with the purpose of minimizing adverse environmental impacts include (1) an existing curtain wall, (2) a submerged weir and CWIS overhang, and (3) reduction in seasonal and annual intake flows compared to DIF.

Oconee is equipped with a curtain wall located at the entrance of the intake canal leading to the CWIS. The primary purpose of the curtain wall is to facilitate selective withdrawal of cooler water from the hypolimnion to improve the thermal efficiency of the plant. The curtain wall facilitates water withdrawal from the lower 23 ft of the 90-ft Lake Keowee water column, where dissolved oxygen is naturally lower, creating less favorable conditions for fish. This effectively reduces the number of organisms in the intake canal that would be susceptible to impingement. As a supplemental benefit, the curtain wall reduces the number of ichthyoplankton susceptible to entrainment at the CWIS by withdrawing water from the bottom strata of the water column where fish eggs and larvae are less abundant. A curtain wall study performed at Oconee in 2017 indicates that the existing curtain wall at the inlet of the intake canal reduces the abundance of ichthyoplankton from the lake side to the intake side of the curtain wall by 76 percent or more during the entrainment period (i.e., March through September), and up to 90 percent during the peak entrainment months (i.e., April and May). More details on the curtain wall are provided in Section 7.1.2 and in Appendix 7-A.

In addition to the existing curtain wall, a submerged weir is located approximately 850 ft downstream of the curtain wall located at the mouth of the intake canal and the CWIS is equipped with an overhang, located at the entrance of the intake, to facilitate debris management and protect infrastructure. The overhang extends to a depth of 19 ft at full pond elevation, resulting in in a 20-ft opening in the lower portion of each intake bay (see Sections 3.1 and 9.1 for more detail). The submerged weir was installed as a safety precaution to maintain sufficient water for the safe shutdown of the station in the event of an unexpected drawdown of Lake Keowee. The submerged weir extends from the bottom of the intake canal at 725 ft msl up to 770 ft msl (see Section 3.1 for more detail). Both the submerged weir and the CWIS overhang help minimize the withdrawal zone and potential impingement impacts.

Finally, flow reductions have been shown to result in commensurate reductions in IM at the CWIS and facilities can take credit for reductions in cooling water withdrawals at the CWIS. The AIF withdrawn at the CWIS, as documented over the 5-year period from July 1, 2014 through June 30, 2019, results in a 14.2 percent annual flow reduction and a 34 percent maximum seasonal flow reduction when compared to the design intake flow (DIF) for the station. These reductions in flow are considered commensurate with a reduction in impingement.

6.3 Regulatory Determination of *de Minimis* Rate of Impingement

At §125.94(c)(11), the Rule recognizes that in limited circumstances where rates of impingement at a facility are low, additional impingement controls may not be justified. This determination would be made by the Director based on the review of site-specific data submitted under §122.21(r)(4) and §122.21(r)(6). Under this compliance approach, Oconee would not be required to implement an impingement reduction technology, but would be required to evaluate impingement and provide a justification of the *de minimis* rate of impingement to the Director. The preamble to the Rule provides examples of the information that may be considered by the Director in making a *de minimis* rate of impingement determination, such as (1) low numbers of organisms or age-1 equivalents, or (2) low facility withdrawal rates in relation to the mean annual flow of the river or source waterbody.

Total IM for 2016 and 2017 was estimated using the historical study impingement data collected by ASA Analysis & Communication, Inc. (ASA) (2008) (Section 4.3.1) and total water volumes withdrawn at Oconee between January and December of 2016 and 2017. Although more than 10 years have passed since impingement data were collected, periodic monitoring data and results from an entrainment characterization study documented comparable species composition in Lake Keowee. Therefore, these data are representative of existing conditions in Lake Keowee and at the Oconee CWIS.

Based on this information, 46,437 and 45,399 fish are were impinged per year in 2016 and 2017 (Table 6-1). Approximately 95 percent of the total estimated number of fish impinged were fragile species[20] (i.e., Threadfin Shad and Blueback Herring). Excluding fragile species from the analysis reduces the annualized IM estimates to 2,037 and 2,084 fish for 2016 and 2017, respectively, or around 5.6 and 5.7 fish per day.

Table 6-1. Summary of Estimated Impingement Mortality at Oconee Nuclear Station

Year	Total Estimated Number of Fish Impinged	Total Number of Fragile Fish Impinged	Total Number of Non-fragile Fish Impinged	Number of Non-fragile Fish Impinged Per Day
2016	46,437	44,400 (95.6%)	2,037	5.6
2017	45,399	43,315 (95.4%)	2,084	5.7

The Rule defines fragile species (i.e., those with less than 30 percent on-screen impingement survival, see Section 4.12) and acknowledges that these species are highly sensitive and often demonstrate poor survival under a variety of technologies and operational conditions. To address this concern, impingement technology performance optimization studies required by the Rule (under certain IM options) focus on technology optimization for all non-fragile species (79 FR 158, 48321).

Thus, the Rule acknowledges that facilities like Oconee, where IM is dominated by fragile species, would be at a disadvantage when trying to design and demonstrate optimization of IM reduction technologies. As such, the existing technologies and operations at Oconee support a *de minimis* rate of impingement determination, which is further support by additional factors (e.g., cooling water

[20] Blueback Herring is identified in the Rule as a fragile species. Although not listed in the Rule, Threadfin Shad are in the same family (Clupeidae) and exhibit similar life history characteristics and low impingement survival rates.

withdrawal from a reservoir originally constructed for cooling purposes, a managed fishery subject to state-managed stocking program, the absence of threatened or endangered aquatic species, water quality that is fully attaining aquatic life use designations, and rate and total IM losses at comparable facilities).

A comparison of annual impingement data (EPRI 2011) illustrates impingement rates across different regions and waterbody types throughout the U.S, such as coastal facilities, rivers, and the Great Lakes. The estimated annual rates of impingement at Oconee are similar to rates identified at 237 of the facilities examined (EPRI 2011). The region with the lowest median annual impingement in the database was Hawaii, with 6,077 fish impinged per year (3 facilities surveyed), followed by northeastern coastal facilities with a median impingement of 20,796 fish per year (20 facilities surveyed).

The median annual impingement for reservoirs in the southeastern U.S. region (14 facilities surveyed) was 53,425 fish, which is more than the estimated annual IM at Oconee (Table 6-1). However, when excluding fragile species, impingement at Oconee is estimated at just over 2,000 fish per year, roughly one third of the lowest median annual impingement documented in the analysis (EPRI 2011).

6.4 Section 6 References

ASA Analysis & Communication, Inc. (ASA). 2008. Oconee Nuclear Station Impingement Mortality Characterization Report 2006-2007. Washingtonville, NY.

Electric Power Research Institute (EPRI). 2011. Seasonal Patterns of Fish Entrainment for Regional U.S. Electric Generating Facilities. Technical Update, December 2011. DCN 10-23102.

U.S. Environmental Protection Agency (USEPA). 2014. National Pollutant Discharge Elimination System – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, 79 FR 158, 48299 (August 15, 2014).

7 Entrainment Performance Studies [§122.21(r)(7)]

The information required to be submitted per §122.21(r)(7), *Entrainment Performance Studies,* is as follows:

> *The owner or operator of an existing facility must submit any previously conducted studies or studies obtained from other facilities addressing technology efficacy, through-facility entrainment survival, and other entrainment studies. Any such submittals must include a description of each study, together with underlying data, and a summary of any conclusions or results. Any studies conducted at other locations must include an explanation as to why the data from other locations are relevant and representative of conditions at your facility. In the case of studies more than 10 years old, the applicant must explain why the data are still relevant and representative of conditions at the facility and explain how the data should be interpreted using the definition of entrainment at 40 CFR 125.92(h).*

Each of these requirements is addressed in the following subsections.

7.1 Site-Specific Studies

7.1.1 Historic Curtain Wall Studies (Olmsted and Adair 1981)

Olmsted and Adair (1981) conducted studies at two power plants with curtain walls in the 1970s to examine the efficacy of curtain walls in reducing ichthyoplankton entrainment. The first study, conducted at Oconee, compared entrained organisms to standing crops of ichthyoplankton in the intake canal, at the curtain wall, and on the lake side of the curtain wall from March to August 1976. Data collection on the lake side of the curtain wall was performed by USFWS and consisted of larval collections, specifically. Entrainment samples were collected at the CWIS via the condenser taps connected directly to the circulating water system. Standing crops of ichthyoplankton were simultaneously estimated on the intake side of the curtain wall by towing a 794-micron (μm) mesh net, with a 3-ft-diameter mouth opening, at the surface as well as at a depth of 16.5 ft. An identical net was suspended in the curtain wall opening (i.e., near the bottom of the intake canal) while the tows were conducted to capture ichthyoplankton that passed under the curtain wall. Larval samples on the lake side of the curtain wall were collected on a monthly basis by the USFWS (eggs were not identified or analyzed).

A total of 98 samples were collected on the lake side of the curtain wall by the USFWS, resulting in a range of densities from 0.1 to 12.8 larvae/1,000 cubic meters (m^3), with peak densities occurring in May. Twenty-three samples were collected from the net suspended in the opening of the curtain wall, which sampled a volume range of 101.2 to 743.2 m^3 and resulted in the collection of five ichthyoplankton, for a density of 0.22 ichthyoplankton per sample. One Threadfin Shad larvae, one Black Crappie larvae, and three Threadfin Shad eggs were collected from the net suspended in the curtain wall opening. One-hundred samples were collected in the intake canal, with sample volumes ranging from 310.2 to 1,286.3 m^3, yet only resulted in the collection of a single larval-stage Threadfin

Shad for a density of 0.01 larvae per sample. No ichthyoplankton were collected from the condenser taps at the CWIS for the duration of the study.

The second study, conducted at Marshall Steam Station (Marshall) on Lake Norman in Sherrills Ford, North Carolina, compared ichthyoplankton entrainment data collected from condenser traps at Marshall (inside the curtain wall) to ichthyoplankton standing stock data collected from the lake side of the curtain wall in Lake Norman. Ichthyoplankton entrainment data were collected during 24-hour sampling events performed three times per week from March through August 1976. Samples were collected from the 5.1-centimeter (2.0-inch) diameter gate valve in the water box (upstream of condenser at Unit 1 and Unit 4) by filtering water through a 794-µm mesh plankton net suspended in a 208-liter (55-gallon) filled drum to minimize mechanical damage to entrained ichthyoplankton.

Larval fish densities in Lake Norman (the lake side of the curtain wall) were estimated by towing a 0.9-m (2.95 ft) circular plankton net with 794-µm mesh. Plankton tows were performed at night, from March through August 1975, and replicated at the surface and at a depth of 5 m (16 ft). Sample densities (number/1,000 m^3) from the two depths were averaged to estimate the monthly mean density on the lake side of the curtain wall. Data from the comparison showed intake side densities that ranged from 0.0 (June) to 0.5 (April) larvae/1,000 m^3. Intake side samples consisted of crappie (*Pomoxis* spp.); shad (*Dorosoma* spp.); and Channel Catfish. Mean monthly entrainment densities from the intake side of the wall were compared to mean monthly densities on the lake side of the curtain wall, which ranged from 15.5 (April) to 677.2 (June) larvae/1,000 m^3. Ichthyoplankton samples from the lake side of the curtain wall were dominated by Yellow Perch. It is important to note that some of the variability observed across the two locations may exist because the data were collected in different years (i.e., the Lake Norman data were collected in 1975 while the entrainment data were collected in 1976).

In both studies, Olmstead and Adair (1981) concluded that the curtain walls were effective at reducing entrainment by excluding larval fish from the intake structures. The authors concluded that the depth of the curtain wall opening, in relation to thermal and DO stratification in the source waterbody, was the key factor in reducing ichthyoplankton abundance on the intake side of the curtain wall in comparison to the lake side at both facilities.

7.1.2 Curtain Wall Entrainment Reduction Performance Study

A Curtain Wall Entrainment Reduction Performance Study was performed by Duke Energy from March through October of 2017 to characterize the ichthyoplankton communities on the intake and lake sides of an existing curtain wall at Oconee to evaluate the efficacy of the curtain wall at reducing entrainment at the station's CWIS (HDR 2018a; Appendix 7-A). The objectives of the study were to evaluate potential selectivity of the curtain wall on certain species and life stages, to determine the taxonomic resolution appropriate for the efficacy evaluation, and to quantify curtain wall efficacy at reducing entrainment at the Oconee CWIS. Located at the intake canal entrance leading to CWIS, the primary purpose of the curtain wall is to facilitate the withdrawal of cooler water from the bottom of the reservoir, which is conveyed to the CWIS to improve the plant's thermal efficiency. The curtain wall also helps to reduce the number ichthyoplankton susceptible to entrainment at the CWIS by removing water from the lower strata of the water column where fish eggs and larvae are not as abundant. Historical curtain wall studies conducted at Oconee concluded that the curtain wall is effective at reducing ichthyoplankton passage from Lake Keowee to the intake side of the curtain wall (Olmsted and Adair 1981); therefore, Duke Energy elected to conduct an additional study to build upon the historical data and to further evaluate curtain wall effectiveness in reducing entrainable organisms at Oconee.

During the eight-month study, 32 ichthyoplankton samples were collected from each side of the curtain wall for a total of 64 samples. Samples were collected once per month from March through October 2017 (eight sampling events). The duration and sampling period for the field study were selected to coincide with the period of anticipated entrainment, which was determined from a review of historical data and life history information for the fish species present in Lake Keowee.

Sampling was performed by field crews on each side of the curtain wall, sampling concurrently. Samples were collected by pulling nets away the curtain wall along perpendicular transects. A boat-towed Tucker Trawl with 33-µm-mesh net fitted with a 4.0-inch diameter PVC cod-end bucket and a 0.5-m square mouth opening was used to collect samples. A sample volume of 100 to 150 m^3 was targeted for each sample. Eight, 5-minute nighttime ichthyoplankton samples were collected during each sampling event, four on the intake side and four on the lake side of the curtain wall, at an approximate depth of 10 ft below the water surface. Surface water temperature was also collected on each side of the curtain wall.

Data were summarized to calculate sample counts and organism densities standardized to the water volume filtered by the net during sampling, as recorded by the flow meter. Collection densities, expressed as number per 100 m^3, were calculated for each taxon and life stage on both sides of the curtain wall. The seasonal pattern in ichthyoplankton densities (all taxa combined) susceptible to entrainment through the curtain wall was evaluated at a data-screening level to determine if further statistical analyses were needed. As curtain wall efficacy can be taxon-specific, the mean density and standard error of the mean across all surveys was computed and presented for each side of the wall.

A total of 179 ichthyoplankton consisting of at least three distinct taxa representing two families were collected during 8 months of sampling on both sides of the Oconee curtain wall. A higher number of ichthyoplankton were collected on the lake side (n=145) than on the intake side (n=34). The dominant taxa on the lake side of the curtain wall were shads and herrings (81.4 percent), the Shad Group (ichthyoplankton identified as possible Threadfin Shad or Gizzard Shad (16.6 percent), and unidentified sunfish species (*Lepomis* spp., 2 percent). Samples on the intake side of the curtain wall were dominated by the Herring Group (ichthyoplankton identified as possible Blueback Herring or Alewife [*Alosa pseudoharengus*], 61.7), shads and herrings (26.4 percent), Shad Group (5.9 percent), Alewife (2.9 percent) and unidentified fish (2.9 percent).

Only larval life stage specimens were collected on the lake side of the curtain wall. Eggs accounted for 65.0 percent of the collection on the intake side of the curtain wall, and the larval and young-of-year life stage specimens accounted for 32.0 percent of the collection. The species diversity and life stages caught on either side of the curtain wall are consistent with species diversity and life stages collected during the 2016-2017 Entrainment Study (Appendix 9-A).

Over the eight-month sampling period, densities of ichthyoplankton on the intake side of the curtain wall were 76.6 percent lower than ichthyoplankton densities on the lake side to (Table 7-1). However, an 89.7 percent reduction was observed when considering just the peak density period (April to May), which is just less than what is expected with installation of wet cooling towers (95 percent; 79 FR 158, 48303).

Table 7-1. Effort Adjusted Abundance (No./100 m³) by Family and Percent Reduction from the 2017 Curtain Wall Study at Oconee Nuclear Station

Family	March to October			April and May (peak period only)		
	Effort-Adjusted Abundance (No./100 m³)		Percent Reduction	Effort-Adjusted Abundance (No./100 m³)		Percent Reduction
	Lake Side	Intake Side		Lake Side	Intake Side	
Clupeidae	81.8	18.9	76.9	77.3	8.1	89.5
Centrarchidae	1.7	0	100.0	1.1	0	100.0
Unidentified Fish	0	0.6	N/A*	0	0	None
Total	**83.5**	**19.5**	**76.6**	**78.4**	**8.1**	**89.5**

*Taxa collected on the intake side only

Samples collected from the intake side of the curtain wall exhibited similar ichthyoplankton densities and periods of peak entrainment to those collected at the CWIS during the 2016-2017 Entrainment Characterization Study (HDR 2018b). Conversely, peak sample densities on the lake side of the curtain wall occurred in April and May during this Study and were significantly higher in comparison to the densities documented on the intake side during the same period. This suggests that the curtain wall is effectively reducing the ichthyoplankton at risk to entrainment at Oconee. These trends are consistent with other curtain wall studies performed by Olmsted and Adair (1981) and HDR (2018b), which documented similar ichthyoplankton density reductions due to curtain wall effects.

7.2 Studies Conducted at Other Locations

7.2.1 Marshall 2016 Curtain Wall Report

A Curtain Wall Entrainment Reduction Performance Study was conducted by Duke Energy from March through October of 2016 to characterize the ichthyoplankton communities on the intake and lake sides of the curtain wall at Marshall to evaluate the efficacy of a curtain wall at reducing entrainment at the Marshall CWIS (HDR 2018c). The objectives of the study were to evaluate potential selectivity of the curtain wall on species and life stages, to determine the taxonomic resolution appropriate for the efficacy evaluation and quantify curtain wall efficacy at reducing entrainment at the Marshall CWIS.

The curtain wall study consisted of Tucker trawl ichthyoplankton sampling performed concurrently (i.e., same sample week) with the entrainment sampling conducted at the CWIS. The study was performed from March through October 2016 and consisted of 32-paired samples, with four collected upstream of the wall (Lake Norman) and four collected downstream of the wall (Intake Side) during each of the 8 nighttime sampling events. This sampling period was chosen to coincide with the peak periods of entrainment identified in historical data (Olmsted and Adair 1981) and based on life history information of the fish species present in Lake Norman. Samples were collected approximately 10 feet below the water surface using a boat-towed Tucker trawl (0.5-meter square mouth opening, 8.0-meter length, 333-micron mesh net) with a 4.0-inch diameter PVC cod-end bucket. Each Lake and Intake Side sample consisted of a 5-minute tow, which began at the curtain wall and moved along a perpendicular transect away from the wall.

A total of 6,779 ichthyoplankton were collected from the Lake Side of the curtain wall, while only 124 ichthyoplankton were collected from the Intake Side of the curtain wall during the study. Samples were dominated by Clupeid larvae in both locations and consisted of Alewife, Gizzard Shad, and Threadfin Shad. Egg collections consisted of specimens of *Dorosoma spp.* and White Perch.

The species composition and period of occurrence of ichthyoplankton collected during the curtain wall study is generally similar to that found in the 2016 entrainment samples collected at Marshall's CWIS; however, a significantly larger number of specimens were collected during this Study on the Lake Side of the curtain wall. The low numbers of ichthyoplankton collected on the Intake Side of the curtain wall is consistent with the low abundance data from the 2016 entrainment samples collected at the CWIS (HDR 2018c). Based on the total numbers of organisms collected in the 2016 Tucker trawl study, the curtain wall is estimated to reduce the number of ichthyoplankton within the intake canal, and thus entrainment at the facility by greater than 95 percent. Further, these data support the conclusion of prior studies that the curtain wall serves as an effective entrainment reduction method.

7.2.2 Through-plant Survival

In addition to entrainment performance studies, the potential for through-plant survival of entrained organisms at Oconee's CWIS was considered. The Rule assumes "100 percent of entrained organisms suffer mortality" (79 FR 158, 48318). However, through-plant entrainment survival studies demonstrate some survival can occur, depending on site-specific design, operations, and the species and life stages entrained at the facility (EPRI 2018). Through-plant survival has not been assessed at Oconee. However, entrainment survival studies have been performed at other electric utilities and recent research indicates that results of those studies may be transferable to other facilities under certain conditions (EPRI 2018).

Entrainment survival is mainly dependent on three stressors: thermal, chemical, and physical. Thermal stressors are variable due to generating load, pumping rate, ambient temperature, and thermal tolerance of organisms entrained. Chemical stressors are principally attributable to periodic biocide applications used to control biofouling within the cooling system. Therefore, thermal and chemical stressors are often intermittent, and have the potential to cause 100 percent mortality if conditions are severe (very high temperatures or recent/present application of biocides). The physical stress of entrainment is consistent for entrained organisms and may result from multiple sources, the greatest of which is likely the CCW pumps. Physical stressors can impose some mortality; however effects can be variable depending on species and life stages.

Depending on the seasonal influence of temperature, periodic biocide treatments, and facility equipment (particularly CCW pumps), some through-plant survival at Oconee could occur. However, the degree of survival possible depends on site and seasonal-specific conditions. In the absence of site-specific through-plant survival data, the baseline entrainment values presented for Oconee (Section 9) have not been adjusted for potential through-plant survival and should be viewed as a conservative estimate of entrainment under existing design and operational conditions.

The determination of entrainment BTA is made by comparing the costs and benefits, based on estimated performance of alternative entrainment reduction technologies, to the costs and benefits of the existing facility technologies. The assumption of 100 percent through-plant mortality of entrainable-size organisms, as defined in the Rule at 125.92(h), results in a negative bias to this comparison by assuming greater entrainment losses than may actually occur under existing conditions. As a result of this assumption, an overestimation of the benefits of the entrainment technologies (e.g., fine-mesh screens [FMS] or mechanical draft cooling towers [MDCT]) can occur and bias the analysis toward the FMS (as it assumes 100% survival of converts) or MDCTs (reductions based solely on flow reduction). The combination of these biases can cause the benefits analysis to be biased toward the FMS technologies (EPRI 2018). This bias has the potential to result in an entrainment BTA determination of FMS, followed by a post-installation monitoring that demonstrates increased entrainment losses due to higher organism mortality off of FMS compared with potential through-plant survival.

7.3 Summary

The assumption that through-plant mortality of entrained organisms is 100 percent has the potential to overestimate entrainment mortality and underestimate the performance of existing technologies and operational measures employed at facilities like Oconee. For example, the curtain wall at the entrance to the intake canal at Oconee is effective at reducing the susceptibility of ichthyoplankton to being drawn into the intake canal, thus reducing the number of ichthyoplankton susceptible to entrainment at the CWIS. The performance of the curtain wall is further demonstrated by the low ichthyoplankton densities observed in samples collected at the Oconee CWIS in 2016 and 2017 during the two-year Entrainment Study. Together, these two studies demonstrate that properly designed and maintained curtain walls can offer the benefit of a reduction in larval densities in the intake canal and a correlated reduction in entrainment at the CWIS.

7.4 Section 7 References

Electric Power Research Institute (EPRI). 2018. Entrainment Survival Transferability – Application of Prior Studies under the § 316(b) Rule. 2018 Technical Report. Palo Alto, CA.

HDR Engineering, Inc. (HDR). 2018a. 2017 Oconee Nuclear Station Curtain Wall Entrainment Reduction Performance Study Report. Prepared for Duke Energy, 20 Jul 2018.

__________. 2018b. 2016-2017 Entrainment Characterization Study Report, Oconee Nuclear Station. Prepared for Duke Energy. Charlotte, NC.

__________. 2018c. 2016-2017 Entrainment Characterization Study Report. Marshall Steam Station. Prepared for Duke Energy.

Olmsted, L. and W. Adair. 1981. Protection of Fish Larvae at Two Southeastern Power Plants using Skimmer Walls. Duke Power Company, Production Environmental Services. Huntersville, North Carolina.

8 Operational Status [§122.21(r)(8)]

The information required to be submitted per §122.21(r)(8), *Operational status*, is outlined as follows:

(i) *For power production or steam generation, descriptions of individual unit operating status including age of each unit, capacity utilization rate (or equivalent) for the previous 5 years, including any extended or unusual outages that significantly affect current data for flow, impingement, entrainment, or other factors, including identification of any operating unit with a capacity utilization rate of less than 8 percent averaged over a 24-month block contiguous period, and any major upgrades completed within the last 15 years, including but not limited to boiler replacement, condenser replacement, turbine replacement, or changes to fuel type;*

(ii) *Descriptions of completed, approved, or scheduled uprates and Nuclear Regulatory Commission relicensing status of each unit at nuclear facilities;*

(iii) *For process units at your facility that use cooling water other than for power production or steam generation, if you intend to use reductions in flow or changes in operations to meet the requirements of 40 CFR 125.94(c), descriptions of individual production processes and product lines, operating status including age of each line, seasonal operation, including any extended or unusual outages that significantly affect current data for flow, impingement, entrainment, or other factors, any major upgrades completed within the last 15 years, and plans or schedules for decommissioning or replacement of process units or production processes and product lines;*

(iv) *For all manufacturing facilities, descriptions of current and future production schedules; and,*

(v) *Descriptions of plans or schedules for any new units planned within the next 5 years.*

Each of these requirements is addressed in the following subsections.

8.1 Description of Operating Status [§122.21(r)(8)(i)]

8.1.1 Individual Unit Age

Oconee consists of three nuclear-fueled generating units, Units 1, 2, and 3, with a total gross generating capacity of 2,725 MW (Duke Energy 2019b). The individual generating capacities of each unit are as follows: Unit 1 – 902 MW, Unit 2 – 907 MW, and Unit 3 – 916 MW (Duke Energy 2019b). Unit 1 began operations in February 1973, Unit 2 began operations in October 1973, and Unit 3 began operations in July 1974 (USNRC 2018a; 2018b; 2018c). In 2019, Units 1 and 2 will be in their 46th year of operation, while Unit 3 will be in its 45th year of operation.

8.1.2 Station Utilization

The total annual gross generating data for each unit and capacity utilization rate for July 1, 2014 through June 30, 2019 are provided in Table 8-1 and Table 8-2, respectively.

Table 8-1. Oconee Nuclear Station Total Annual Gross Generating Data

Month	Unit	Generation Data July 1, 2014 through June 30, 2019 (MW hours)					
		2014	2015	2016	2017	2018	2019
January	Unit 1		662,303	628,904	672,731	672,259	659,709
	Unit 2		675,044	679,969	676,693	677,522	675,382
	Unit 3		671,389	676,246	680,197	678,035	679,676
February	Unit 1		600,076	622,109	439,692	605,220	606,525
	Unit 2		609,550	636,194	609,621	609,262	612,050
	Unit 3		562,640	634,389	613,267	610,138	612,676
March	Unit 1		667,634	172,598	672,519	671,504	661,252
	Unit 2		676,430	678,014	674,970	675,508	675,353
	Unit 3		679,982	675,946	678,655	673,633	676,023
April	Unit 1		645,405	645,110	650,352	603,447	650,384
	Unit 2		653,971	657,261	652,608	652,967	655,473
	Unit 3		657,925	463,198	656,172	394,863	655,263
May	Unit 1		664,808	665,932	670,018	671,428	671,329
	Unit 2		674,855	676,143	672,152	672,198	677,064
	Unit 3		678,917	327,291	675,284	266,649	676,005
June	Unit 1		640,592	640,626	645,912	647,927	626,472
	Unit 2		649,381	652,237	648,199	650,689	631,806
	Unit 3		653,263	654,318	650,547	653,132	631,111
July	Unit 1	661,644	656,590	656,812	662,272	666,515	
	Unit 2	668,617	607,150	668,699	663,143	669,875	
	Unit 3	673,393	669,697	671,376	637,219	673,619	
August	Unit 1	655,717	650,376	648,202	656,706	661,223	
	Unit 2	662,865	655,086	661,547	656,982	664,674	
	Unit 3	668,204	662,215	664,339	662,401	669,447	

Month	Unit	Generation Data July 1, 2014 through June 30, 2019 (MW hours)					
		2014	2015	2016	2017	2018	2019
September	Unit 1	632,124	629,418	624,421	638,923	633,602	
	Unit 2	638,755	638,180	637,559	637,856	640,549	
	Unit 3	645,357	640,755	640,350	645,125	644,987	
October	Unit 1	657,062	658,640	650,877	663,025	379,517	
	Unit 2	614,743	340,696	665,775	526,939	664,137	
	Unit 3	650,132	669,632	669,415	667,747	668,603	
November	Unit 1	61,744	628,176	149,471	644,523	335,571	
	Unit 2	649,403	397,180	647,723	82,874	651,124	
	Unit 3	656,593	654,702	652,830	652,646	656,273	
December	Unit 1	446,029	661,573	666,702	670,917	503,187	
	Unit 2	672,376	677,276	675,971	676,806	676,281	
	Unit 3	680,036	677,181	679,716	677,087	680,119	
Total Annual		**10,994,794**	**22,898,688**	**22,118,270**	**22,762,780**	**22,225,684**	**11,733,553**

Note: Gray shaded cells are not included in the five-year period of record used to evaluate generation data.
Source: Duke Energy 2019a

Table 8-2. Capacity Utilization Rate (%) from July 1, 2014 to June 30, 2019 at Oconee Nuclear Station

	Year					
	2014	2015	2016	2017	2018	2019
Annual Capacity Utilization Rate (%)*	91	96	92	95	93	100

*Note: Gross generation data was used for calculations.

8.1.3 Major Upgrades in Last 15 Years

Major upgrades at Oconee in the last 15 years are as follows (Duke Energy 2018a):

- Protected service water (PSW) installation (2016); and
- Steam generator replacements (early 2000's).

8.2 Descriptions of Consultation with Nuclear Regulatory Commission [§122.21(r)(8)(ii)]

Oconee operations are regulated by the USNRC. The USNRC licenses for Units 1, 2, and 3 were renewed on May 23, 2000 (USNRC 2018a; 2018b; 2018c). Each unit submitted an application to the USNRC for a measurement uncertainty recapture power uprate on September 20, 2011 (USNRC 2012). On July 31, 2012, Duke Energy requested that the USNRC delay the implementation of the new PSW system at Oconee by two years due to the development of some issues. The PSW system is credited in the measurement uncertainty recapture power uprate application, and the USNRC therefore cannot issue the power uprate without credit for the PSW system. The USNRC staff has placed the review of the measurement uncertainty recapture power uprate application on hold. All three uprate applications are on hold at this time. See Table 8-3 and Appendix 8-A for Oconee relicensing status and on-hold uprates.

Table 8-3. Oconee Nuclear Station's Relicensing Status and Uprates

	Unit 1	Unit 2	Unit 3
Docket Number	05000269	05000270	05000287
Operation License Date	February 6, 1973	October 6, 1973	July 19, 1974
Renewed License Date	May 23, 2000	May 23, 2000	May 23, 2000
License Expiration	February 6, 2033	October 6, 2033	July 19, 2034
Measurement Uncertainty Recapture Power Uprate	Approved: On Hold Submittal Date: September 20, 2011 Percent Uprate (%): 1.6 Megawatt Thermal Increase: 42	Approved: On Hold Submittal Date: September 20, 2011 Percent Uprate (%): 1.6 Megawatt Thermal Increase: 42	Approved: On Hold Submittal Date: September 20, 2011 Percent Uprate (%): 1.6 Megawatt Thermal Increase: 42

Sources: USNRC 2012, 2018a, 2018b, 2018c

8.3 Other Cooling Water Uses for Process Units [§122.21(r)(8)(iii)]

Oconee does not use cooling water for process units; therefore, this subsection is not applicable.

8.4 Descriptions of Current and Future Production Schedules [§122.21(r)(8)(iv)]

Oconee is not a manufacturing facility; therefore, this subsection is not applicable.

8.5 Descriptions of Plans or Schedules for any New Units Planned within the Next 5 Years [§122.21(r)(8)(v)]

Oconee does not have any plans or schedules for new units within the next five years (Duke Energy 2018b).

8.6 Section 8 References

Duke Energy Carolinas, LLC (Duke Energy). 2018a. Oconee Nuclear Station Technical Information Request Response – Major Plant Upgrades in Last 15 Years.

__________. 2018b. Oconee Nuclear Station Technical Information Request Response – Description of Plans or Schedules for any New Units Planned within the Next Five Years.

__________. 2019a. Oconee Nuclear Station Hourly Gross Generating Data Units 1-3 for July 1, 2014 through June 30, 2019.

__________. 2019b. Individual Unit Gross Capacity Confirmation – Email communication with Duke Energy. Email received: 15 Oct 2019.

U.S. Nuclear Regulatory Commission (USNRC). 2012. Oconee Nuclear Station, Units 1, 2, and 3 – Request for Additional Information and Suspension of Review of License Amendment Request for Power Uprate. 31 Aug 2012.

__________. 2018a. Oconee Nuclear Station, Unit 1. [URL]: https://www.nrc.gov/info-finder/reactors/oco1.html. Accessed 4 Dec 2018.

__________. 2018b. Oconee Nuclear Station, Unit 2. [URL]: https://www.nrc.gov/info-finder/reactors/oco2.html. Accessed 4 Dec 2018.

__________. 2018c. Oconee Nuclear Station, Unit 3. [URL]: https://www.nrc.gov/info-finder/reactors/oco3.html. Accessed 4 Dec 2018.

9 Entrainment Characterization Study [§122.21(r)(9)]

The information required to be submitted per §122.21(r)(9), *Entrainment Characterization Study,* is outlined as follows:

(i) *Entrainment Data Collection Method – The study should identify and document the data collection period and frequency. The study should identify and document organisms collected to the lowest taxon possible of all life stages of fish and shellfish that are in the vicinity of the cooling water intake structure(s) and are susceptible to entrainment, including any organisms identified by the Director, and any species protected under Federal, State, or Tribal law, including threatened or endangered species with a habitat range that includes waters in the vicinity of the cooling water intake structure. Biological data collection must be representative of the entrainment at the intakes subject to this provision. The owner or operator of the facility must identify and document how the location of the cooling water intake structure in the waterbody and the water column are accounted for by the data collection locations.*

(ii) *Biological Entrainment Characterization – Characterization of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal law (including threatened or endangered species), including a description of their abundance and their temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in entrainment, including but not limited to variations related to climate and weather differences, spawning, feeding, and water column migration. This characterization may include historical data that are representative of the current operation of the facility and of biological conditions at the site. Identification of all life stages of fish and shellfish must include identification of any surrogate species used, and identification of data representing both motile and non-motile life-stages of organisms.*

(iii) *Analysis and Supporting Documentation – Documentation of the current entrainment of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal law (including threatened or endangered species). The documentation may include historical data that are representative of the current operation of the facility and of biological conditions at the site. Entrainment data to support the facility's calculations must be collected during periods of representative operational flows for the cooling water intake structure, and the flows associated with the data collection must be documented. The method used to determine latent mortality along with data for specific organism mortality or survival that is applied to other life-stages or species must be identified. The owner or operator of the facility must identify and document all assumptions and calculations used to determine the total entrainment for that facility together with all methods and quality assurance/quality control procedures for data collection and data analysis. The proposed data collection and data analysis methods must be appropriate for a quantitative survey.*

The Rule permits the use of recent (within past 10 years) historical entrainment data in support of compliance with §122.21(r)(9); however, historical entrainment studies have not been performed at Oconee since the 1970s. As such, a two-year Study was performed at Oconee with the goal of characterizing entrainment at the CWIS. The methodology, results, and conclusions of the 2016 to 2017 Study (HDR 2018b) performed at Oconee are summarized in the following sections and the report and study plan are provided in Appendix 9-A. The Study standard operating procedures and quality assurance protocols, as well as the analysis calculation appendix are provided in Appendices 9-B and 9-C, respectively.

Although Oconee utilizes a curtain wall that substantially reduces entrainment, it does not employ entrainment reduction technologies such as closed-cycle cooling or fine-mesh screens. The information presented in these studies will be used by the Director to make a site-specific best technology available (BTA) determination for compliance with the entrainment reduction requirements of the Rule. The USEPA considers the entrainment of ichthyoplankton through a CWIS to result in 100 percent mortality; therefore, latent mortality was not addressed in this Study.

9.1 Study Methodology

Twice-monthly ichthyoplankton sampling was performed from March 1 through October 31 in 2016 and 2017 (16 sampling events in each year). Samples were collected upstream of the trash deflector plates and bar racks at the entrance to the CWIS using a pumped sampling technique. Based on life history data of species likely to be entrained at Oconee, the study design (frequency and duration of sampling) allowed for collection of a representative sample of entrainable-sized organisms (i.e., ichthyoplankton) present in Lake Keowee. Further, this sampling window provided the greatest likelihood of capturing the start and end of the spawning season each year, while minimizing sampling effort and costs. The sampling period selected for the Study was also consistent with data collected at other reservoirs in the southeastern U.S., supporting a shortened sampling season (EPRI 2011). Field sampling was coordinated with plant operations personnel to ensure circulating pumps were scheduled to operate during the specified sampling intervals.

9.1.1 Sampling Gear and Collection Protocol

9.1.1.1 Sampling Gear

Ichthyoplankton samples were collected at the CWIS using a pumped sampler due to intake configuration and safety considerations. There were four primary components to the sample collection system employed at Oconee; (1) the liquid propane pump and motorized platform, (2) the lifting frame, (3) the in-water sampler, and (4) the collection tank and plankton net.

Samples were collected using a liquid propane powered pump, which was mounted to a motorized platform cart with an aluminum lifting frame and a top-mounted roller to guide the in-water sampler (Figure 9-1). The cart was positioned at the edge of the intake structure deck so that the lifting frame was extended over the upstream side of the trash deflector plate (Figure 9-2). A bottom-mounted pulley and winch line was used to lower the in-water sampler during each two-hour sample collection. An additional cart contained a 100-gallon tank to collect samples.

The in-water sampler consisted of a three-inch inside diameter flexible PVC suction hose. Samples were collected on the upstream side of the CWIS at two depths: just beneath the top of the CWIS curtain wall opening (Figure 9-3) and near the bottom of the intake structure. Two sections of the flex hose at El. 774 feet above mean sea level (ft msl) and El. 768 ft msl were replaced with threaded 3-inch aluminum pipe sections with orifices sized to allow equal flow from both locations during sampling. The pipe was attached to a 5/16-inch AmSteel-blue SK-75 Dyneema HMPE (high modulus poly ethylene) fiber rope winch line. The flexible hose and sampling pipe were lowered in front of an intake bay for a unit that was operational at the time of deployment (Figure 9-2). A section view of the approximate location of the sample pipe is provided on Figure 9-3.

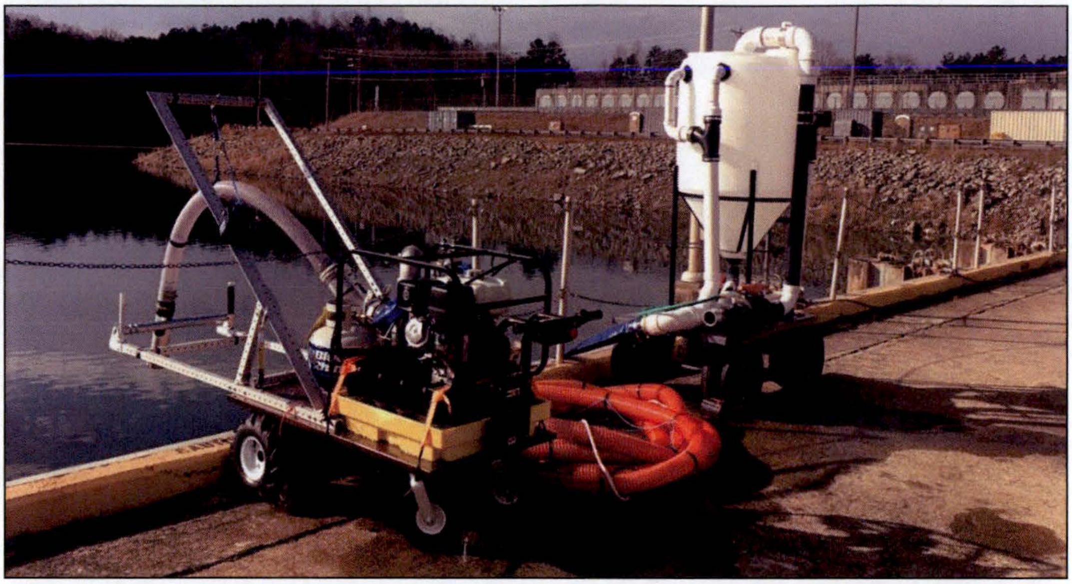

Figure 9-1. Electric Motor-Driven Platform Cart and Secondary Cart with a 100-gallon Collection Tank System for Entrainment Sampling at Oconee Nuclear Station

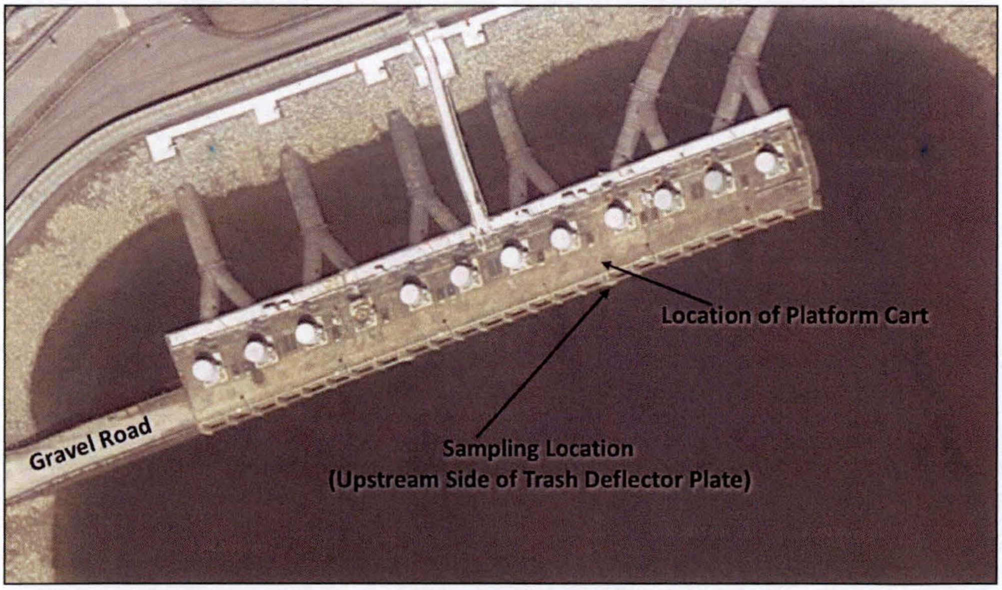

Figure 9-2. Sampling Location at Oconee Nuclear Station

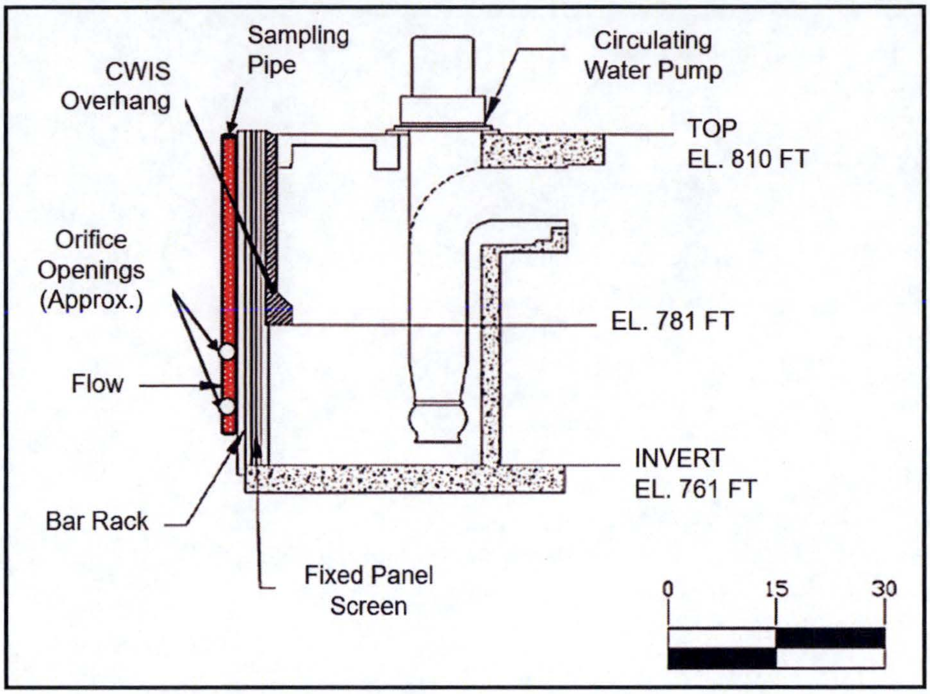

Figure 9-3. Location of the Approximate Sampling Pipe Placement at the Oconee Nuclear Station Cooling Water Intake Structure

9.1.1.2 Sample Collection Protocol

The Study consisted of samples collected at a sufficient duration and frequency to capture seasonal patterns in entrainment, as specified by the Rule. During each of the twice-monthly sampling events, ichthyoplankton samples were collected within each of the following discrete 6-hour time intervals[21]: 0300-0900 hours (morning), 0900-1500 hours (day), 1500-2100 hours (evening), and 2100-0300 hours (night), for a total of four diel samples over 24 hours.

During daylight savings time, sample start and end times were adjusted to maintain their representativeness of the target diel period (i.e., crepuscular versus night). To accurately capture crepuscular periods throughout the sampling season, the sampling start time was adjusted for each event based on the estimated time of sunrise/sunset. Sampling for the crepuscular periods was then initiated approximately one hour before sunrise/sunset and completed approximately one hour after sunrise/sunset.

A combined total of 128 entrainment samples were collected in 16 sample events from March to October, 2016 and 2017. The sampling protocol is summarized in Table 9-1. Additional details of the sampling protocol are available in the 2016 to 2017 Study report (HDR 2018b) as well as Section 6 of the Study Plan (HDR 2016) as provided in Appendix 9-B.

[21] During summer months, sunrise occurs earlier and sunset occurs later in the day. As a result, sample start and end times were shifted accordingly. For example, sample collection for events in June and July (2016 and 2017) were initiated between 1930 and 1950 and completed between 2133 and 2156, ending outside of the target evening diel period. During these months, the target 6-hour diel time intervals were shifted to accommodate this change, such that subsequent diel samples were also started at a later time, to avoid overlapping diel samples within each 24-hour sampling event.

One depth-integrated sample, with a target volume of 100 m^3, was collected during each 6-hour diel period. The sample volume was measured using an in-line flowmeter, similar to that illustrated in Figure 9-4. Depending upon pump flow rates, each sample required approximately two hours to collect.

Table 9-1. Ichthyoplankton Sampling Details at Oconee Nuclear Station

Parameter	Details
Sample Location	Upstream side of the trash deflector plate and bar racks of a unit that was operational at the time of deployment.
Sampling Events (Days)	Thirty-two (32) sampling events; twice per month; between March 1 and October 31, 2016 and March 1 and October 31, 2017.
Daily Collection Schedule	Samples collected within four, 6-hour diel periods within each 24-hour sample event; on average, pumped for 2 hours per 6-hour period[1].
Targeted Organisms	Fish eggs, larvae, and juveniles.
Depths	Depth-integrated sample collected from just below the top of the CWIS curtain wall opening and just above the intake bottom[2].
Sample Duration	Approximately 100-m^3 samples collected within each 6-hour sampling interval.
Total Number of Samples	Sixteen (16) sampling events/year x 4 samples/sampling event (days) x 2 years = 128 samples.

[1]During daylight saving time, sample start and end times were adjusted to maintain their representativeness of the target diel period (i.e., crepuscular versus night).
[2]Although the Entrainment Characterization Study Plan proposed the use of three sample depths, a two-depth integrated sampling design was determined sufficient to collect representative samples from the 20-ft water opening under the CWIS overhang.

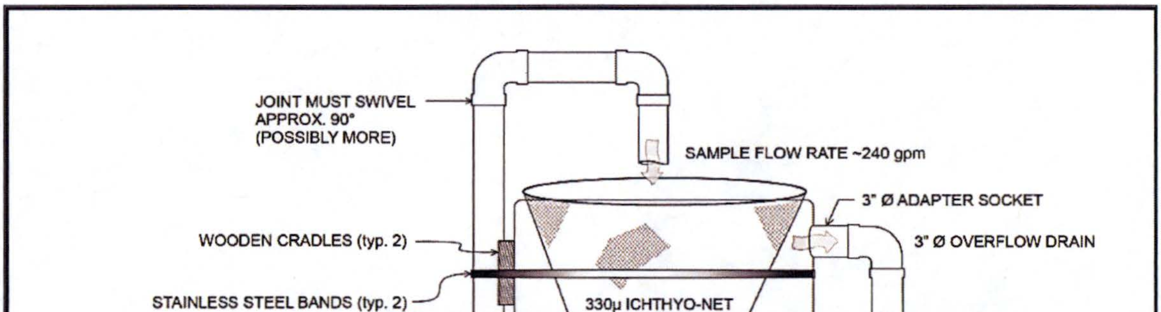

Figure 9-4. Example Ichthyoplankton Pump Sampling System Configuration

Sample water was filtered through a 330-micron (µm) plankton net suspended in a water-filled tank to reduce velocity and turbulence and prevent extrusion of larvae through the mesh. The mouth of the plankton net was suspended above the water line in the tank to prevent loss of organisms in the event of tank overflow. In an effort to minimize organism damage, the net was rinsed at least twice during each 100-m^3 pumped sample collection. Net rinses were combined in the field to provide a single concentrated 100-m^3 sample. More frequent net rinses were conducted if debris buildup caused net clogging. The net and collection cup were carefully rinsed into sample jars with preprinted labels (internal and external) and preserved in 5 to 10 percent formalin solution.

Total sample volume and sample duration (time in minutes) were recorded on field data sheets. Samples were transported to the Normandeau Associates, Inc. (Normandeau) Biological Laboratory in Bedford, New Hampshire, for analysis under a required chain-of-custody.

9.1.1.3 Water Quality

At the beginning of each sample period, water quality parameters including intake water temperature (°C), DO, pH, and specific conductance were collected from the sample tank using a calibrated water quality meter. Data were recorded on a field data sheet.

9.1.2 Laboratory Sample Processing

Samples were processed by Normandeau according to data quality objectives outlined in the Quality Assurance Plan and Standard Operating Procedures (Normandeau 2016), provided in Appendix 9-B. Samples that were estimated to contain more than 400 fish eggs and larvae (all taxa combined) were split with a plankton splitter to a subsample quota of approximately 200 eggs and larvae combined prior to analysis. Ichthyoplankton from each sample were placed in individually labeled vials and preserved in 5 to 10 percent formalin prior to taxonomic analysis.

Fish eggs, larvae, and juveniles were identified to the lowest practical taxonomic level using current references and taxonomic keys (e.g., Auer 1982; Wallus et al. 1990; Kay et al. 1994; Simon and Wallus 2004; EPRI 2016). Samples were assigned a life stage category based on the following definitions:

- Eggs: Required to be whole, show signs of fertilization, and live (i.e., no fungus present).
- Yolk-sac larvae: Transition stage from hatching through development of complete, functioning digestive system.
- Post yolk-sac larvae: Transition stage from completely developed digestive system through the transition to the juvenile form.
- Young-of-year: Stage from complete transformation to Age 1 (fin rays identical to adult stage).
- Age 1+: Yearling and older.
- Unidentified larvae: Specimens unidentifiable as yolk- or post yolk-sac larvae due to organism damage.

Species-specific size distributions were assessed through the collection of morphometric data. Only whole organisms were selected for measurements. For each diel sample, the following morphometric data were collected:

- Up to 10 yolk-sac, post yolk-sac and "larvae" of each fish species were measured for total length, greatest soft tissue body depth, and head capsule depth to the nearest 0.1 mm. Among dorso-ventrally compressed organisms whose body or head capsule width exceeds the body or head capsule depth, soft tissue body and head capsule width were also measured to the nearest 0.1 mm.
- Up to 10 eggs of each taxon were measured for minimum and maximum diameter to the nearest 0.1 mm. If more than 10 eggs or larvae were present, a randomly selected subset of each species and life stage was measured.

9.1.3 Data Analysis

Upon receipt of sample data from the laboratory, a thorough quality control (QC) review was completed to confirm species identifications were consistent with regional taxa, and to confirm parity between laboratory-provided data and the field data sheets. Data were then imported to a project-specific Microsoft Access® database.

9.1.1.4 Exclusion Calculation

The orifices of the sample pipes used at Oconee were larger than the maximum opening of 0.56 inches or 0.53 inches allowed by the USEPA in discerning between impingement and entrainment[22]. As a result, impingeable-size organisms could be collected in the ichthyoplankton samples. However, no organisms collected during the Study exhibited a body depth or body width greater than 13.5 mm (0.53-inches) and therefore none of the organisms were excluded from entrainment estimates.

9.1.1.5 Density Calculations

Ichthyoplankton densities, expressed as number per 100 m^3, were calculated for each taxon and life stage by year, month, sampling event (i.e., including all samples collected within a 24-hour period), and by 6-hour diel period across all sampling events. Detailed descriptions and formulas for each calculation performed on the raw sample data (diel sample density, sample event density, interpolated daily density, and monthly density) are provided in Appendix 9-C.

9.2 Results

9.1.4 Species Composition

The Study collected a total of 176 ichthyoplankton from two taxonomic families, Clupeidae (shads and herrings) and Centrarchidae (sunfish and black bass) (

[22] In the Rule, USEPA allows facilities to differentiate between entrainment and impingement based on passage of organisms through a 1/2 by 1/4-inch screen (0.56-inch diagonal opening) or a 3/8-inch screen (0.53-inch diagonal opening).

Table 9-2). The 2016 sampling effort resulted in the collection of 82 ichthyoplankton representing both families while the 2017 sampling effort resulted in the collection of 94 ichthyoplankton from the Clupeidae family, only. The Clupeidae family dominated sample collections in 2016 (98.8 percent) and 2017 (97.9 percent) (Figure 9-4). Other than clupeid species, a single individual from the Centrarchidae family was collected in 2016 and two unidentified Osteichthyes were collected in 2017.

Table 9-2. Summary of Ichthyoplankton by Family Collected during the Entrainment Characterization Study at Oconee Nuclear Station, 2016-2017

Family	Taxa Richness	Mar-Oct 2016		Mar-Oct 2017		Two-Year Total	
		Total No. Collected	Percent Total	Total No. Collected	Percent Total	Total No. Collected	Percent Total
Clupeidae	2	81	98.8	92	97.9	173	98.3
Centrarchidae	1	1	1.2	--	--	1	0.6
Unidentified Osteichthyes	--	--	--	2	2.1	2	1.1
Totals		**82**	**100**	**94**	**100**	**176**	**100**

(--) No ichthyoplankton collected

Three distinct taxa were identified in 2016 and two distinct taxa were identified in 2017 (Table 9-3). Blueback Herring eggs dominated the total catch in 2016 (92.7 percent) and 2017 (78.7 percent), followed by the Clupeid Group (individuals identified as possible Blueback Herring, Alewife, Gizzard Shad, or Threadfin Shad; 3.7 percent and 12.8 percent for 2016 and 2017, respectively) and Shad Group (individuals identified as possible Gizzard Shad or Threadfin Shad; 2.4 percent and 6.4 percent for 2016 and 2017, respectively). A single sunfish identified to genus (*Lepomis* sp.) was collected in 2016. Samples collected in both years were predominantly eggs (92.7 percent and 86.2 percent for 2016 and 2017, respectively) followed by post yolk-sac larvae (Table 9-4). Few yolk-sac and no young-of-year or yearling life stages were collected in either sample year.

Table 9-3. Composition and Relative Abundance of Taxa Collected in the Entrainment Characterization Study at Oconee Nuclear Station, March to October 2016 and 2017

Common Name	Scientific Name	2016		2017	
		Total No. Collected	Percent Total	Total No. Collected	Percent Total
Blueback Herring	*Alosa aestivalis*	76	92.7	74	78.7
Clupeid Group[1]	Clupeidae	3	3.7	12	12.8
Shad Group[2]	*Dorosoma* spp.	2	2.4	6	6.4
Sunfish Species	*Lepomis* sp.	1	1.2	--	--
Unidentified Fish	Unidentified Osteichthyes	--	--	2	2.1
	Total	**82**	**100**	**94**	**100**
Total Number of Unique Taxa Collected		**3**	**100.0**	**2**	**100.0**

(--) No ichthyoplankton collected
[1]Clupeid Group – Blueback Herring/Alewife/Gizzard Shad/Threadfin Shad;
[2]Shad Group – Gizzard Shad/Threadfin Shad

Table 9-4. Total Number of Ichthyoplankton Collected by Life Stage during the Entrainment Characterization Study at Oconee Nuclear Station, March to October 2016 and 2017

Life Stage	2016		2017	
	Total No. Collected	Percent Total	Total No. Collected	Percent Total
Egg	76	92.7	81	86.2
Yolk-sac larvae	2	2.4	--	--
Post yolk-sac larvae	2	2.4	8	8.5
Unidentified larval stage	2	2.4	5	5.3
Total	**82**	**100**	**94**	**100**

9.1.5 Size Distribution

The minimum, median, and maximum of egg width and fish body depth, head depth, and total length of organisms collected during the Study are presented in Table 9-5. During the two years of sampling, body depths ranged from a minimum of 0.2 mm for Clupeid Group yolk-sac larvae, unidentified larval stage, and the Shad Group unidentified larval life stage to a maximum 1.5 mm for sunfish species post yolk-sac larvae. Total lengths ranged from a minimum of 2.9 mm for Clupeid Group unidentified larval life stage to a maximum of 8.1 mm for a single post yolk-sac Sunfish.

Table 9-5. Morphometric Data by for Organisms Collected during the Entrainment Characterization Study at Oconee Nuclear Station, March to October 2016 and 2017

Common Name	Life Stage[1]	Morphometric (mm)	2016 and 2017 Combined Data[2,3]			
			Min	Med	Max	N
Blueback Herring	Egg	Egg Width	0.9	1.1	1.1	52
Clupeid Group[4]	YSL	Body Depth	0.20	0.40	0.60	2
		Head Depth	0.30	0.30	0.30	1
	PYSL	Body Depth	0.30	0.30	0.40	9
		Head Depth	0.30	0.30	0.40	3
		Total Length	3.80	4.30	5.30	3
	UNID LS	Body Depth	0.20	0.25	0.30	4
		Total Length	2.90	2.95	3.00	2
Sunfish Species	PYSL	Body Depth	1.50	1.50	1.50	1
		Head Depth	1.50	1.50	1.50	1
		Total Length	8.10	8.10	8.10	1
Shad Group[5]	Egg	Egg Width	1.00	1.00	1.10	6
	UNID LS	Body Depth	0.20	0.20	0.20	1
		Head Depth	0.20	0.20	0.20	1

[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: Unidentified larval stage
[2]Minimum (Min), median (Med), and maximum (Max), and number measured for morphometrics (N).
[3]Damaged specimens resulted in differences in the N value among a single taxon.
[4]Clupeid Group – Blueback Herring/Alewife/Gizzard Shad/Threadfin Shad
[5]Shad Group – Gizzard Shad/Threadfin Shad.

9.1.6 Temporal and Spatial Patterns in Abundance

9.2.1.1 Average Daily Density by Month

Based on the average daily density (No./100m^3) of ichthyoplankton by month for the two-year Study, the primary period of entrainment at the Oconee CWIS occurs in June and July (Table 9-6 and Table 9-7). The period of entrainment and timing of entrainment peaks documented at Oconee was consistent with data collected at other southeastern U.S. reservoirs containing landlocked Blueback Herring (EPRI 2011).

Table 9-6. Average Daily Density of Entrainment (No./100 m^3) by Month Observed during the Entrainment Characterization Study at Oconee Nuclear Station, March to October 2016

Common Name	Life Stage[1]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Blueback Herring	Egg	--	--	--	1.60	7.73	0.13	--	--
Clupeid Group[2]	YSL	--	--	--	0.27	0.02	--	--	--
Shad Group[3]	UNID LS	--	--	--	0.27	0.02	--	--	--
Clupeid Group[2]	PYSL	--	--	--	0.13	0.01	--	--	--
Sunfish Species	PYSL	--	--	--	--	--	0.13	0.01	--
2016 Average Daily Rate by Month		**--**	**--**	**--**	**2.27**	**7.78**	**0.26**	**0.01**	**--**

(--) No organisms estimated
[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: Unidentified larval stage
[2]Clupeid Group – Blueback Herring/Alewife/Gizzard /Threadfin Shad
[3]Shad Group – Gizzard Shad/Threadfin Shad

Table 9-7. Average Daily Density of Entrainment (No./100 m^3) by Month Observed during the Entrainment Characterization Study at Oconee Nuclear Station, March to October 2017

Common Name	Life Stage[1]	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Blueback Herring	Egg	--	--	--	1.66	6.53	0.02	--	--
Clupeid Group[2]	PYSL	0.02[4]	0.09	0.64	0.09	0.18	--	--	--
Shad Group[3]	Egg	--	--	0.27	0.65	--	--	--	--
Clupeid Group[2]	UNID LS	--	0.22	0.01	0.04	0.18	--	--	--
Unidentified Fish	Egg	--	0.03	0.07	--	--	--	--	--
Unidentified Fish	UNID LS	--	0.03	0.07	--	--	--	--	--
2017 Average Daily Rate by Month		**0.02**	**0.37**	**1.06**	**2.44**	**6.89**	**0.02**	**--**	**--**

(--) No organisms estimated
[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: Unidentified larval stage
[2]Clupeid Group – Blueback Herring/Alewife/Gizzard /Threadfin Shad
[3]Shad Group – Gizzard Shad/Threadfin Shad
[4] No ichthyoplankton were collected during March sampling events; however, an average daily density was calculated for the clupeid group due to the interpolation approach.

9.2.1.2 Diel Densities

Ichthyoplankton densities were highest during morning hours (0300-0900 hours) and lowest during daytime hours (0900-1500) for both years of sampling (Figure 9-5), a pattern potentially resulting from the timing of spawning activity of Blueback Herring and proximity to the Oconee CWIS. Blueback Herring eggs accounted for the majority of the organisms collected during the morning diel period (Appendix 9-A). Blueback Herring spawn in shallow, fast moving water along the shoreline of river tributaries (Rohde et al. 2009; SCDNR 2009), broadcasting demersal, adhesive eggs at the surface of the waterbody. Blueback Herring and other clupeids have a relatively short egg incubation period (2-6 days) and high fecundity (EPRI 2012). Given this information, the patterns illustrated in Figure 9-5 suggest that the egg densities observed in this Study were the result of spawning by resident Blueback Herring in the intake canal and likely within close proximity to the CWIS.

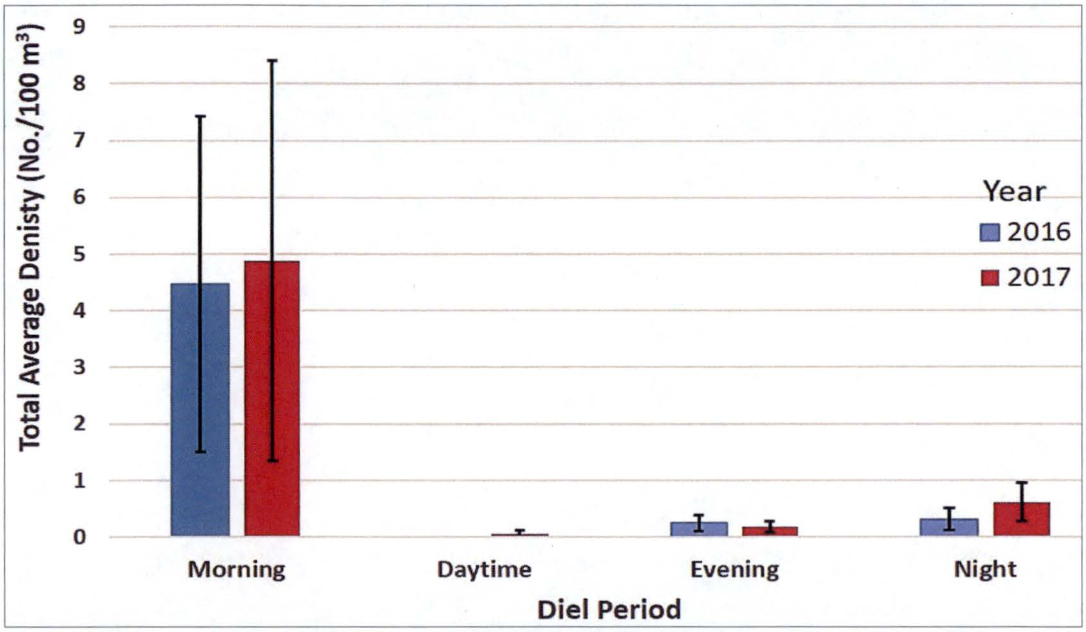

Figure 9-5. Average Ichthyoplankton Densities (No./100 m^3) by Diel Period at Oconee Nuclear Station during the Entrainment Characterization Study, 2016-2017 (bars represent standard error)

9.1.7 Monthly and Annual Entrainment Estimates

9.2.1.3 Cooling Water Intake Flows

Maximum water withdrawals were calculated using the daily design pump capacity of the CCW pumps and were adjusted to take into consideration a condenser pipe restriction that limits the capacity of each unit to 708,000 gallons per minute (gpm). Actual water withdrawals were calculated using the number of pumps running each day (Duke Energy 2018) and also taking into consideration the condenser pipe restrictions when multiple pumps are in operation for each unit. These values were summarized on a monthly basis and are presented as maximum and actual water withdrawals (m^3) for 2016 and 2017 (Table 9-8). Fluctuations in actual water withdrawals are dependent upon facility operations and are affected primarily by energy demand and intake water temperatures.

Table 9-8. Total Monthly Volume (m³) Withdrawn at Maximum Water Withdrawals and Actual Water Withdrawals at Oconee Nuclear Station, 2016 and 2017

Month	Total Maximum Water Withdrawals (m³)		Total Actual Water Withdrawals (m³)		Percent Reduction (%) from Maximum Water Withdrawals	
	2016	2017	2016	2017	2016	2017
January	358,915,012	358,915,012	292,380,518	290,674,063	18.5	19.0
February	335,759,205[1]	324,181,301	246,223,984[1]	247,918,668	26.7	23.5
March	358,915,012	358,915,012	278,199,099	303,743,313	22.5	15.4
April	347,337,108	347,337,108	272,255,525	299,182,221	21.6	13.9
May	358,915,012	358,916,012	273,154,624	309,369,722	23.9	13.8
June	347,337,108	347,337,108	318,735,762	339,782,036	8.2	2.2
July	358,915,012	358,915,012	358,915,012	358,915,012	0.0	0.0
August	358,915,012	358,915,012	358,915,012	358,915,012	0.0	0.0
September	347,337,108	347,337,108	347,337,108	346,933,839	0.0	0.1
October	358,915,012	358,915,012	352,837,215	336,878,970	1.7	6.1
November	347,337,108	347,337,108	266,319,763	247,828,255	23.3	28.6
December	358,915,012	358,915,012	309,100,459	308,727,743	13.9	14.0

[1] Values based on 29 days due to Leap Year

9.2.1.4 Estimates of Annual Entrainment Based on Maximum Water Withdrawals

Estimated annual entrainment losses for 2016, assuming the maximum water withdrawals at design pump capacity, were 36.7 million ichthyoplankton (Table 9-9). Blueback Herring was the most abundant taxon entrained with approximately 33.8 million organisms, and organisms belonging to the Clupeidae family contributed over 98 percent to the total estimated annual entrainment.

The estimated annual entrainment losses for 2017 were 38.4 million ichthyoplankton based on maximum water withdrawals (Table 9-10). The most abundant taxon in 2017 samples was Blueback Herring with an estimated 29.2 million eggs entrained, followed by the Clupeid Group at almost 5.3 million and the Shad Group at 3.2 million. Remaining unidentified fish contributed less than 1 million organisms to the estimated annual entrainment.

9.2.1.5 Estimated Annual Entrainment Based on Actual Water Withdrawals

An estimated total 36.1 million ichthyoplankton were entrained at Oconee during 2016 based on actual water withdrawals (Table 9-11). Blueback Herring accounted for 33.3 million eggs, or 92.3 percent of the estimated annual total entrainment. Estimated annual entrainment under actual water withdrawals in 2016 were 1.8 percent lower than that estimated under maximum water withdrawals.

An estimated total of 37.5 million ichthyoplankton were entrained at Oconee during 2017 based on actual water withdrawals at the facility (Table 9-12). Blueback Herring accounted for 77.6 percent of the estimated annual total entrainment, followed by the Clupeid Group at 12.7 percent. Total annual entrainment during 2017 based on actual water withdrawals represents a reduction in entrainment of 2.4 percent from estimates based on maximum water withdrawals.

Table 9-9. 2016 Estimated Annual Entrainment Based on Maximum Water Withdrawals at Oconee Nuclear Station

Common Name	Life Stage[1]	Monthly Estimated Entrainment Based on Maximum Water Withdrawals												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Blueback Herring	Egg	--	--	--	--	--	5,559,974	27,747,979	473,299	--	--	--	--	33,781,252
Clupeid Group[2]	YSL	--	--	--	--	--	934,552	56,639	--	--	--	--	--	991,191
Shad Group[3]	UNID LS	--	--	--	--	--	931,987	56,484	--	--	--	--	--	988,471
Clupeid Group[2]	PYSL	--	--	--	--	--	467,276	28,320	--	--	--	--	--	495,596
Sunfish Species	PYSL	--	--	--	--	--	--	--	457,836	37,760	--	--	--	495,596
	Total	**0**	**0**	**0**	**0**	**0**	**7,893,789**	**27,889,422**	**931,135**	**37,760**	**0**	**0**	**0**	**36,752,106**

(--) No organisms estimated
[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: unidentified larval stage
[2]Clupeid Group – Blueback Herring/Alewife/Gizzard Shad/Threadfin Shad
[3]Shad Group – Gizzard Shad/Threadfin Shad

Table 9-10. 2017 Estimated Annual Entrainment Based on Maximum Water Withdrawals at Oconee Nuclear Station

Common Name	Life Stage[1]	Monthly Estimated Entrainment Based on Maximum Water Withdrawals												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Blueback Herring	Egg	--	--	--	--	--	5,760,753	23,420,588	65,355	--	--	--	--	29,246,696
Clupeid Group[2]	PYSL	--	--	72,814	323,619	2,312,250	310,799	647,283	--	--	--	--	--	3,666,765
Shad Group[3]	Egg	--	--	--	--	962,805	2,265,424	--	--	--	--	--	--	3,228,229
Clupeid Group[2]	UNID LS	--	--	--	768,626	24,272	145,623	647,213	--	--	--	--	--	1,585,734
Unidentified Fish	Egg	--	--	--	111,231	242,686	--	--	--	--	--	--	--	353,917
Unidentified Fish	UNID LS	--	--	--	111,014	242,212	--	--	--	--	--	--	--	353,226
	Total	**0**	**0**	**72,814**	**1,314,490**	**3,784,225**	**8,482,599**	**24,715,084**	**65,355**	**0**	**0**	**0**	**0**	**38,434,567**

(--) No organisms estimated
[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: unidentified larval stage
[2]Clupeid Group – Blueback Herring/Alewife/Gizzard Shad/Threadfin Shad
[3]Shad Group – Gizzard Shad/Threadfin Shad

Table 9-11. 2016 Estimated Annual Entrainment Based on Actual Water Withdrawals at Oconee Nuclear Station

Common Name	Life Stage[1]	Monthly Estimated Entrainment Based on Actual Water Withdrawals												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Blueback Herring	Egg	--	--	--	--	--	5,102,140	27,747,979	473,299	--	--	--	--	33,323,418
Clupeid Group[2]	YSL	--	--	--	--	--	857,596	56,639	--	--	--	--	--	914,235
Shad Group[3]	UNID LS	--	--	--	--	--	855,242	56,484	--	--	--	--	--	911,726
Sunfish Species	PYSL	--	--	--	--	--	--	--	457,836	37,760	--	--	--	495,596
Clupeid Group[2]	PYSL	--	--	--	--	--	428,798	28,320	--	--	--	--	--	457,118
Total		**0**	**0**	**0**	**0**	**0**	**7,243,776**	**27,889,422**	**931,135**	**37,760**	**0**	**0**	**0**	**36,102,093**

(--) No organisms estimated
[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: unidentified larval stage
[2]Clupeid Group – Blueback Herring/Alewife/Gizzard Shad/Threadfin Shad
[3]Shad Group – Gizzard Shad/Threadfin Shad

Table 9-12. 2017 Estimated Annual Entrainment Based on Actual Water Withdrawals at Oconee Nuclear Station

Common Name	Life Stage[2]	Monthly Estimated Entrainment Based on Actual Water Withdrawals												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Blueback Herring	Egg	--	--	--	--	--	5,635,448	23,420,588	65,355	--	--	--	--	29,121,391
Clupeid Group[2]	PYSL	--	--	61,621	278,753	1,993,062	304,039	647,283	--	--	--	--	--	3,284,758
Shad Group[3]	Egg	--	--	--	--	829,989	2,216,148	--	--	--	--	--	--	3,046,137
Clupeid Group[2]	UNID LS	--	--	--	662,064	20,922	142,456	647,213	--	--	--	--	--	1,472,655
Unidentified Fish	Egg	--	--	--	95,810	209,185	--	--	--	--	--	--	--	304,995
Unidentified Fish	UNID LS	--	--	--	95,623	208,777	--	--	--	--	--	--	--	304,400
Total		**0**	**0**	**61,621**	**1,132,250**	**3,261,935**	**8,298,091**	**24,715,084**	**65,355**	**0**	**0**	**0**	**0**	**37,534,336**

(--) No organisms estimated
[1]YSL: yolk-sac larvae; PYSL: post yolk-sac larvae; UNID LS: unidentified larval stage
[2]Clupeid Group – Blueback Herring/Alewife/Gizzard Shad/Threadfin Shad
[3]Shad Group – Gizzard Shad/Threadfin Shad

9.3 Summary

A combined two-year total of 176 ichthyoplankton representing three distinct taxa from two families were collected during the Study. No federally protected species are listed in the vicinity of the Oconee CWIS (USFWS 2019) and none were collected during the Study; therefore, it is unlikely that federally protected species are susceptible to entrainment at the Oconee CWIS. With the exception of the invasive Asian clam (*Corbicula fluminea*), no mussels or shellfish were collected during the Study and based on habitat requirements, none are expected to occur near the Oconee CWIS.

The period of entrainment documented at Oconee was primarily during spring and summer months, from June through September in 2016 and from March through August in 2017. Peak ichthyoplankton densities occurred in June and July of both years, however entrainment rates were low throughout the Study period. The peak densities observed reflects the spawning period of Blueback Herring, the species with the highest rate of entrainment throughout the Study.

Based on the maximum water withdrawals, the average annual number of ichthyoplankton entrained at the Oconee CWIS over the two-year Study was estimated at 37.5 million. Based on actual water withdrawals, the average annual number of ichthyoplankton entrained was estimated at 36.8 million, which represents a 2.1-percent reduction from the entrainment estimate based on maximum water withdrawals.

A single sunfish was the only recreational species collected throughout the Study. Greater than 98 percent of ichthyoplankton entrained in 2016 and 2017 were forage species of the Clupeidae family Species in this family identified in Lake Keowee include Blueback Herring and Threadfin Shad (Duke Energy 2007, 2013). Blueback Herring and Threadfin Shad are prolific, broadcast spawners: Blueback Herring may spawn up to 350,000 eggs (Pardue 1983) and Threadfin Shad up to 22,000 eggs (Hendrickson et al. 2015) per female. Given the high fecundity and high natural mortality of Threadfin Shad and Blueback Herring, the estimated level of annual entrainment documented for Oconee is not anticipated to have an impact on population viability for these forage species. Further, Blueback Herring are not native to Lake Keowee and were introduced to the impoundment in the 1970s (Prince and Barwick 1981).

A Curtain Wall Study performed at Oconee in 2017 indicated that the existing curtain wall at the inlet of the intake canal reduces the number of economically valuable species and overall abundance of ichthyoplankton from the lake side to the intake side of the curtain wall by 76 percent or more during the entrainment period, and up to 89.7 percent in April and May (period of greatest density of ichthyoplankton near the curtain wall) (HDR 2018a). The low numbers and diversity of ichthyoplankton collected during the 2016 to 2017 Study are comparable to the results of the Curtain Wall Study, indicating that the curtain wall is effective at reducing ichthyoplankton densities on the intake side of the wall and that the reduction extends to the Oconee CWIS.

9.4 Section 9 References

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10 Comprehensive Technical Feasibility and Cost Evaluation Study [§122.21(r)(10)]

The information required to be submitted per §122.21(r)(10), *Comprehensive Technical Feasibility and Cost Evaluation Study*, is outlined as follows:

> *The owner or operator of an existing facility that withdraws greater than 125 MGD AIF must develop for submission to the Director an engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies.*
>
> §122.21(r)(10)(i): *Technical feasibility. An evaluation of the technical feasibility of closed-cycle recirculating systems as defined at 40 CFR 125.92(c), fine-mesh screens with a mesh size of 2 millimeters or smaller, and water reuse or alternate sources of cooling water. In addition, this study must include:*
>
> *(A) A description of all technologies and operational measures considered (including alternative designs of closed-cycle recirculating systems such as natural draft cooling towers, mechanical draft cooling towers, hybrid designs, and compact or multi-cell arrangements);*
>
> *(B) A discussion of land availability, including an evaluation of adjacent land and acres potentially available due to generating unit retirements, production unit retirements, other buildings and equipment retirements, and potential for repurposing of areas devoted to ponds, coal piles, rail yards, transmission yards, and parking lots;*
>
> *(C) A discussion of available sources of process water, grey water, waste water, reclaimed water, or other waters of appropriate quantity and quality for use as some or all of the cooling water needs of the facility; and*
>
> *(D) Documentation of factors other than cost that may make a candidate technology impractical or infeasible for further evaluation.*
>
> §122.21(r)(10)(ii): *Other entrainment control technologies. An evaluation of additional technologies for reducing entrainment may be required by the Director.*
>
> §122.21(r)(10)(iii): *Cost evaluations. The study must include engineering cost estimates of all technologies considered in paragraphs (r)(10)(i) and (ii) of this section. Facility costs must also be adjusted to estimate social costs. All costs must be presented as the net present value (NPV) and the corresponding annual value. Costs must be clearly labeled as compliance costs or social costs. The applicant must separately discuss facility level compliance costs and social costs, and provide documentation as follows:*
>
> *(A) Compliance costs are calculated as after-tax, while social costs are calculated as pre-tax. Compliance costs include the facility's*

administrative costs, including costs of permit application, while the social cost adjustment includes the Director's administrative costs. Any outages, downtime, or other impacts to facility net revenue, are included in compliance costs, while only that portion of lost net revenue that does not accrue to other producers can be included in social costs. Social costs must also be discounted using social discount rates of 3 percent and 7 percent. Assumptions regarding depreciation schedules, tax rates, interest rates, discount rates and related assumptions must be identified;

(B) Costs and explanation of any additional facility modifications necessary to support construction and operation of technologies considered in paragraphs (r)(10)(i) and (ii) of this section, including but not limited to relocation of existing buildings or equipment, reinforcement or upgrading of existing equipment, and additional construction and operating permits. Assumptions regarding depreciation schedules, interest rates, discount rates, useful life of the technology considered, and any related assumptions must be identified; and

(C) Costs and explanation for addressing any non-water quality environmental and other impacts identified in paragraph (r)(12) of this section. The cost evaluation must include a discussion of all reasonable attempts to mitigate each of these impacts.

Each of these requirements is addressed in the following subsections.

10.1 Approach to Technical Feasibility and Cost Evaluation

An evaluation of potential entrainment reduction technologies was performed to identify those that are potentially feasible and practicable at Oconee to address requirements of §122.21(r)(10). The evaluation included the identification of potential locations for entrainment reduction technologies that would cause minimal impacts to station operations and the community surrounding the station. The evaluation has attempted to specify a system for each technology that: 1) minimizes operational issues; 2) minimizes costs to the extent practicable; and 3) minimizes impacts to the station's operational reliability.

An Association for the Advancement of Cost Engineering (AACE) Class 4 cost estimate has been developed for each potentially feasible entrainment reduction technology to facilitate an entrainment BTA determination at Oconee. As such, detailed designs have not been developed. A conceptual design has been developed for each of the potentially feasible entrainment reduction technologies for use in estimating costs and identifying constraints that would affect costs and feasibility. While the approach and assumptions used in this evaluation are appropriate for addressing compliance requirements of §122.21(r)(10), the potential exists for circumstances that have not been identified in this evaluation. A detailed design process could result in different costs than those presented herein, and could identify constraints that could significantly impact technology feasibility. A detailed design process would be required prior to the installation of any of the potential entrainment reduction technologies or operational measures described herein.

Retrofitting an entrainment reduction technology at an existing and active facility presents different challenges than including these technologies designed for a new facility. Maintaining safe station conditions is critical during a technology retrofit - especially for a nuclear power station. Tie-ins to the existing station or other modifications to the existing cooling system invariably increase station outage and associated costs. Therefore, this evaluation considers scenarios where much of the hypothetical construction work would be performed without disrupting station operations to the extent practicable, and station tie-ins would be performed after the majority of the new construction is complete.

10.1.1 Technology Cost Estimating

The engineering evaluation presented herein aims to develop a Class 4 cost estimate as defined by AACE, and illustrated in Table 10-1. A Class 4 estimate suggests between 1 and 15 percent design of the system and is meant to assess the feasibility of a project. Such an estimate is expected to be accurate to between -15 and -30 percent on the lower end to between 20 and 50 percent on the upper end of actual project costs. Additional information about cost estimating accuracy can be found at AACE (2016).

Table 10-1. AACE Costing Categories (AACE 2016)

	Primary Characteristic	***Secondary Characteristic***			
Estimate Class	**Level of Project Definition[1]**	**End Usage[2]**	**Methodology[3]**	**Expected Accuracy Range[4]**	**Preparation Effort[5]**
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid	Detailed Unit Cost with Forced Detailed Take-off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to100%	Check Estimate Bid/Tender	Detailed Unit Cost with Detailed Take-off	L: -3% to -10% H: +3% to +15%	5 to 100

1) Expressed as percent of complete definition
2) Typical purpose of estimate
3) Typical estimating method
4) Typical variation in low and high ranges
5) Typical degree of effort relative to least cost index of 1

10.1.1.1 Cost Estimate Components

The engineering cost estimate for each potentially feasible entrainment reduction technology includes the following components:

(i) Capital costs;
(ii) Annual operation and maintenance (O&M) costs;
(iii) Station outage costs associated with technology installation; and
(iv) Mitigation costs associated with non-water quality impacts.

Capital costs include the following (as applicable):

1. Construction direct costs, including:
   - Demolition;
   - Civil / sitework;
   - Mechanical components;
   - Structural components;
   - Architectural components; and
   - Electrical, instrumentation, and controls components.
2. Construction indirect costs, including:
   - Contractor site supervision;
   - General conditions; and
   - General administration and profit.
3. Percentage-based estimates for:
   - Design engineering;
   - Engineering project management;
   - Owner's costs[23]; and
   - Contingencies.

Annual O&M costs include the following (as applicable)[24]:

1. Labor;
2. Chemicals;
3. Parts repair and replacement costs; and
4. Solids disposal.

[23] The Rule requires that additional taxes that may be paid by the Owner be included in the Owner's costs. Duke Energy is exempt from paying sales tax on equipment and services. The Duke Energy Power System Model incorporates asset depreciation and potential tax savings that Duke Energy could gain. Therefore, taxes are not explicitly incorporated into this evaluation.

[24] Electricity consumed by hypothetical technologies would be considered a net reduction in the station's power production, and would not be counted as an additional O&M cost.

Owner's Costs: Owner's costs include costs to plan and manage the project, costs to prepare design changes, assess consistency with the existing station design, and coordinate with regulators and contractors. These costs would be distributed proportional to each year's project spending.

Station Outage Costs: This engineering evaluation estimated the station outage that would be required for construction and tie-ins of each hypothetical technology implementation. Associated costs were developed by the Duke Energy Power Systems Model and were not included in this evaluation.

Mitigation Costs Associated with Non-water Quality: Potential mitigation measures will be presented in Section 12 of this document and are quantified where appropriate and feasible.

10.1.1.2 Remaining Station Life

The remaining life of each generating unit and each technology impacts O&M costs, potential future technology replacement costs (if the life of a generating unit is longer than the anticipated life of a technology), and the associated social benefits. This evaluation assumes that Units 1 and 2 at Oconee will operate through 2033, and Unit 3 will operate through 2034, in accordance with Oconee's current renewed operating license (USNRC 2018a; 2018b; 2018c). If the hypothetical entrainment reduction technology is in good operating order at that time, it is assumed that the technology would be retired at that time (no salvage value has been included). If the anticipated life of the technology is shorter than the anticipated life of the units, then this evaluation assumes that the technology would be rebuilt or replaced and made available to service the generating units through 2033 for Units 1 and 2, and 2034 for Unit 3.

10.2 Technologies and Operational Measures Considered

The objective of this evaluation is to assess and describe technologies and operational measures that could reduce entrainment rates at the Oconee CWIS[25]. The Rule requires that three technologies be considered: (1) a retrofit of the existing once-through cooling system to a closed-cycle cooling system; (2) the installation and operation of FMS, and (3) water reuse and/or use of alternate water sources. In addition to these three technologies, the Rule at §122.21(r)(10)(ii) indicates that the Director may require consideration of additional entrainment reduction technologies. Section 10.3 describes the different types of closed-cycle cooling systems that were considered at Oconee, Section 10.4 describes the fine-mesh and fine-slot screen systems that were considered at Oconee, and Section 10.6 provides an evaluation of potential water reuse and alternate water sources at Oconee. Each entrainment reduction technology or operational measure that was considered, along with a subset of the technologies and measures that were deemed technically feasible, are summarized in Table 10-29 and Table 10-30, respectively.

10.3 Closed-cycle Recirculating Systems (§122.21(r)(10)(i))

The Rule requires that the CCRS evaluation consider the retrofit of the existing once-through cooling system with various types of closed-cycle cooling systems, including closed-cycle cooling towers and impoundments. As discussed in Section 6 of this document, Duke Energy considers the design

[25] Measures and technologies that are focused on impingement mortality reduction are addressed in Section **Error! Reference source not found.** of this document.

and operation of Lake Keowee to meet the Rule's definition of a CCRS impoundment. The remainder of Section 10.3 discusses the implementation of hypothetical closed-cycle cooling towers.

The potential feasibility and practicability of a specific closed-cycle cooling tower type depends on the station's condenser design, local atmospheric conditions, site topography and layout, station operating constraints, and other site-specific criteria. Additionally, different closed-cycle cooling towers have different operating criteria. The evaluation, therefore, has attempted to match the closed-cycle cooling tower operating criteria and constraints with conditions at the site.

10.3.1 Description of Existing Cooling System

The existing CWIS and cooling water system at Oconee are described in detail in Section 3 and Section 5 of this document, respectively. Relevant portions of the cooling water system with respect to a CCRS retrofit are described herein.

10.3.1.1 Cooling Water Intake Structure

The CWIS provides water to Oconee's three electric power generating units via 12 CCW pumps (four CCW pumps per unit). Each pump has a design rating of 246,000 gpm (354.2 MGD). However, there is a condenser piping restriction in the 8-ft diameter header pipes on the downstream side of the CCW pumps that limits the capacity of each unit to 708,000 gpm (1,019.5 MGD), for a station DIF of 2,124,000 gpm (3,059 MGD) (Duke Energy 2002). The pumps are vertical, wet-pit type pumps and are located downstream of the fixed panel screens (EPRI 2008). There are two fixed panel mesh screens per pump, for a total of 24 screens. Screen cleaning is performed by lifting screens with a mobile crane and spraying with high pressure water to remove debris (Duke Energy 2013). Debris loading at the station is typically low. There is a bar rack and a trash deflector plate at the head of each intake bay and an overhang directly downstream of the fixed-panel mesh screens. The overhang functions like a curtain wall structure and provides entrainment reduction benefits (see Section 3 for more details). The existing CWIS is described in additional detail in Section 10.4.1.

10.3.1.2 DIF and AIF

As discussed in Section 3 of this document, the Oconee DIF is 3,059 MGD, and the AIF from July 1, 2014 through June 30, 2019 is 2,625 MGD[26].

10.3.1.3 Flow Rates Used in the CCRS Evaluation

Each unit at Oconee has three condensers, and each condenser is rated for a design flow of 226,000 gpm (325.4 MGD) (Duke Power Company 1970). The station also uses service water at a design flow rate of 30,000 gpm (43.2 MGD) per unit[27]. It is assumed the total station DIF of 3,059 MGD would be utilized in a hypothetical CCRS retrofit at the station, which includes both circulating water and service water flows (see Section 10.3.6.1 for design flow and other cooling tower design parameters).

[26] Both the DIF and AIF include service water flows.

[27] The design service water flow rate was calculated by subtracting the design condenser flow rate from the station DIF.

10.3.2 Cooling Tower Principles

Once-through cooling systems can be retrofitted with a variety of closed-cycle cooling tower systems. Key design factors of the various closed-cycle cooling tower systems include:

- Method of heat transfer: wet, dry, or a combination of wet and dry heat transfer;
- Method of air flow: natural draft, mechanical forced draft, or mechanical induced draft;
- Direction of air flow: counterflow or cross-flow; and
- Configuration: rectilinear (i.e., in-line or back-to-back) or circular.

These factors impact the cooling tower design, sizing, and operation, which subsequently drives environmental and social impacts. The method of heat transfer is perhaps the most important factor in determining the type of cooling tower. The different types of cooling towers are described in Section 10.3.4.

10.3.2.1 Method of Heat Transfer

A cooling tower acts as a mechanism to transfer waste heat[28] from the circulating fluid to the atmosphere. Heat can be transferred to the atmosphere in three different ways:

- Latent heat transfer, which is associated with the phase changes of water, such as evaporation;
- Sensible heat transfer, which is associated with the incremental change in temperature of a medium, such as air in the atmosphere; or
- A combination of both latent heat transfer and sensible heat transfer.

Cooling towers that employ a combination of both latent and sensible heat transfer are evaporative-type towers and are typically referred to as wet cooling towers. Cooling towers that employ only sensible heat transfer utilize dry surface heat exchangers and are typically referred to as dry cooling towers or dry cooling systems. Cooling towers that utilize both an evaporative section and a dry surface heat exchanger are typically referred to as wet-dry cooling towers or hybrid cooling towers.

10.3.2.2 Method of Air Flow

Air flow through a cooling tower is critical to facilitate heat transfer. The method of air flow can be either natural draft, mechanical forced draft, or mechanical induced draft. With respect to natural draft cooling towers (NDCTs), the hyperboloid shape has been shown to improve heat transfer. The density differential between the heated, less dense air inside the cooling tower and the cooler, denser air outside the cooling tower produces air flow through the tower (SPX 2009).

Mechanical forced draft cooling towers have a fan located on the ambient air intake, which blows air through the cooling tower. Mechanical forced draft cooling towers often have high entrance air velocities and low exhaust air velocities and can be susceptible to recirculation (SPX 2009). Recirculation occurs when the exhaust air is drawn back into the cooling tower intake, which

[28] Heat energy is utilized in the generation of electricity; heat energy that is not converted to electricity is transferred to cooling water within the station's surface condenser(s).

increases the ambient air wet-bulb temperature and decreases cooling tower performance (SPX 2009).

Mechanical induced draft cooling towers have a fan located on the exhaust side, which draws air into the cooling tower. Mechanical induced draft cooling towers often have high exhaust air velocities and low entrance air velocities, which decreases the susceptibility of recirculation (SPX 2009).

10.3.2.3 Direction of Air Flow

Air flow through a cooling tower can be either counterflow or cross-flow. In counterflow cooling towers, air moves vertically through the cooling tower fill[29], counter to the downward cascade of water (SPX 2009). In a cross-flow cooling tower, the configuration of the fill is such that the air flows horizontally across the downward cascading water (SPX 2009). In both counterflow and cross-flow cooling towers, the ambient air enters from the side and exits through the top of the cooling tower (EPRI 2011).

10.3.2.4 Configuration

Cooling towers can also be characterized by their configuration. While all NDCTs are circular, a mechanical draft cooling tower (MDCT) is typically comprised of multiple rectangular cells that can be arranged in a rectilinear or circular configuration. In a rectilinear configuration, the MDCT cells are typically aligned in a single row (in-line) or a double row (back-to-back) (EPRI 2011). A rectilinear wet cooling tower should be configured parallel to prevailing wind patterns to maximize cooling performance (SPX 2009). In a circular configuration, the cells should be clustered as closely as possible to the center point of the cooling tower or arranged octagonally (SPX 2009).

10.3.3 Cooling Tower Terminology

Cooling towers are selected based on factors that affect their performance. The following is a discussion of key terms related to cooling tower operation and design.

10.3.3.1 Heat Load

The cooling tower heat load is the total amount of heat removed from the circulating water by a cooling tower and is a function of the mass flow rate of water entering a cooling tower and the cooling tower range (EPRI 2011; SPX 2009).

10.3.3.2 Range

The cooling tower range is the difference between the temperature of the hot water entering a cooling tower and the temperature of the cold water exiting a cooling tower. The cooling tower range is equivalent to the temperature rise across the station's condensers, commonly referred to as the delta T or temperature differential (ΔT). The size and cost of a cooling tower is proportional to the design cooling tower heat load and the design cooling tower range (SPX 2009).

[29] Fill is an important component of cooling towers because it affects cooling performance by maximizing the contact surface and contact time between air and water, while providing the least amount of air flow restriction (SPX 2009).

10.3.3.3 Approach

The cooling tower approach is the difference between the temperature of the cold water exiting a cooling tower and the wet-bulb temperature[30] of the ambient air entering a cooling tower. Cooling tower size and performance are inversely proportional to the cooling tower approach. As cooling tower size is increased (while holding other design factors constant), the cooling tower approach moves towards 5 degrees Fahrenheit (°F). A cooling tower approach of less than 5°F is typically not realistic or guaranteed (SPX 2009). A design cooling tower approach of 10°F was selected at Oconee because this value represents a high performance cooling tower system, and is common in preliminary cooling tower design.

10.3.3.4 Drift

Cooling tower drift occurs when circulating water is lost from a cooling tower as liquid droplets are captured in the exhaust air stream (EPRI 2011). In order to reduce the amount of water lost as cooling tower drift, drift eliminators are always employed in a cooling tower to reduce the drift to a rate as low as 0.0005 percent of the circulating water flow rate (EPRI 2011).

10.3.3.5 Evaporation

Water in a cooling tower is also lost due to evaporation, which is the primary cooling mechanism in a wet cooling tower. A portion of the water absorbing heat evaporates, and this evaporation process cools the remainder of the water.

10.3.3.6 Blowdown

Blowdown is the portion of circulating water that is removed from the system to prevent the buildup of solids and minerals in concentrations high enough to cause corrosion and scaling of various cooling system components. The higher the cycles of concentration (COC) in a closed-cycle cooling tower system, the lower the blowdown rate – see the following discussion of COC. Blowdown that is discharged to a receiving waterbody that is classified as WOTUS is regulated by the facility's NPDES permit. Operating a closed-cycle cooling tower system with high total dissolved solids (TDS) can produce scale and precipitate, lead to corrosion problems, and increase O&M costs (USDOE 2016; USEPA 2014).

10.3.3.7 Cycles of Concentration

As water is evaporated from a wet cooling tower, dissolved solids remain in the circulating water, and the concentration of dissolved solids continues to increase as the process continues (USDOE 2016). Cooling towers are designed to operate within a particular range of COC, which is defined by the USEPA[31] as "the ratio of dissolved solids in the recirculated water versus that in the make-up water" (USEPA 2014). The COC is controlled via the discharge of blowdown. The USEPA notes that the Rule does not establish fixed requirements for COC because it recognizes that unavoidable circumstances could exist where an established COC might not be achievable. One such instance

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[30] Wet-bulb temperature is the temperature of air if it were cooled to 100% relative humidity (i.e., saturation) by the evaporation of water into it through latent heat transfer.

[31] The USEPA also indicates that when data are available, COC can be estimated as the "ratio of the measured parameter for the cooling tower water such as conductivity, calcium, chlorides, or phosphate, to the measured parameter for the make-up water" (USEPA 2014).

could be that "site-specific circumstances could include situations where water quality-based discharge limits might limit the concentration of a pollutant that is not readily treatable in the cooling tower blowdown..."

The discharge of water quality parameters that would be constrained by the facility's NPDES permit due to limitations in the receiving waterbody should be considered prior to determination of COC.

10.3.3.8 Make-up Water

Circulating water that is lost from the closed-cycle cooling tower system via evaporation, drift, and blowdown is replaced with make-up water. Make-up water is typically withdrawn from the source waterbody through a make-up water intake structure or CWIS.

10.3.4 Review of Candidate Closed-Cycle Cooling Technologies

Based on an initial evaluation of standard MDCTs, NDCTs, hybrid, multi-cell, and plume-abated cooling towers, and dry cooling systems, standard MDCTs were selected for more detailed evaluation in subsequent sections. The following sub-sections provide detail on the various closed-cycle cooling systems considered, the applicability of each at Oconee, and the basis for selection of standard MDCTs as the CCRS technology to be evaluated further.

10.3.4.1 Mechanical Draft Cooling Towers

Description

MDCTs are comprised of multiple rectangular cooling cells arranged in a rectilinear or round configuration. In an MDCT, water flows downward through fill material contacting air in either a counterflow or cross-flow pattern. MDCTs utilize fans to either induce or force air through the cooling tower and can be susceptible to air recirculation or interference from other cooling towers (SPX 2009). Figure 10-1 provides a schematic of an MDCT with induced draft.

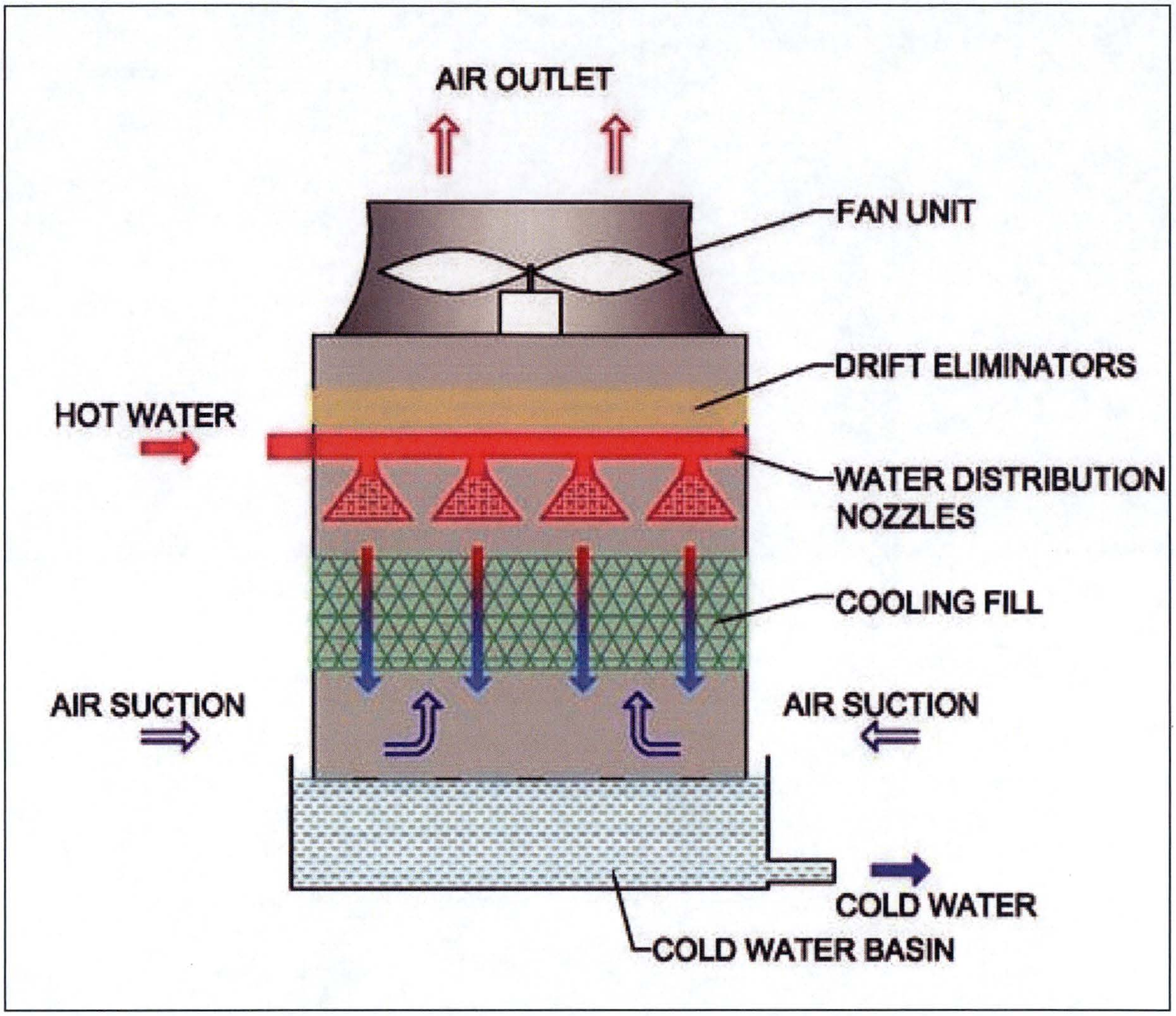

Figure 10-1. Cross-section Schematic of a Counterflow Mechanical Induced Draft Cooling Tower (Sara Cooling Tower Co., LTD 2019)

Feasibility

The feasibility of an MDCT depends on cooling system design, location, environmental impacts, and overall station impacts. The footprint of an MDCT requires a relatively flat, rectangular area. Both MDCTs and NDCTs have similar cooling performance (SPX 2009). MDCTs can be significantly shorter in height than NDCTs (up to 10 times), and because their air flow is mechanically forced, they can be designed with a lower cooling tower approach temperature than NDCTs.

The environmental impacts of MDCT operation include on-site particulate matter (PM) emissions, increased water consumption, and increased residual waste generation. MDCTs produce noise from falling water and the use of pumps, fans, and other equipment. MDCTs have a high potential for ground-level fog and ice formation due to the resultant cooling tower plume. MDCTs typically have lower capital costs than other cooling tower types, but not the lowest O&M costs.

10.3.4.2 Natural Draft Cooling Towers

Description

NDCTs typically have a hyperboloid shape, which has been found to improve cooling performance (EPRI 2011). NDCTs do not use fans to force or induce air flow. The density differential due to temperature differential causes air to move upward through the tower. When the cooling tower range is large, the density differential is easily induced. When the cooling tower range is small, a taller cooling tower is needed to help induce an adequate density differential to cause air to move up through the tower. Similar to MDCTs, water flows downward through fill material contacting air in either a counterflow or cross-flow pattern. NDCTs are typically very tall structures (up to 600 ft in height) and impacts from fog and ice formation due to cooling tower plume are not generally experienced within the immediate surroundings, if at all. However, these impacts are dependent upon the meteorological conditions of the site (CTI 2003). Figure 10-2 provides a schematic of an NDCT.

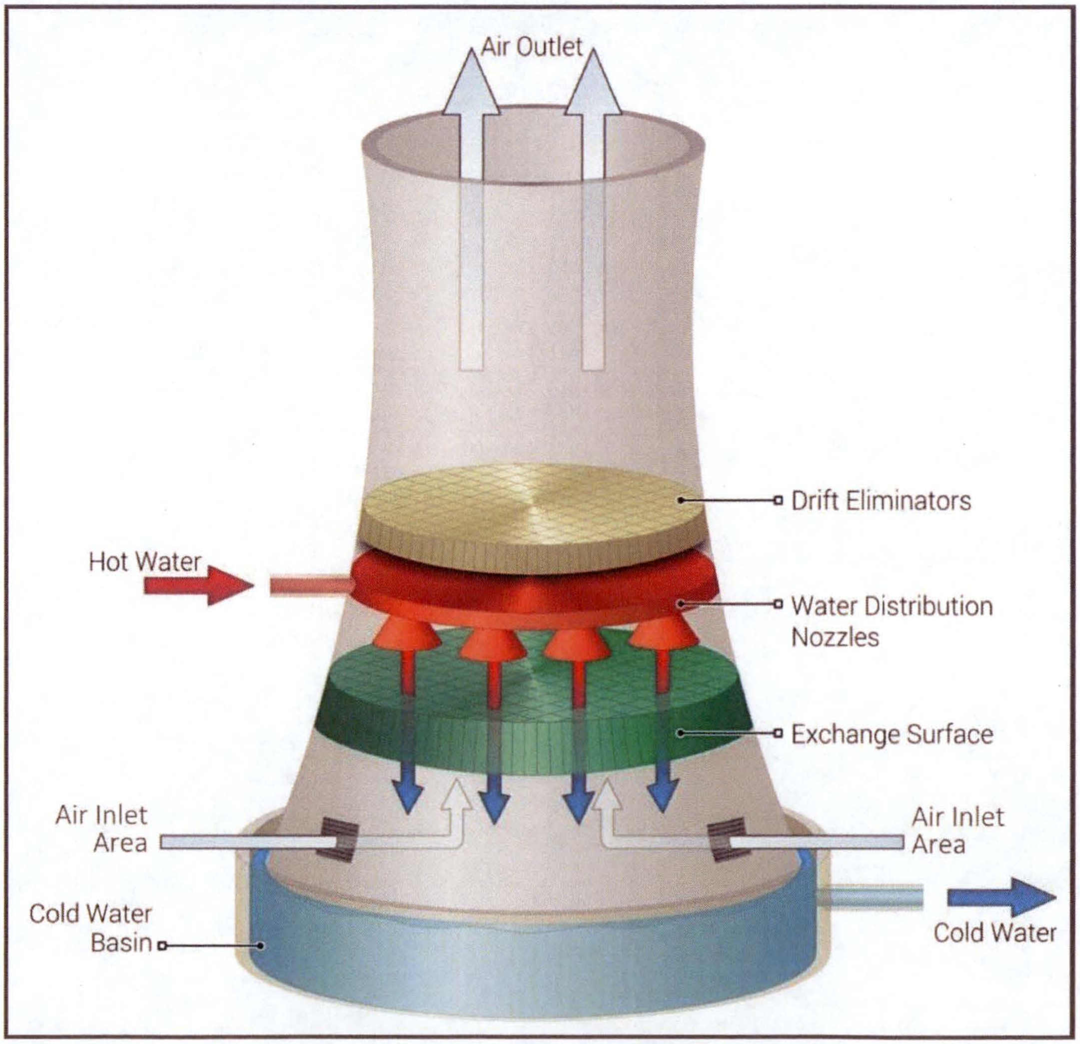

Figure 10-2. Cross-section Schematic of a Counterflow Natural Draft Cooling Tower (Sara Cooling Tower Co., LTD 2019)

Feasibility

NDCT feasibility depends on cooling system design, location, environmental impacts, and overall station impacts. The footprint of an NDCT requires a relatively large and flat land area. NDCTs are typically the tallest of cooling tower types (up to 10 times the height of MDCTs) and can pose potential adverse aesthetic impacts on the viewscape.

Environmental impacts of NDCTs are generally similar to MDCTs with respect to PM emissions, water consumption, and residual waste generation. While there is no fan noise related to NDCT operation, the noise created by cascading water in the tower can be significant. NDCTs have a higher visible plume than MDCTs, but reduced impacts due to fog and ice formation. While O&M costs for NDCTs are typically lower than MDCTs, the capital costs can be significantly higher.

Due to their significant footprint and capital costs, NDCTs are typically designed and implemented at new facilities with long expected life and base load operation. While Oconee maintains a high capacity factor and is considered a base load station (see Table 8-2 in Section 8), this evaluation assumes that its units are to be retired in 2033 (Units 1 and 2) and 2034 (Unit 3). As such, NDCTs were found to be impractical for further evaluation at Oconee.

10.3.4.3 Hybrid, Multi-cell, and Plume-abated Cooling Towers

Description

Hybrid, multi-cell and plume-abated cooling systems each utilize a combination of wet and dry cooling technologies. Hybrid cooling systems are typically operated as a parallel wet/dry system in which a dry (direct or indirect) cooling system operates in parallel with a wet system, which typically consists of a wet cooling tower and surface steam condenser. These hybrid systems are typically designed to reduce the water consumption to approximately half of a similar wet cooling system. Hybrid cooling systems can be constructed in multi-cell configurations, where both wet and dry cells are integrated into a single structure with the intent of achieving a significant reduction to the make-up water requirements. Both parallel wet/dry and multi-cell hybrid cooling systems have the advantages of reduced water consumption compared to a similar wet cooling system, reduced annual heat rate penalty compared to a similar dry cooling system, and reduced costs compared to a similar dry cooling system. However, equipment footprint and capital costs would be higher than MDCTs.

Plume-abated cooling towers are hybrid systems that utilize the dry portion of the system to reduce the cooling tower's visible plume. The degree of plume abatement achieved depends on the ambient air characteristics and the height of the dry coil section compared to the wet section (SPX 2009). A cross-section schematic of a plume-abated cooling tower is provided in Figure 10-3.

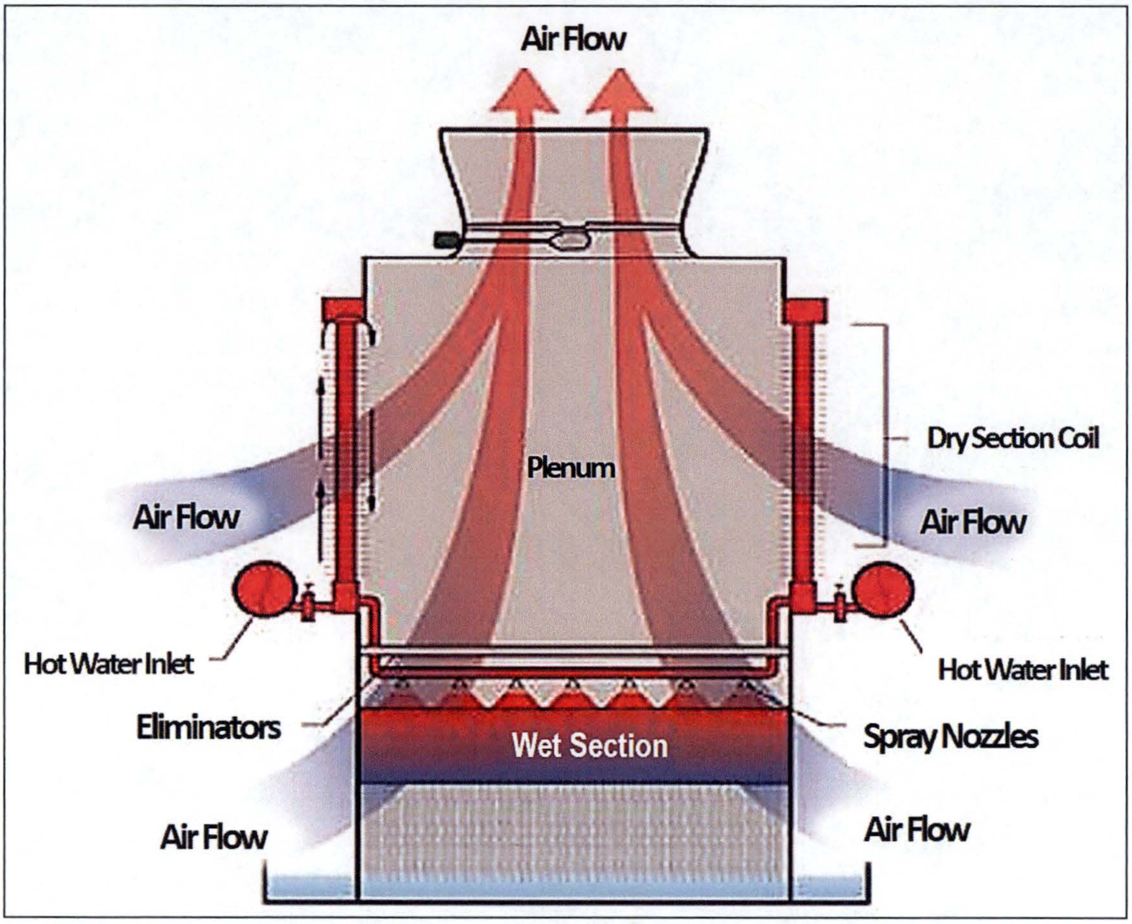

Figure 10-3. Cross-section Schematic of a Plume-abated Cooling Tower (CTI 2010)

Plume-abated cooling towers do not need to be operated in plume-abated mode at all times. They may be operated in plume-abated mode when needed (typically during cooler months when the visible plume is more likely) and operated in wet-only mode during other times of the year to reduce energy consumption.

In plume-abated cooling towers, the hot water from the condenser(s) is used as the heat source. When operated as such, water enters the cooling tower at the top of the dry portion, where sensible heat transfer lowers the temperature of the circulating water, while raising the temperature of the air leaving the tower and reducing the visible plume. The slightly cooled circulating water then cascades down to the wet portion of the tower, where it is further cooled through latent heat transfer (EPRI 2011). No contact is made between the air and water in the dry portion of the tower; however, there is contact between air and water in the lower, wet portion of the tower (EPRI 2011).

Feasibility

Hybrid and multi-cell cooling systems are typically used at facilities located in arid climates or at facilities that have restrictions on water consumption. They require a larger footprint and have higher capital costs than MDCTs, and a larger energy penalty. Because Oconee is not located in an arid climate nor does it have significant restrictions on water consumption, hybrid and multi-cell cooling systems are considered technically feasible, but impractical.

Plume-abated cooling towers are typically used in areas where the plume would have adverse impacts, including safety concerns, or in areas where long-range visibility is important, such as near airports. Plume-abated cooling towers have a larger footprint, lower cooling performance, lower summer output, and a higher energy penalty than standard MDCTs (SPX 2009). Most environmental impacts associated with plume-abated cooling towers are less than or similar to standard MDCTs. Plume-abated cooling towers have minimal visible plume and reduced PM emissions when operated in plume-abatement mode.

Plume-abated cooling towers are technically feasible at Oconee but were not advanced for further evaluation for several reasons. The capital costs of plume-abated cooling towers are greater than standard MDCTs due to the increased footprint, height, and auxiliary equipment requirements (EPRI 2011). O&M costs of plume-abated cooling towers are also greater than standard MDCTs due to lower cooling performance and additional energy requirements. In addition, plume abatement is likely not necessary at Oconee because the station is not located in close proximity to airports or major roadways.

10.3.4.4 Dry Cooling Systems

Description

Dry cooling systems use only sensible heat transfer and can use ambient air directly or indirectly. In a direct dry cooling system like an air-cooled condenser (ACC), a dry-surface, finned-tube heat exchanger provides the non-evaporative transfer of heat to the atmosphere (SPX 2009). Steam from a turbine is sent directly to the ACC, where the steam is condensed inside air-cooled finned tubes. There is no surface condenser, nor contact between the ambient air and steam. An ACC can be up to two to three times the height of MDCTs. Figure 10-4 provides an aerial rendering of an ACC.

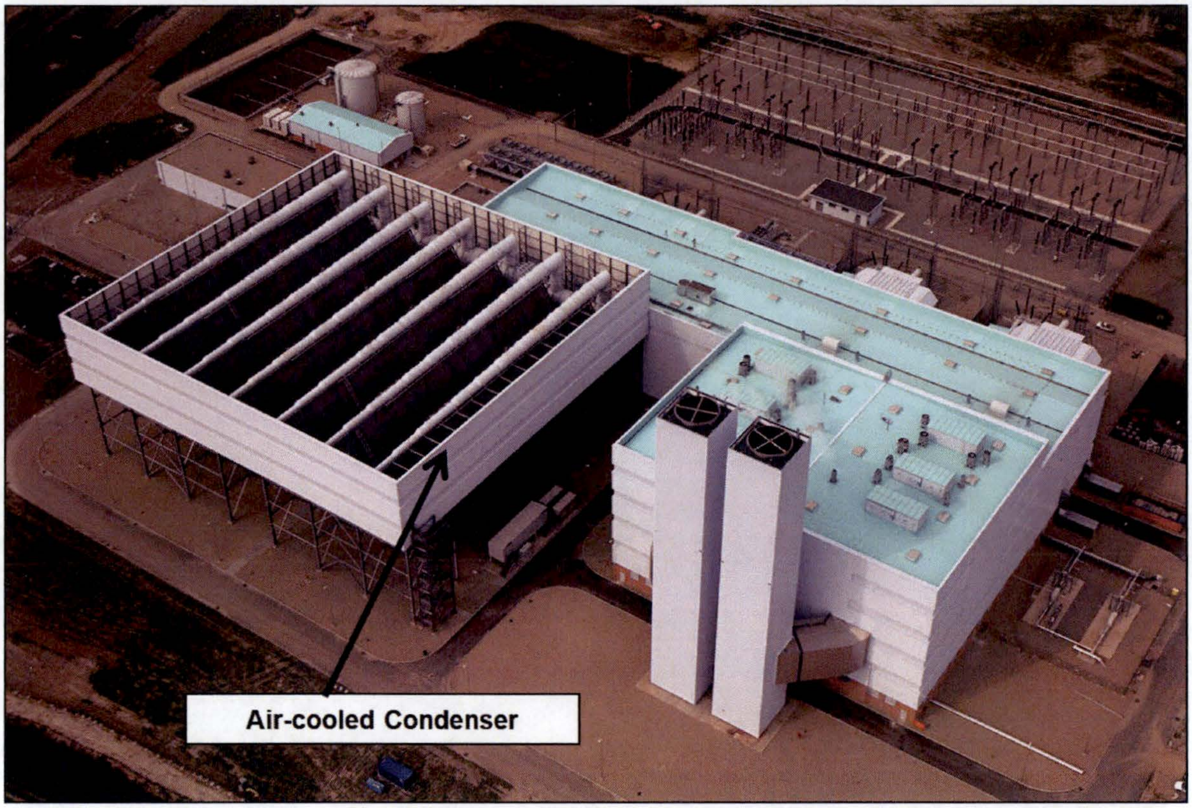

Figure 10-4. Aerial Rendering of an Air-cooled Condenser (Direct Dry Cooling) (Enexio 2020a)

Indirect dry cooling systems use the combination of a dry cooling tower (natural or mechanical draft) and a surface condenser. In these dry cooling towers, the heated water is pumped to heat exchangers arranged vertically around what looks like a standard wet cooling tower. But as shown in Figure 10-5, no water cascades down through the tower; instead, water flows through the bundles of tubes placed around the tower. Air flow through the tower cools the water within the bundles of tubes (SPX 2009). There is no contact between air and the circulating water (EPRI 2011).

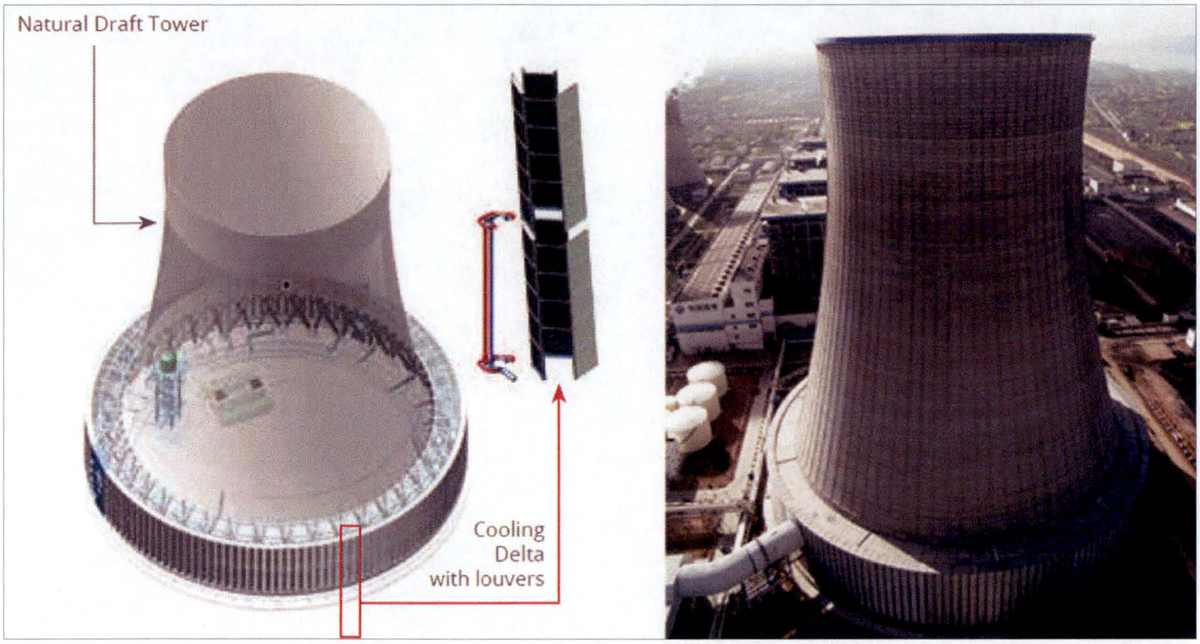

Figure 10-5. Schematic of an Indirect Dry Cooling Tower (SPX 2017; Enexio 2020b)

Feasibility

Dry cooling systems are typically implemented at facilities located in arid climates, or at facilities that have strict restrictions on water consumption. Dry cooling systems require the largest footprint of all cooling systems because they use only sensible heat transfer[32]. Dry cooling systems have the lowest cooling performance and lowest summer output of all cooling systems, which results in the highest energy penalty (EPRI 2011). Dry cooling systems require considerable energy to operate the fans. Cooling performance is limited by the ambient dry-bulb temperature rather than the ambient wet-bulb temperature, and because the ambient dry-bulb temperature is always greater than or equal to the ambient wet-bulb temperature, the resulting cold water temperature for a dry cooling system is higher than a wet cooling system.

The operation of a dry cooling system does not cause a visible plume, direct PM emissions, cascading water noise, water consumption, or the accumulation of residual waste. Dry cooling systems result in the largest reduction in water use of all cooling systems, but also the most fan noise and largest footprint.

Capital and O&M costs for dry cooling systems are typically the highest of all cooling systems. A retrofitted dry cooling system would operate at a higher backpressure and higher heat rate, which would impact performance (EPRI 2007). Installation of a dry cooling system typically requires significant redesign and reconstruction of condensers and cooling water piping. Due to the large energy penalty, dry cooling system operation may have impacts on the reliability of the station. For

[32] Wet cooling towers utilize both sensible and latent heat to transfer heat from water to air. The latent heat of vaporization for water is 970.3 British thermal units per pound-mass (Btu/lbm) (Lindeburg 2003). The specific heat of water is 1 Btu/lbm-°F. That is, 970.3 Btu are required to evaporate 1 pound of water, and only 1 Btu is required to raise the temperature of 1 pound of water by 1°F. Cooling via evaporation using latent heat transfer is more effective than using just sensible heat transfer.

these reasons, a dry cooling system at Oconee is considered infeasible and was not evaluated further.

10.3.4.5 Condenser Replacement

The previous discussion of cooling tower types (NDCTs, MDCTs, hybrid, multi-cell, and plume-abated cooling towers, and dry cooling systems) was based on reuse of the existing condensers. A hypothetical closed-cycle cooling tower retrofit would need to accommodate the existing condenser characteristics, including pressure rating, backpressure impacts, water flow rate, and temperature differential.

The design process for new power plants would include an evaluation of cooling towers and condensers in tandem to achieve optimal performance of the cooling system. However, in a CCRS retrofit at an existing power station, the existing condensers are used to the extent practicable (EPRI 2007). The design, construction, and age of the existing condensers may not always be compatible with a CCRS retrofit. The replacement of the existing condensers would eliminate those constraints, but a condenser replacement would result in significant station reconstruction, construction outage, capital costs, and disturbance to the site and surroundings. For these reasons, a condenser replacement is considered infeasible at Oconee and is not evaluated further. This evaluation assumes the existing condensers would remain in place in a hypothetical CCRS retrofit, and the technology selected would conform to the constraints of the existing condensers.

10.3.4.6 Selected Cooling Tower Type

Based on the initial evaluation of various closed-cycle cooling systems discussed in this section, the potential feasibility of each closed-cycle system at Oconee is summarized below. Potential design impacts, environmental impacts, site-specific applicability, and overall feasibility of each closed-cycle cooling system are further summarized in Table 10-2.

At Oconee:

- Dry cooling systems are considered infeasible due to site footprint constraints and incompatibility with the existing condensers;
- NDCTs are considered technically feasible if designed with a large cooling tower approach and range, but impractical due to expected unit retirements and site footprint constraints;
- Hybrid, multi-cell, and plume-abated cooling towers are considered technically feasible, but impractical due to the lack of stringent water consumption restrictions, the lack of critical infrastructure in the immediate vicinity of the station where visible plume would be a concern, and site footprint constraints; and
- MDCTs are considered technically feasible, but challenging due to site footprint constraints, significant construction and operational challenges, and significant costs. Standard MDCTs will be evaluated in the remainder of Section 10.3, as well as Sections 11 and 12 of this document.

Table 10-2. Comparison Matrix of Closed-cycle Cooling System Types

Parameter	Type of Closed-cycle Cooling System			
	MDCT	NDCT	Dry Cooling System	Hybrid, Multi-cell, and Plume-abated Cooling Systems
	Base Case	Compare to MDCT	Compare to MDCT	Compare to MDCT
	Design Impacts			
Footprint Area	• MDCTs would have the smallest footprint. • MDCT cells can be arranged in a modular fashion to meet on-site space constraints (with limitations). • Rectilinear tracts of flat land required, ideally oriented with prevailing winds	• Larger footprint than base case • Large, circular areas required	• Largest area required, approximately 2 to 4 times the area required for the base case. • Rectilinear tracts of flat land required, ideally oriented with prevailing winds	• Larger footprint than base case • Rectilinear tracts of flat land required, ideally oriented with prevailing winds
Height	• Base case	• Tallest of all towers • Approximately 600-ft-tall towers (or greater) may be needed to induce the necessary draft	• Taller than base case	• Taller than base case
Performance	• Base case	• Similar to base case	• Lowest cooling system performance • Lowest summer output	• Lower than base case
Energy Penalty	• Base case	• Lower than base case with respect to fan requirements	• Highest energy consumption; large energy requirement for fans • Cooling limited by dry-bulb temperature rather than wet-bulb temperature; dry-bulb temperature always higher than wet-bulb temperature, therefore, dry cooling systems have warmest cold water temperature and greatest backpressure energy penalty	• Similar to base case

Parameter	Type of Closed-cycle Cooling System			
	MDCT	NDCT	Dry Cooling System	Hybrid, Multi-cell, and Plume-abated Cooling Systems
	Base Case	Compare to MDCT	Compare to MDCT	Compare to MDCT
Environmental Impacts				
Visible Plume	• Potential for fogging or icing	• Visible plume at higher elevation • Reduced likelihood for ground level fogging or icing due to height of plume emission	• No visible plume • No fogging or icing	• Minimal to no visible plume for plume-abated system • Minimal fogging or icing for plume-abated system
PM Emissions	• Dependent upon source water TDS, COC, and drift eliminator efficiency	• Similar to base case	• No PM emissions	• Potentially reduced PM emissions • Dependent upon rate of use of dry portion of tower
Noise Emissions	• Fan noise • Cascading water	• No fan noise • Greater water noise	• Greatest fan noise • No water noise	• Significant fan noise
Water Consumption	• Significantly reduced water withdrawal rate, but larger evaporation rate, compared to once-through cooling	• Similar to base case	• No water consumption • Greatest reduction in water use of alternatives	• Lower than base case
Residual Waste	• Dependent upon water and air quality, basin sizing, and use of chemical additives	• Similar to base case	• No scale, sediment, sludge accumulation • Some waste from cleaning of exterior tube surfaces	• Similar to base case
Overall Station Impacts				
Capital Costs	• Base case	• Higher than base case	• Highest capital costs	• Higher than base case
O&M Costs	• Base case	• Lower than base case	• Highest operating costs	• Higher than base case

Parameter	Type of Closed-cycle Cooling System			
	MDCT	NDCT	Dry Cooling System	Hybrid, Multi-cell, and Plume-abated Cooling Systems
	Base Case	Compare to MDCT	Compare to MDCT	Compare to MDCT
Site-Specific Applicability	• Challenging due to limited suitable space availability • Significant construction in close proximity of existing station infrastructure, and in undeveloped areas	• Typically designed for new facilities with long expected life and base load operations • Large towers may have an adverse visual impact on area	• Typically used in arid climates or at facilities with stringent water consumption restrictions • Incompatible with existing condensers • Insufficient available space • Could impact station and regional reliability	• Typically used at facilities with stringent water consumption restrictions, or in areas in close proximity to critical infrastructure where visible plume is a concern • Similar to base case, except costlier
Overall Feasibility	• Feasible from an engineering perspective, but extremely challenging • Least expensive closed-cycle cooling tower option • Impractical due to expected unit retirements and site footprint constraints at Oconee	• Feasible from an engineering perspective using a large tower approach and range, but extremely challenging • Impractical due to expected unit retirements and site footprint constraints at Oconee	• Infeasible due to site footprint constraints and incompatibility with existing condensers	• Feasible from an engineering perspective, but extremely challenging • Impractical due to lack of water consumption restrictions, lack of critical infrastructure, and site footprint constraints

Sources: EPRI 2011; CTI 2003; Maulbetsch and Stallings 2012; EPRI 2002

10.3.5 Existing Condensers

Steam electric power generation facilities use steam turbines and condensers to generate electricity. Turbines typically consist of a rotor assembly, which is a shaft or drum with blades attached; steam is generated and moves through the turbine turning the blades and shaft. The rotational energy from the rotor assembly is converted into usable energy to produce electricity[33]. The exhaust steam from the turbine is then condensed to liquid water for recirculation through the system by use of a condenser, which is a type of heat exchanger.

Condensers typically consist of multiple tubes encased in a shell. Steam flows through the shell and is condensed when passed across tubes, which contain cold water. Tubes may be in a single-pass or multiple-pass arrangement, depending on the design requirements of the condenser. The condensate is then collected where it is reheated to steam and recirculated through the system.

A waterbox is located on both sides of the condenser. On the inlet side, the cold water enters and is directed with uniform distribution towards the tube sheet. The tube sheet is a metal sheet with perforations that allow entry of water into the condenser tubes. On the discharge side, the warmed water is collected in the outlet waterbox and removed from the condenser. In a once-through system, the warmed water is discharged to a receiving waterbody, and in a CCRS system, the warmed water is directed to the cooling towers to be cooled and reused.

There are three condensers per unit at Oconee, for a total of nine condensers at the station. Each condenser is a single shell, four bank, five lane, single pass condenser with two waterboxes and a heat duty rated at 1.94×10^9 Btu/hr (Duke Power Company 1970). With three condensers per unit, the total heat duty per unit is approximately 5.82×10^9 Btu/hr. The condensers are designed with a cleanliness factor of 90 percent and are mechanically cleaned with an Amertap system[34], consisting of twelve Amertap pumps per unit (Duke Power Company 1970; Duke Energy 2013). In total, Oconee's condensers are designed for a circulating water flow rate of 678,000 gpm (976.3 MGD) and an inlet design temperature of 70°F (Duke Power Company 1970). The water flows through the condenser tubes at approximately 8.12 fps (Duke Power Company 1970).

The various parts of the condensers are welded; these welds are designed to safely hold a maximum pressure differential of 30 pounds per square inch[35] (psi) externally or 30 psi internally, measured at the centerline of the condenser shell (Duke Power Company 1970). The waterboxes are designed for 15 psi external pressure and 30 psi internal pressure (Duke Power Company 1970). The separation at the waterboxes allows one section to operate while the other is out-of-service. The waterboxes have 78-inch inlet and outlet cooling water pipe connections (Duke Power Company 2001).

The condenser intake and discharge pipes are made of steel and rated for internal pressures between 29 and 44 psi and external pressures between 10 and 20 psi (Duke Power Company 2001). The intake pipes are rated for a temperatures between 40°F and 90°F, and the discharge

[33] The rotor assembly operates in conjunction with an electrical generator.

[34] The Amertap system utilizes specially-designed cleaning balls that are injected in the inlet waterbox, move through and clean the condenser tubes, and then are collected in the outlet waterbox or discharge channel.

[35] 1 psi is approximately 2.3 ft of water (depth).

pipes are rated for a maximum temperature of 115.7°F (Duke Power Company 2001). The intake piping for each unit begins by flowing through four 96-inch pipes per unit, which combine into two 132-inch pipes, which then combine to form a single 186-inch pipe (Duke Power Company 2001). This 186-inch pipe is then reduced to six 78-inch pipes, each of which is welded to a condenser inlet valve. There are two 78-inch pipes per condenser (Duke Power Company 2001; Duke Power Company 1970).

The discharge pipes from the condensers begin with six 78-inch pipes per unit, which then combine into two 132-inch pipes. A total of six 132-inch pipes from the three units lead to the discharge structure on Lake Keowee (Duke Power Company 2001). Design parameters of the condensers pertinent to the cooling tower feasibility evaluation are summarized in Table 10-3. The existing intake and discharge piping at Oconee is shown on Figure 10-6.

Table 10-3. Design Parameters from the Existing Condenser Specification at Oconee Nuclear Station

Parameter	Value	Units
Condenser		
Number of Condensers Per Unit	3	-
Design Duty Per Condenser	1.94×10^9	Btu/hr
Design Flow Per Condenser	226,000	gpm
Design Circulating Water Inlet Temperature	70.0	°F
Design Temperature Differential (ΔT)	17.2[36]	°F
Absolute Pressure at Condenser Inlet	2.0	Inches HgA[37]
Tubes		
Number of Tubes Per Condenser	16,690	-
Tube Effective Length Per Condenser	44.0	ft
Tube Effective Surface Area Per Condenser	170,000	square ft
Tube Cleanliness Factor	90	%
Number of Passes	1	-
Tube Water Velocity	8.12	fps
Tube Outer Diameter	0.875	inch
Tube Material	304 Stainless Steel	-

Sources: Duke Power Company 1970; Duke Power Company 2001; Duke Energy 2015.

[36] The condenser design temperature differential was calculated using the condenser design duty and design flow values at Oconee.

[37] Inches of Mercury at Absolute Pressure.

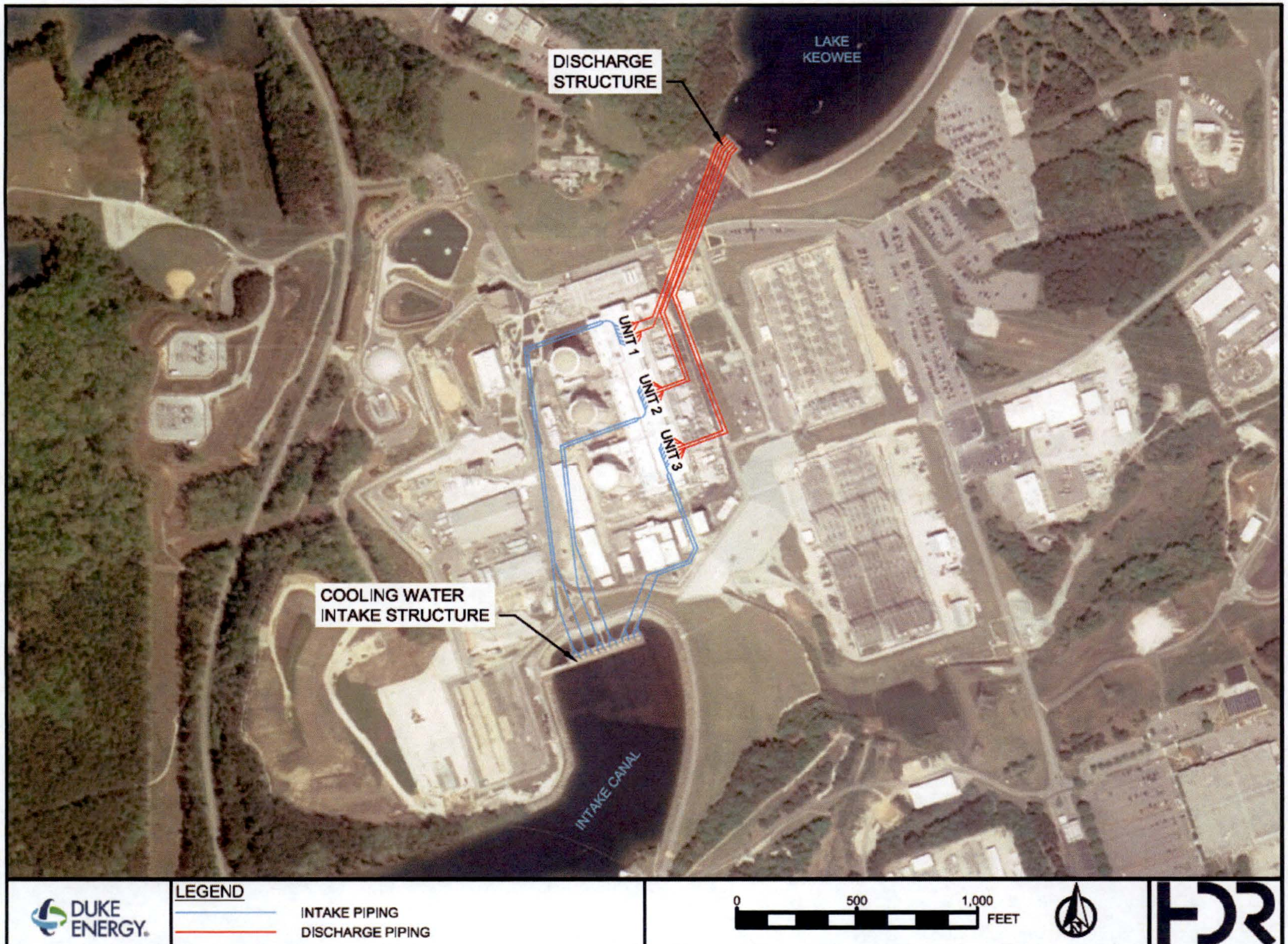

Figure 10-6. Existing Intake and Discharge Piping at Oconee Nuclear Station

10.3.6 Description of Selected CCRS Technology (§122.21(r)(10)(i)(A))

10.3.6.1 Cooling Tower Design Parameters

Flow

The existing once-through cooling water flow rate used by the condensers at Oconee is approximately 678,000 gpm (976.3 MGD) per unit. The station also uses service water[38] at a design flow rate of 30,000 gpm[39] per unit. The total design flow per unit at the station is 708,000 gpm, which includes both circulating and service water flows. Because the hypothetical layout of the MDCTs is conducive to recirculating the total flow, it is assumed that the water quality of the service water would be acceptable for recirculation in a hypothetical CCRS retrofit. Therefore, the design cooling tower flow rate for each unit would be 708,000 gpm. Cooling tower design evaporation, drift, blowdown, and make-up water flow rates were estimated and are provided in Table 10-4. Detailed calculations are provided in Appendix 10-A.

Table 10-4. Hypothetical Closed-cycle Cooling Tower Design Water Use at Oconee Nuclear Station

Parameter	Units	Unit 1	Unit 2	Unit 3	Total
Design Cooling Tower Flow Rate	gpm	708,000	708,000	708,000	2,124,000
Design Evaporation Rate[40]	gpm	9,714	9,714	9,714	29,141
Design Drift Rate[41]	gpm	3.5	3.5	3.5	10.6
Design Blowdown Rate	gpm	2,425	2,425	2,425	7,275
Design Make-up Rate[42]	gpm	12,142	12,142	12,142	36,427
Design Percent Reduction in Water Withdrawal	%	98.3	98.3	98.3	98.3

Temperatures

The ambient wet-bulb temperature that is exceeded during one percent of the record at Greenville/Spartanburg, SC (76°F) was used for the basis of the cooling tower design (WMO 1999).

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[38] Some service water uses at Oconee have an associated heat load. The temperature differential (ΔT) of service water varies at Oconee, and is often different from the condenser ΔT.

[39] The design service water flow rate was calculated by subtracting the design condenser flow rate from the station DIF.

[40] The design evaporation rate was calculated using the design cooling tower range of 17.2°F. The actual evaporation rate would be less than the design evaporation rate if the cooling towers were operated at a lower range.

[41] The design drift rate was calculated assuming the hypothetical cooling towers would employ drift eliminators with a 0.0005 percent drift rate.

The design cooling tower approach temperature was selected to be 10°F[43], meaning that during the warmest and most humid periods, the cold recirculating water temperature leaving the cooling towers would be approximately 86°F. It is possible that the hypothetical cooling towers could operate at a lower approach than 10°F under actual operating conditions.

The design cooling tower range is assumed to be approximately 17.2°F, which is equivalent to the design ΔT across the condensers[44] (Duke Power Company 1970). This design cooling tower range is a conservative estimate of the cooling tower heat duty and would provide a factor of safety to account for the unknown and variable service water heat loads while increasing overall cooling tower performance. It is possible that the hypothetical cooling towers could operate at a lower range than 17.2°F under actual operating conditions. The ΔT was calculated using the condenser design parameters listed in Section 10.3.5. With a design cooling tower range of 17.2°F, the hot water temperature entering the cooling towers would be approximately 103.2°F (i.e., cold recirculating water temperature + ΔT). The hot water temperature entering the cooling towers would be lower if the towers were to operate at a lower range and/or approach temperature.

Cycles of Concentration

Because Lake Keowee is a fresh waterbody, 5.0 COCs were selected for this evaluation[45]. If cooling towers are determined to be BTA at Oconee, the impact of COC on parameters listed in the NPDES permit would need to be evaluated, and the distribution of suspended and dissolved components, how the suspended components may be treated, how the solids may be disposed of, and their associated costs would need to be assessed. For dissolved water quality constituents, Duke Energy may need to pilot test potential treatment techniques to assess treatability and costs prior to the cooling tower design. Based on a thorough evaluation of parameters of concern, the cooling towers may need to be operated at a lower COC than 5.0. All these additional studies and operating measures would increase the costs beyond what has been estimated in this evaluation.

10.3.6.2 Cooling Tower Sizing

Hypothetical MDCTs were sized by SPX for the cooling water system at Oconee. Cooling tower sizing information for Units 1, 2, and 3 is provided in Table 10-5.

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[42] This evaluation assumes that there are no other leaks in the system. The design make-up rate equals the sum of design evaporation, design drift, and design blowdown.

[43] A design approach temperature of 10°F was selected at Oconee because this value represents a high performance cooling tower system and is common in preliminary cooling tower design.

[44] The hypothetical design assumes that all circulating water and service water would be recirculated in the cooling towers, and that the cooling tower range would be equal to the condenser ΔT. Service water uses at Oconee have unknown and variable heat loads.

[45] The operation of closed-cycle cooling towers would cause increased concentrations of parameters in the blowdown when compared to ambient concentrations in the source waterbody. COC may vary during cooling tower operation due to changes in water quality. If cooling towers were to be determined BTA, the water quality of the blowdown would require evaluation to further refine the COC.

Table 10-5. Hypothetical Closed-cycle Cooling Tower Design Information at Oconee Nuclear Station (SPX 2019)

Parameter	Units	Unit 1	Unit 2	Unit 3
Tower Type	-	MDCT	MDCT	MDCT
Number of Cells	-	30	30	30
Number of Towers	-	1	1	1
Tower Size (l x w x h)	ft	825 x 126 x 60	825 x 126 x 60	825 x 126 x 60
Configuration[46]	-	Back-to-back	Back-to-back	Back-to-back
Basin Size (l x w x d)	ft	825 x 136 x 6	825 x 136 x 6	825 x 136 x 6
Fan Motor Input Power (Per Cell)	hp[47]	300	300	300
Total Fan Motor Input Power	hp	9,000	9,000	9,000
Total Booster Pump Head	ft	92.7	92.7	92.7
Design Cooling Tower Flow Rate	gpm	708,000	708,000	708,000
Design Cooling Tower Range	°F	17.2	17.2	17.2
Design Wet-bulb Temperature	°F	76	76	76
Wet-bulb Temperature Percentile	%	99	99	99
Prevailing Wind Direction	-	Southwest	Southwest	Southwest
Minimum Distance Between Towers[48]	ft	413	413	413

10.3.6.3 Existing Geotechnical Conditions

Based on previous geotechnical investigations and on-site boring logs, partially weathered bedrock is assumed to be at a depth of between 30 ft and 50 ft (Duke Energy 2015). This evaluation assumes that cooling tower basins would be pile-supported and that the hypothetical pilings would be driven to a depth of 50 ft.

10.3.6.4 Potential Cooling Tower Locations (§122.21(r)(10)(i)(B))

Figure 10-7 shows the topography of the area around Oconee. The property and surrounding areas are generally at elevations between 20 ft and 40 ft elevation contours. There are areas of steep topography throughout the property, with the steepest areas existing to the west, on either side of

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[46] MDCTs were sized by SPX (2019) as linear back-to-back towers. Circular MDCTs could also be potentially feasible at Oconee, but would be expected to have similar footprint requirements, similar cooling performance, and similar capital and annual O&M costs as linear back-to-back MDCTs.

[47] Horsepower.

[48] Minimum separation distance between MDCTs assumes the MDCTs are fully offset and is calculated as half the basin length.

the intake canal. The station is bounded by Lake Keowee to the west and north, by the Keowee River to the east, and by hilly forest area to the south.

Figure 10-7. Topography in the Vicinity of Oconee Nuclear Station

The following site characteristics were considered when identifying potential locations for cooling tower placement; one potential location was then selected for use in the remainder of the feasibility evaluation:

1. The location should have existing space available for construction. The footprint of the cooling tower basins, booster pumphouse, construction access, excavation space, and space to install equipment were considered under this category. This evaluation attempted to locate cooling towers in the same general area. Additionally, the topography of the site should be amenable to construction, or the site should be amenable to re-grading.
2. The location should have existing space available for cooling tower operation. Good air circulation is needed for the cooling towers to operate at high performance.
3. The location should facilitate the minimization of construction outages to the extent practicable. Station downtime is costly, affects the reliability of the electric grid, and, for a nuclear station, results in the loss of greenhouse gas-free generation.
4. The location should facilitate the minimization of O&M costs. To the extent practicable, the evaluation attempted to locate cooling towers and other related new equipment to minimize fuel, labor, and other maintenance costs.
5. The location should be in close proximity to existing condensers. Long distances between condensers and cooling towers increases the cost of construction and increases headloss through the system that would need to be compensated with larger pumps. Therefore, the distances between condensers and cooling towers were minimized to the extent practicable during the assessment.
6. The location should be in close proximity to the existing CWIS and discharge. Much of the existing cooling water piping is buried beneath the station and intertwined with other utilities. Locating the hypothetical cooling towers in close proximity to the existing discharge canal facilitated the utilization of existing infrastructure to the maximum extent possible, reducing disruption to station operations, and reducing disturbances to the site.
7. The location should have pipe or channel routes available between the condensers and cooling towers. Pipe routes that avoid crossing transmission corridors and other densely utilized areas of the site are preferable. Cooling tower locations that allow for practical hot and cold water channel routes are also preferred. The evaluation also attempted to avoid cooling water pipe crossings.
8. The location should facilitate minimal construction-related disturbance to the extent practicable. This evaluation attempted to locate and sequence work to minimize disturbed areas.
9. The location should have existing space available for equipment laydown. It is convenient and cost-effective for contractors to have laydown space readily available near construction activities. When there is not sufficient space, equipment would need to be hauled to the construction site as needed.
10. The location should be outside of the 100-year floodplain. This evaluation attempted to locate cooling towers outside of the floodplain.

10.3.6.5 Conceptual Approach to Hypothetical Closed-cycle Cooling

In a hypothetical closed-cycle cooling tower retrofit at Oconee, new cooling tower booster pumps would be installed to route hot water from the condensers to the cooling towers. These booster pumps would be in addition to the existing CCW pumps in the existing CWIS, which would remain in place and would continue to pump water from the intake canal to the condensers. A pump station to house the cooling tower booster pumps would be constructed on-site near the existing discharge canal. Piping to route hot water from the condensers to the cooling towers would be tied into the existing hot water piping upstream of the existing discharge structure. Each of Units 1, 2, and 3 would require 14 booster pumps (42 booster pumps total), each rated at approximately 51,000 gpm. The booster pumps would be expected to develop approximately 93 ft of total dynamic head.

Cold water leaving the cooling towers would be routed to the existing intake canal for recirculation. The existing CWIS and CCW pumps would remain operational and would recirculate the closed-cycle cooling water back to the existing condensers. Blowdown from the three cooling towers would be discharged from the CCRS to a new outfall location.

The existing curtain wall would be retrofitted to act as a passive make-up water intake system to supply cooling tower make-up water to the existing CWIS. The make-up water would replace circulating water lost from the cooling towers via evaporation, drift, and blowdown. A wall of concrete would be installed from the bottom of the existing curtain wall to the lake bottom to hydraulically close off the intake canal from Lake Keowee. A steel gate system would be installed in the new concrete to allow an opening for make-up water to pass through. The opening would be fitted with bar racks and screens. The gate would be automated to open and close based on concentration levels of applicable water quality parameters in the intake canal[49]. A separate make-up water intake structure would not be required, nor would additional make-up water pumps. The make-up water would be withdrawn through the opening via the existing CCW pumps in the existing CWIS. Figure 10-8 is a conceptual elevation view of the hypothetical passive make-up water system at Oconee.

Pump and pipe selection calculations for the hypothetical closed-cycle cooling tower retrofit at Oconee are provided in Appendix 10-B.

Figure 10-9 is a schematic of the cooling water system before and after the hypothetical closed-cycle cooling tower retrofit at Oconee.

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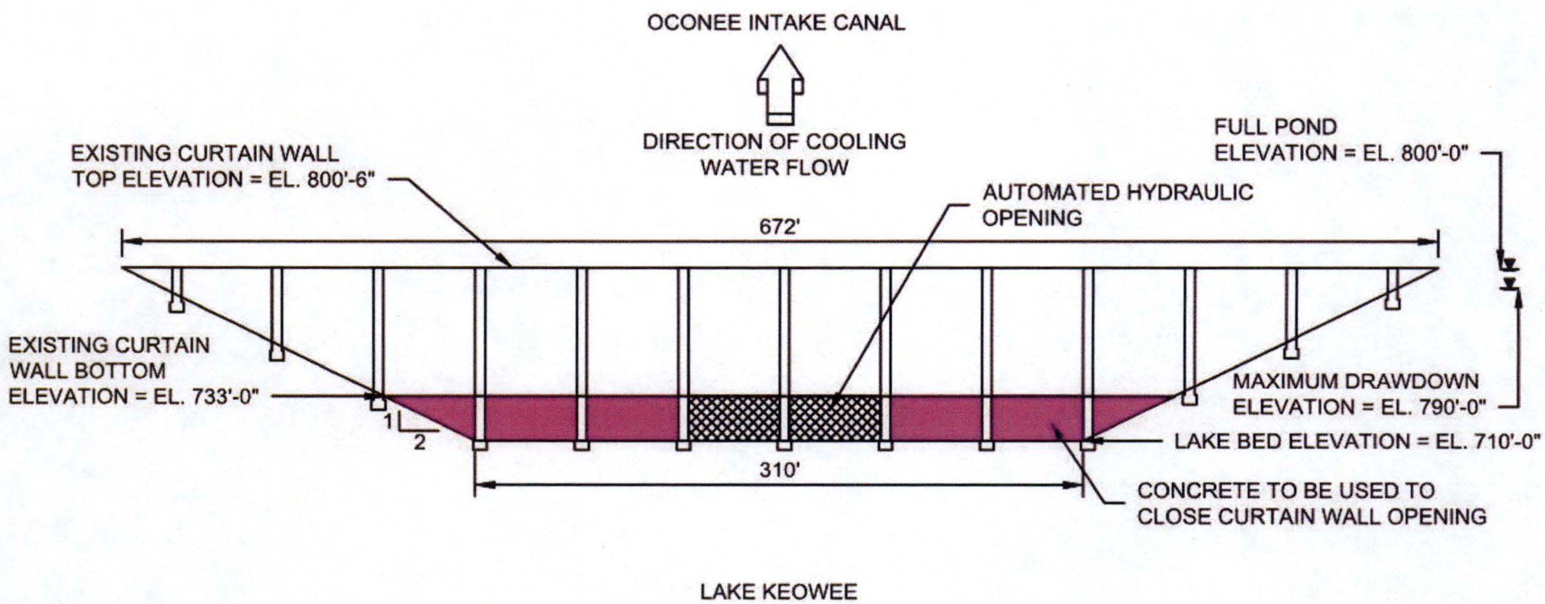
[49] The sizing of the passive make-up water system would be determined during future design phases if a hypothetical MDCT retrofit were considered BTA for entrainment reduction at Oconee.



DUKE ENERGY.	HYPOTHETICAL PASSIVE MAKE-UP WATER SYSTEM (ELEVATION VIEW)	(NOT TO SCALE)	FDR

Figure 10-8. Conceptual Elevation View of the Hypothetical Make-up Water System at Oconee Nuclear Station

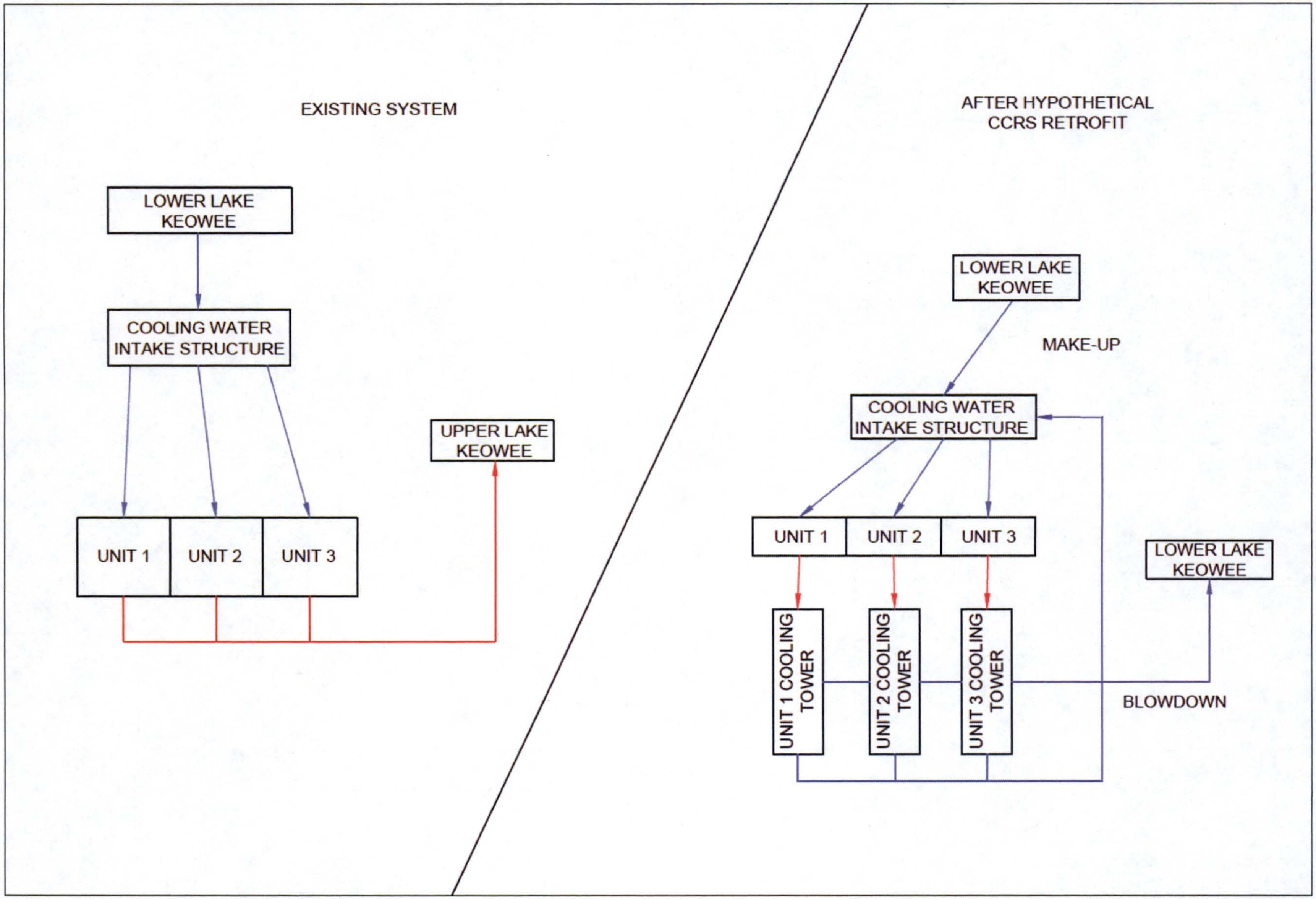


Figure 10-9. Schematic of Existing Once-through Cooling System and Hypothetical Closed-cycle Cooling System at Oconee Nuclear Station

10.3.6.6 Orientation of the Hypothetical Closed-cycle Cooling Towers

Wind speed and direction can significantly influence cooling tower performance as well as the potential effects of station emissions. While moderate wind speeds are critical for transporting the saturated plume away from cooling towers and increasing cooling tower performance, excessive wind speeds can diminish cooling tower performance by restricting the plume from rising up and out of the towers. A cooling tower array performs best when its primary (long) axis is oriented in the predominant wind direction, because this orientation minimizes the potential for saturated air recirculation. When space and other physical conditions allow, MDCTs are oriented with the dominant wind direction that coincides with the design wet-bulb temperature. Meteorological data from the World Meteorological Organization (WMO Station Number 723120) for Greenville/Spartanburg, SC has been used for this evaluation. Wind roses[50], which depict prevailing wind direction and percent frequency of observed wind speeds for the different months of the year, are shown on Figure 10-10.

Recirculation occurs when the saturated air leaving the cooling tower is introduced back into the tower's air inlets (SPX 2009). Interference is similar to recirculation, with the exception that the saturated air leaving the cooling tower is introduced into a nearby cooling tower's air inlet (SPX 2009). When multiple cooling towers are utilized in a side-by-side fashion, a minimum distance[51] between the towers must be maintained to minimize interference[52]. Minimum separation distance between the towers is provided in Table 10-5.

The winter (December, January, and February) wind rose shows that the prevailing winds are generally from the northeast and southwest directions. Wind from the northeast occurs approximately 11 percent of the time, while wind from the southwest occurs approximately 12 percent of the time. Wind speeds are commonly between 6 and 14 knots (approximately 7 and 16 miles per hour (MPH). The spring (March, April, and May) wind rose shows that the prevailing winds are also generally from the northeast and southwest directions. Wind from the northeast occurs approximately 9 percent of the time, while wind from the southwest occurs approximately 12 percent of the time. Wind speeds are commonly between 6 and 14 knots (approximately 7 and 16 MPH). The summer (June, July, and August) wind rose shows that the prevailing winds again are generally from the northeast and southwest directions. Wind from both the northeast and southwest occurs approximately 10 percent of the time. Wind speeds are commonly between 6 and 14 knots (approximately 7 and 16 MPH). The autumn (September, October, and November) wind rose shows

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[50] A wind rose is a graphical representation of how prevailing wind direction and percent frequency of wind speed are distributed at a specific location for a given period of record of data. The wind rose is plotted in a circular format. Straight lines directing towards the center represent the prevailing wind direction; the concentric circles (or dashes on the straight lines) represent the percent frequencies of wind speed, which increase in percent frequency from the center of the wind rose (NRCS 2016). The percent of time the wind speed is observed as calm is typically provided as a note to the wind rose. Wind speeds may be provided in units of either MPH or in knots.

[51] The minimum distance is typically a function of the length of the cooling tower and the amount of offset between the side-by-side towers. When the site does not allow for this minimum separation between towers or does not allow for the appropriate orientation of towers, the inefficiencies may be overcome by using more powerful fans or adding a few extra cooling tower cells.

[52] Recirculation is minimized by limiting the size of any tower. For example, if a station needs 48 cooling tower cells, the design can minimize recirculating by utilizing four 12-cell towers instead of a single 48-cell tower.

that the prevailing winds are generally from the northeast direction, occurring approximately 15 percent of the time. Wind speeds are commonly between 6 and 14 knots (approximately 7 and 16 MPH).

The predominant wind during the design wet-bulb temperature conditions (i.e., the summer months) is from the southwest; therefore, the main axis of the cooling towers would be oriented in the southwest to northeast direction. The direction and speed of winter winds have a greater influence on ice and resulting safety concerns arising from station activities.

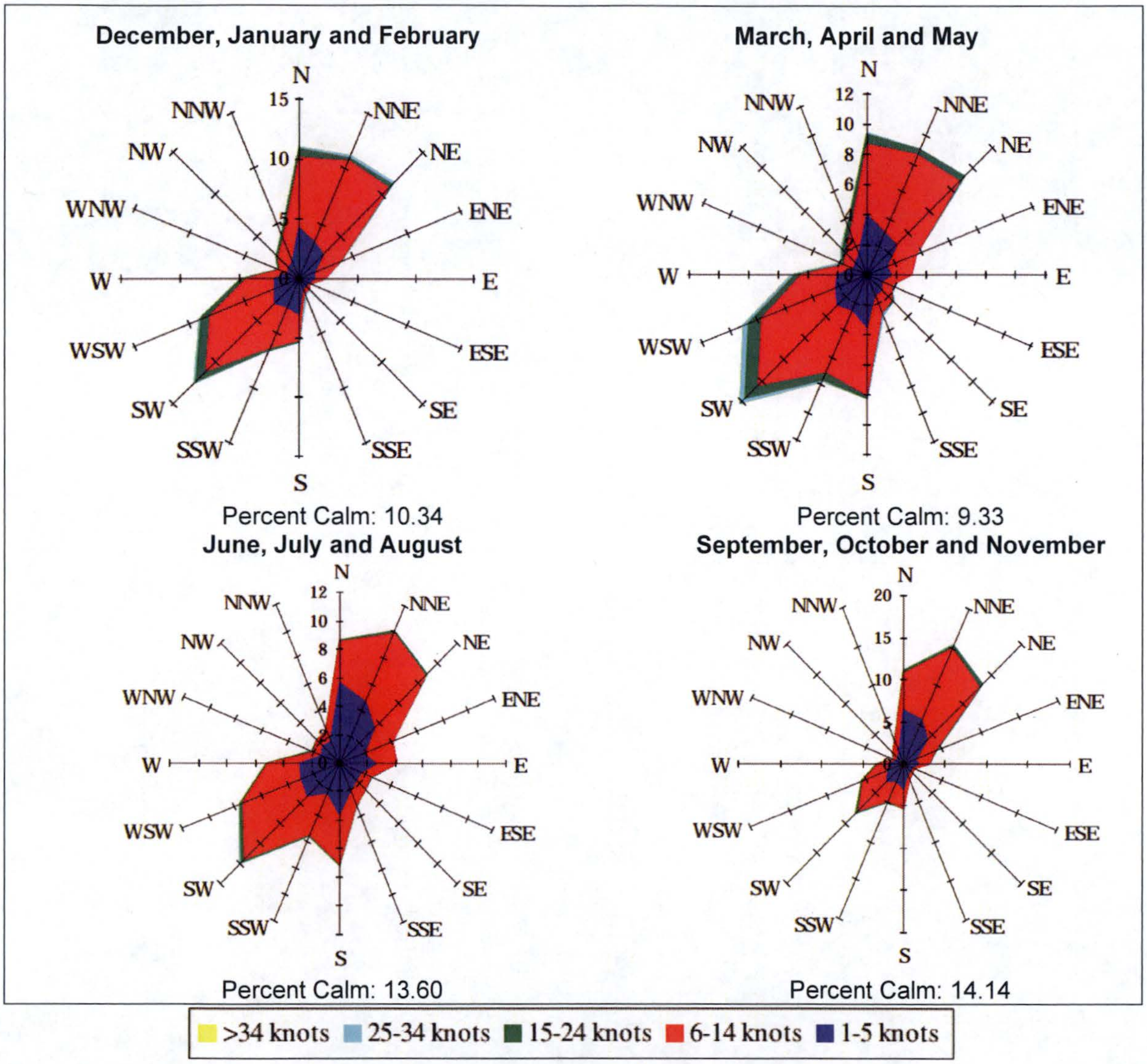

Figure 10-10. Wind Roses for Greenville/Spartanburg, SC (WMO 1999)

10.3.7 On-site Hypothetical MDCT Locations

Two on-site locations were evaluated for the hypothetical MDCTs at Oconee (Location A and Location B), as shown on Figure 10-11. These locations are described in the following sections.

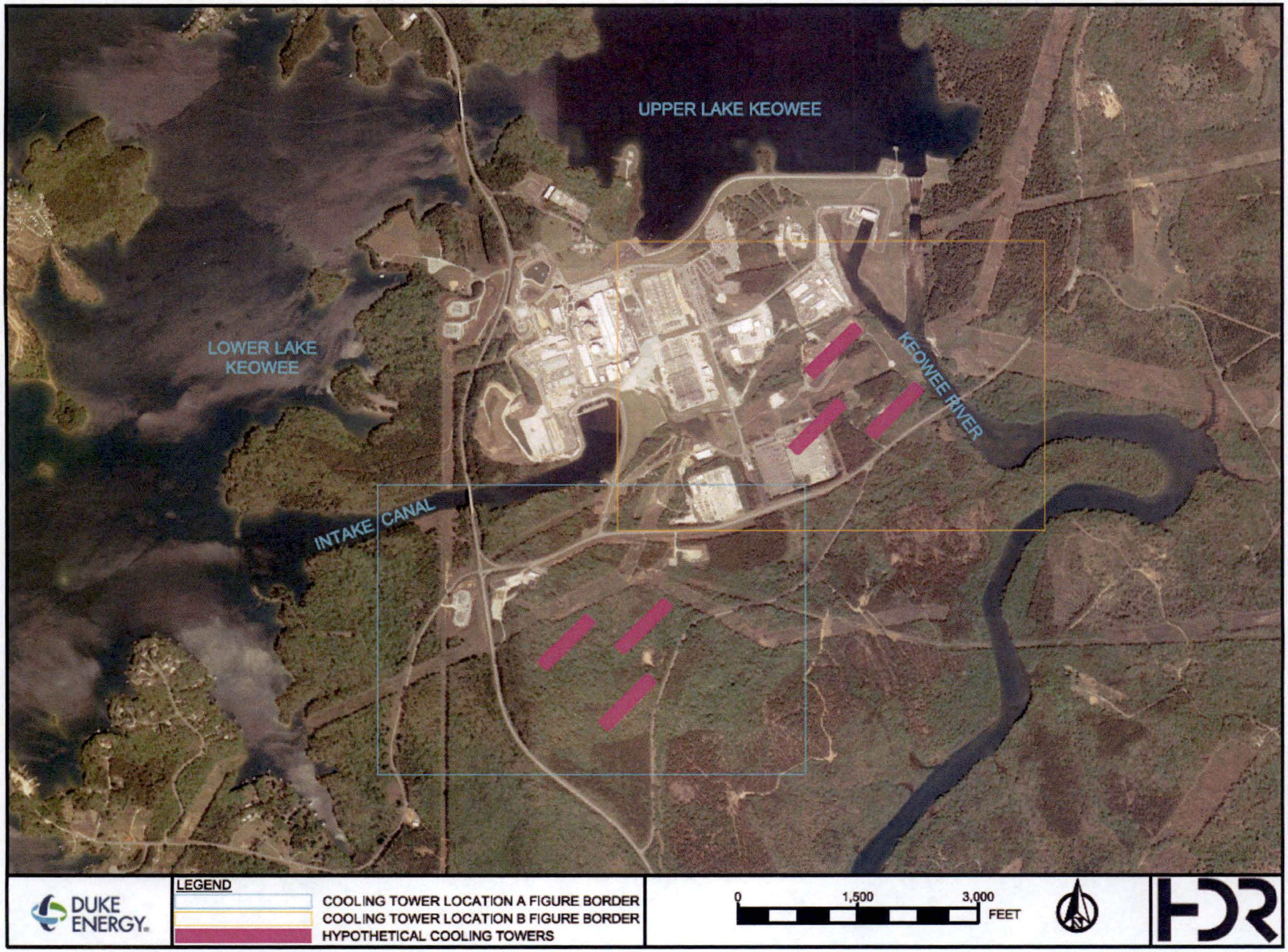

Figure 10-11. Hypothetical Cooling Tower Location Map at Oconee Nuclear Station

10.3.7.1 Hypothetical Cooling Tower Location A

The conceptual design for hypothetical cooling tower Location A includes placing three linear back-to-back MDCTs[53], one for each unit, to the southwest of the station in an undeveloped forest area, as shown in Figure 10-12. This hypothetical location avoids station infrastructure and the 100-year floodplain, but poses construction constraints including steep topography, potential interference with overhead transmission lines, and crossing(s) of Walhalla State Highway (South Carolina Highway 183).

For hypothetical cooling tower Location A at Oconee, a CCRS would be constructed that utilizes the existing intake canal and curtain wall, as described in Section 10.3.6.5. The existing curtain wall would be retrofitted to act as a passive make-up water intake that would provide make-up water to the CCRS from Lake Keowee.

The existing discharge piping from the Units 1, 2, and 3 generation buildings currently routes hot water to the discharge structure on Lake Keowee. As such, the condenser discharge would be rerouted to the hypothetical MDCTs. A pump station to house new cooling tower booster pumps would be constructed on-site near the existing discharge structure. Piping to route hot water from the condensers to the hypothetical cooling towers would be tied into the existing hot water piping upstream of the discharge structure. Additionally, cold water from the cooling towers would be routed to the intake canal, and cooling tower blowdown would be routed to a new outfall location in a cove in Lower Lake Keowee to the southwest of the station.

At hypothetical cooling tower Location A, new piping would be installed across Oconee's existing station infrastructure and under the Walhalla State Highway, which would require significant permitting and construction. Steep topography present throughout the site and this hypothetical MDCT location would require significant site clearing, regrading, and restoration. Construction and operation of the hypothetical cooling towers would occur in the vicinity of existing overhead transmission lines. This could cause potential icing concerns, and would likely require transmission line relocation. Cooling tower blowdown would be routed back to Lake Keowee and may require settling/treatment basins to reduce solids and other constituent concentrations prior to discharge. While Location A is not ideal for the construction and operation of hypothetical closed-cycle cooling towers at Oconee, other potential locations considered were less suitable, as discussed in subsequent sections.

[53] MDCTs were sized by SPX (2019) as linear back-to-back towers. Circular MDCTs could also be potentially feasible at Oconee, but would be expected to have similar footprint requirements, similar cooling performance, and similar capital and annual O&M costs as linear back-to-back MDCTs.

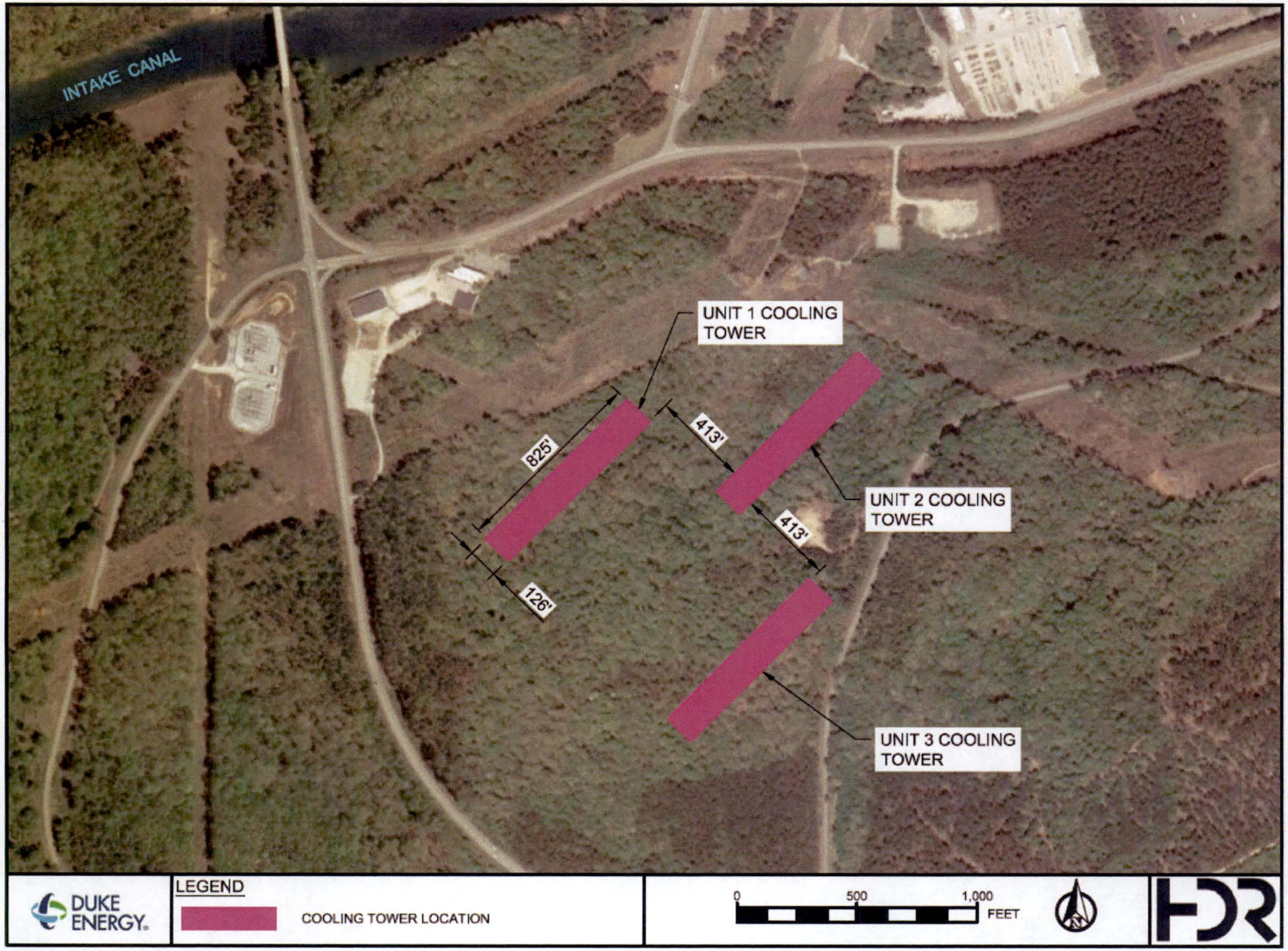

Figure 10-12. Hypothetical Cooling Tower Location A at Oconee Nuclear Station

10.3.7.2 Hypothetical Cooling Tower Location B

The conceptual design for hypothetical cooling tower Location B includes placing three linear back-to-back MDCTs[54], one for each unit, to the southeast of Oconee's generating units, as shown in Figure 10-13. This hypothetical location avoids the 100-year floodplain and road crossings but poses construction constraints including the relocation of existing station infrastructure (including a large office building), steep topography, and the relocation of existing overhead transmission lines.

For hypothetical cooling tower Location B at Oconee, a CCRS would be constructed that utilizes the existing intake canal and curtain wall, as described in Section 10.3.6.5. The existing curtain wall would be retrofitted to act as a passive make-up water intake that would provide make-up water to the CCRS from Lake Keowee.

The existing discharge piping from the Units 1, 2, and 3 generation buildings currently routes hot water to the discharge structure on Lake Keowee. As such, the condenser discharge would be rerouted to the hypothetical MDCTs. A pump station to house new cooling tower booster pumps would be constructed on-site near the existing discharge structure. Piping to route hot water from the condensers to the hypothetical cooling towers would be tied into the existing hot water piping upstream of the discharge structure. Additionally, cold water from the cooling towers would be routed to the intake canal, and cooling tower blowdown would be routed to a new outfall location in the Keowee River to the east of the station.

At hypothetical cooling tower Location B, new piping would be installed across Oconee's existing station infrastructure, which would require significant permitting, demolition, and construction. Steep topography present throughout the site and this hypothetical MDCT location would require significant site clearing, regrading, and restoration. Additionally, station infrastructure including several buildings and other structures would require demolition and relocation. Existing high voltage overhead transmission lines in the vicinity of Location B would require demolition and relocation as well. Location B, while closer to the existing generating units at Oconee, is less suitable for the construction and operation of hypothetical closed-cycle cooling towers at Oconee due to the necessary and significant demolition and relocation of station infrastructure.

See Figure 10-14 for a conceptual design of the hypothetical closed-cycle cooling tower retrofit at Location A at Oconee, including hot and cold water piping, blowdown piping, booster pump station location, and cooling tower locations.

[54] MDCTs were sized by SPX (2019) as linear back-to-back towers. Circular MDCTs could also be potentially feasible at Oconee, but would be expected to have similar footprint requirements, similar cooling performance, and similar capital and annual O&M costs as linear back-to-back MDCTs.

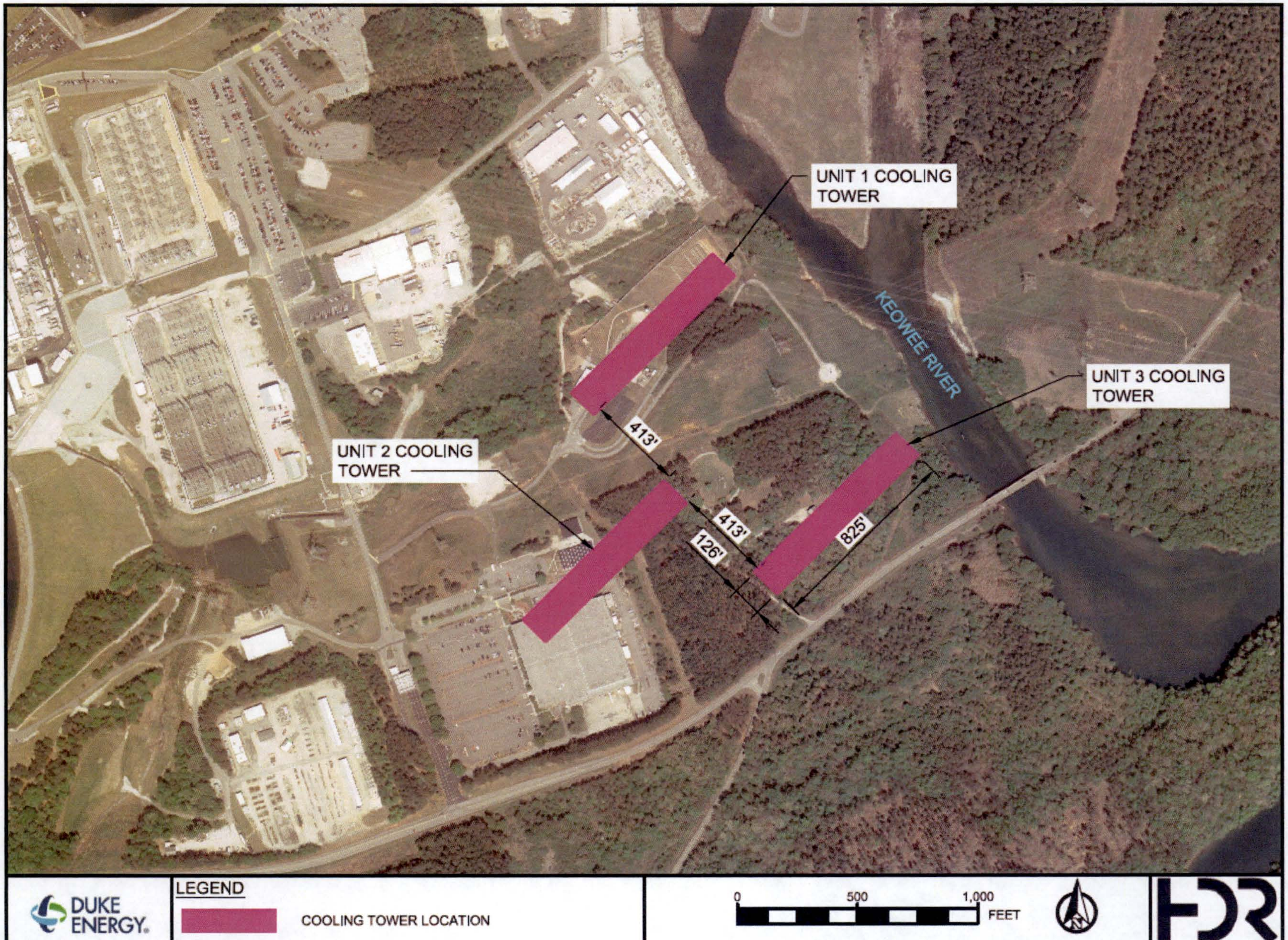

Figure 10-13. Hypothetical Cooling Tower Location B at Oconee Nuclear Station

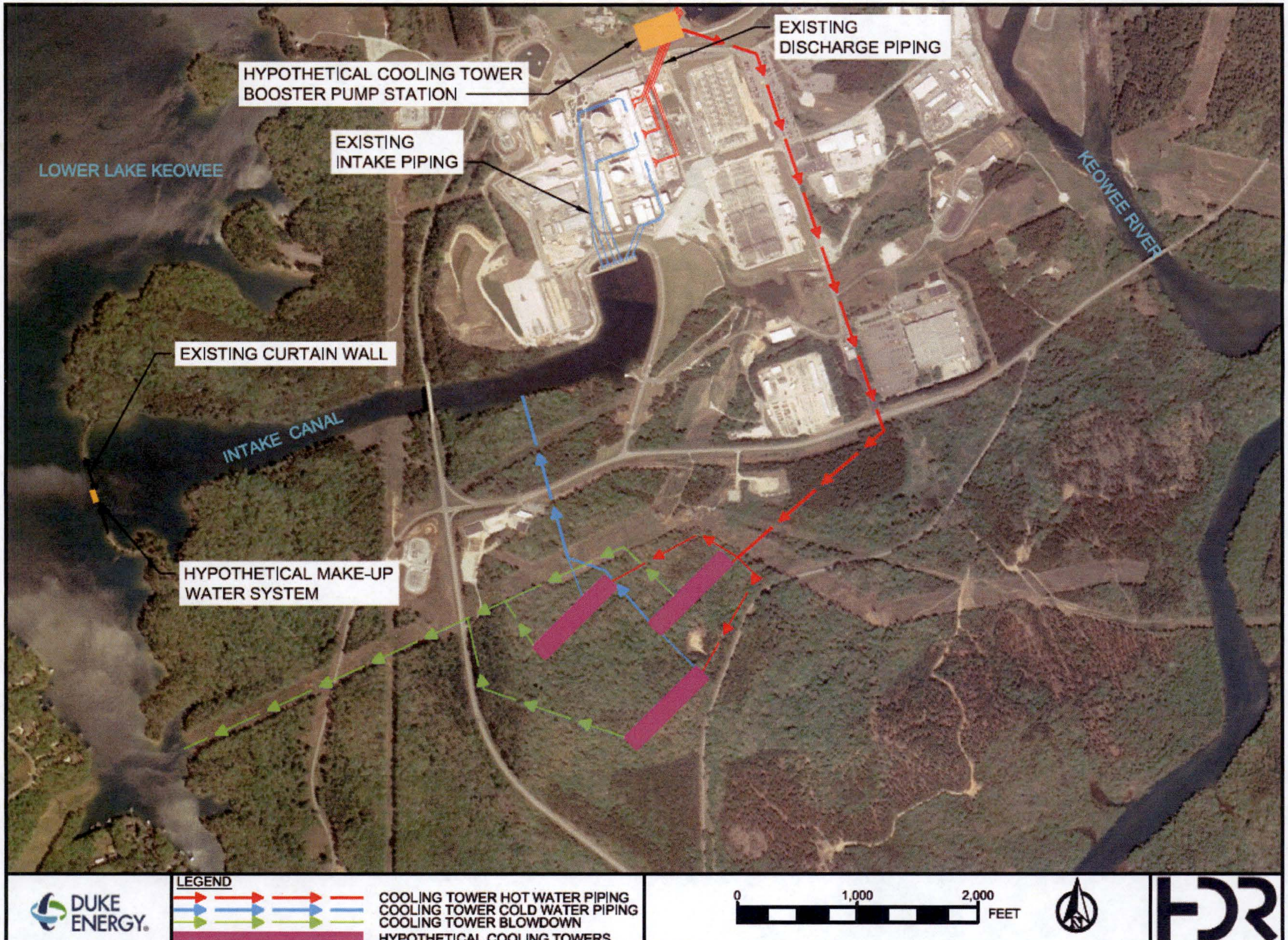

Figure 10-14. Hypothetical Closed-cycle Cooling Tower Conceptual Design at Oconee Nuclear Station

10.3.8 Off-site Locations

Off-site locations for the construction and operation of hypothetical closed-cycle cooling towers at Oconee were not considered. The shoreline of Lake Keowee borders the northern boundary of the station's property limits, and the west bank of the Keowee River borders the eastern boundary of the station's property limits. Off-site land to the west of the station is within the 100-year floodplain. Off-site land to the south of the station would present similar construction constraints as hypothetical cooling tower Location A, while being greater in distance from the station's intake canal and generating units.

10.3.8.1 Repurposing of Existing Station Infrastructure

Repurposing existing station infrastructure for use in a hypothetical closed-cycle cooling system is not considered to be feasible at Oconee.

10.3.9 Construction Sequencing

A preliminary construction sequence for the hypothetical MDCT retrofit at Oconee was developed, and includes the following major construction tasks:

1. Prepare temporary parking, site access, and equipment laydown areas;
2. Site clearing and regrading;
3. Relocation of transmission lines;
4. Drive piles for cooling tower basin foundations;
5. Drive piles for cooling tower booster pump station foundation;
6. Drive piles for hot and cold water piping;
7. Drive piles for curtain wall make-up water system;
8. Construct cooling tower basins;
9. Construct cooling tower blowdown treatment basins;
10. Construct cooling tower booster pump station;
11. Install hot water piping, cold water piping, and blowdown piping;
12. Erect Unit 1 cooling tower and install Unit 1 cooling tower booster pumps;
13. Tie into existing Unit 1 condenser discharge piping (includes outage);
14. Testing and commissioning of the Unit 1 cooling tower, Unit 1 returns to operation;
15. Erect Unit 2 cooling tower and install Unit 2 cooling tower booster pumps;
16. Tie into existing Unit 2 condenser discharge piping (includes outage);
17. Testing and commissioning of the Unit 2 cooling tower, Unit 2 returns to operation;
18. Erect Unit 3 cooling tower and install Unit 3 cooling tower booster pumps;
19. Tie into existing Unit 3 condenser discharge piping (includes outage);
20. Install make-up water system in the existing curtain wall (includes outage);

21. Testing and commissioning of the Unit 3 cooling tower, Unit 3 returns to operation; and
22. Site restoration.

10.3.10 Construction Outage

Based on the preliminary construction sequence provided in Section 10.3.9, the construction outage due to a hypothetical closed-cycle cooling tower retrofit at Oconee is assumed to be 6 months in total for each unit. The construction outage for each unit would include a regularly-scheduled unit maintenance outage (approximately 1 month) to help reduce downtime costs.

The approximate construction outage schedule for each unit is as follows:

- **Unit 1** – June 1, 2026 through November 30, 2026 (includes scheduled Unit 1 maintenance outage);
- **Unit 2** – June 1, 2027 through November 30, 2027 (includes scheduled Unit 2 maintenance outage); and
- **Unit 3** – March 1, 2028 through August 31, 2028 (includes scheduled Unit 3 maintenance outage).

10.3.11 Feasibility Discussion (§122.21(r)(10)(i)(D))

Overall, a hypothetical closed-cycle cooling tower retrofit at Oconee is considered to be technically feasible, but extremely challenging and impractical. Figure 10-15 includes a visual representation of construction constraints associated with both hypothetical cooling tower locations discussed previously, including existing roadways, overhead transmission lines, steep slopes, areas excluded from the evaluation per instruction from Duke Energy[55], and 100-year floodplains.

The key construction-related challenges associated with a hypothetical closed-cycle cooling tower retrofit at Oconee include:

- While hypothetical cooling tower Location A is outside the 100-year floodplain and avoids significant relocation of existing station infrastructure, it poses potential interferences with existing overhead transmission lines and would require multiple pipe crossings of a state highway;
- Construction of hypothetical cooling towers at Location A would require significant site clearing, regrading, and site restoration to alleviate the steep topography in this area. This would include extensive tree clearing;
- Hypothetical cooling tower construction and tie-ins would require significant unit outages, which would have operational and financial impacts to the station;
- In-water construction of the make-up water system would require extensive review by the U.S. Army Corps of Engineers (USACE); and
- Preparation of Environmental Impact Assessment(s).

[55] Certain station infrastructure has been excluded from the hypothetical cooling tower siting evaluation, per instruction by Duke Energy (Amec Foster Wheeler 2015).

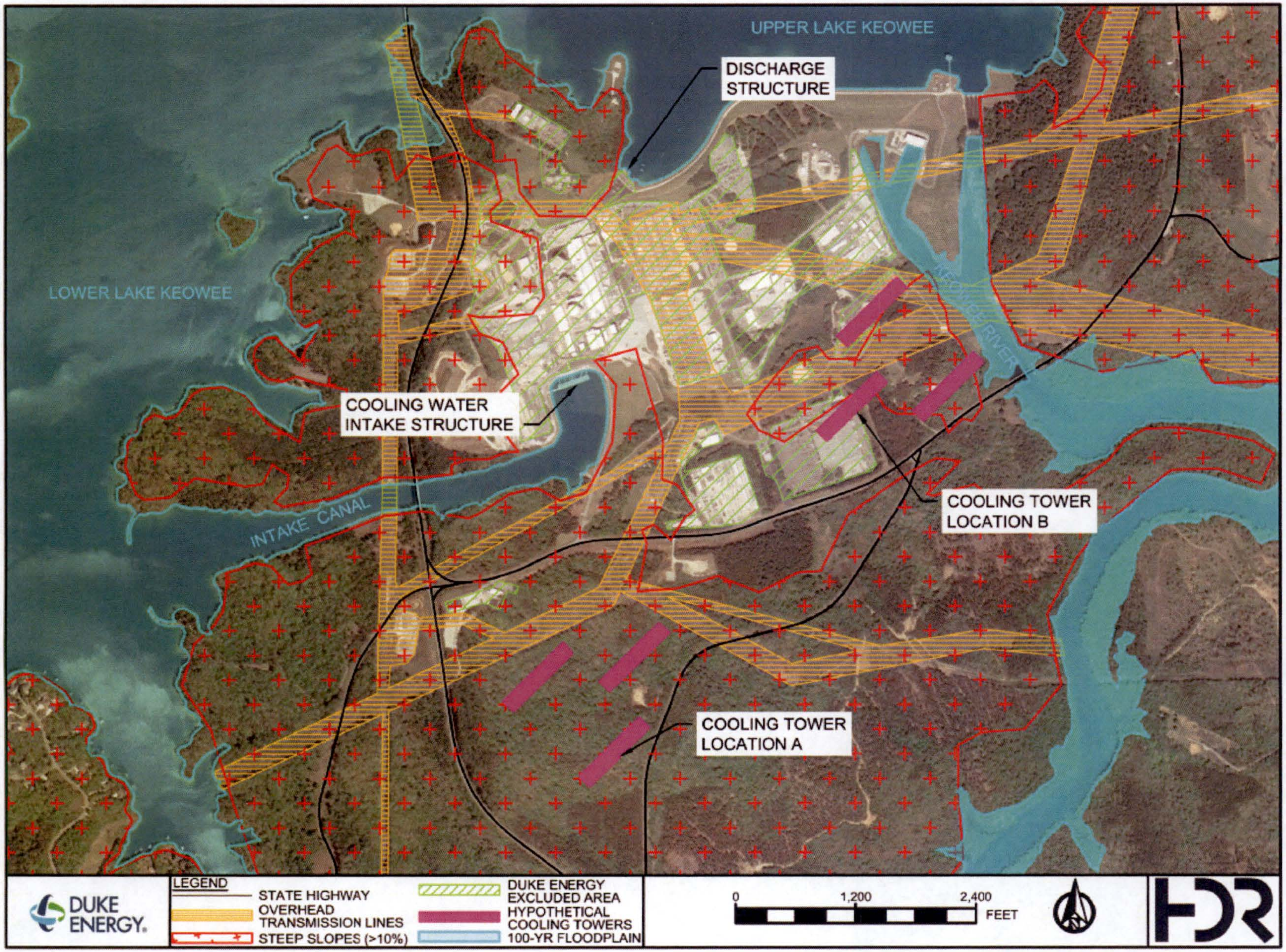

Figure 10-15. Hypothetical Closed-cycle Cooling Tower Retrofit Construction Constraints at Oconee Nuclear Station

The key operations-related challenges associated with a hypothetical closed-cycle cooling tower retrofit at Oconee include:

1. The hypothetical MDCTs would be designed to the 99 percent wet-bulb temperature, which means that 1 percent of the time annually (approximately 88 hours), on average, but concentrated during the warmest times of the year, the towers would not be able to cool the full heat load from the units, and the station would potentially be required to de-rate;
2. Operation of MDCTs would require new pumps, fans, and related equipment, which would consume additional energy. This new equipment would increase the annual energy consumption at the station, and could reduce the station's electrical output;
3. Operation of MDCTs would impact turbine operation and station power output due to increased backpressure caused by warmer condenser cooling water when compared to current operations, especially during the warmest times of the year. These impacts are discussed further in Section 12 of this document;
4. Due to the relatively low height of MDCTs, there would be potential for fogging and icing impacts on the station and surrounding areas, including a state highway;
5. Operation of MDCTs would create PM emissions that could impact the station and surrounding areas. These impacts are discussed further in Section 12 of this document;
6. Operation of MDCTs would create additional noise from fans, pumps, and cascading water inside the cooling towers. These impacts are discussed further in Section 12 of this document;
7. Operation of MDCTs would increase water consumption at the station due to the higher evaporation rate of MDCTs when compared to the existing once-through cooling system. These impacts are discussed further in Section 12 of this document; and
8. Operation of MDCTs would generate residual waste, including scale, sediment, and sludge, which would require collection and disposal.

10.3.12 Permitting Requirements

Construction and operation of hypothetical closed-cycle cooling towers at Oconee would require several federal, state, and local permits, including the following:

1. FERC permit modification for changes to the existing system at Oconee;
2. Modification to the 2014 Operating Agreement between the USACE, Southeastern Power Administration, and Duke Energy (related to increased consumptive water use and potential effect on reservoir levels and downstream flow releases from the Keowee Development);
3. SCDHEC air quality permit under the Prevention of Significant Deterioration Program due to cooling tower emissions;
4. SCDHEC NPDES permit major modification to account for cooling water system modifications (e.g., lower discharge flow, cooling tower blowdown, cooling tower chemical usage);

5. SCDHEC water withdrawal registration updates;
6. SCDHEC and USACE permits to fill and construct within wetlands and waterways;
7. Preparation of Environmental Impact Assessment(s); and
8. Local and state construction permits.

10.3.13 Implementation Schedule

A preliminary implementation schedule for the hypothetical closed-cycle cooling tower retrofit at Oconee is provided in Table 10-6.

Table 10-6. Hypothetical Closed-cycle Cooling Tower Retrofit Implementation Schedule at Oconee Nuclear Station

Task Start Date	Task End Date	Project Year (Task End Date)	Implementation Task
-	December 2020	0	Submit §316(b) Information
December 2020	December 2021	1	Final BTA Determination
December 2021	June 2022	1.5	Site Investigations; Engineering Contract
June 2022	December 2022	2	30 Percent Design; Permitting
December 2022	June 2023	2.5	60 Percent Design; Permitting
June 2023	December 2023	3	Procurement Contracts
December 2023	June 2024	3.5	90 Percent Design
June 2024	December 2024	4	Bid Construction; Contractor Selection
December 2024	June 2025	4.5	General Conditions; Local Permits; Demolition
June 2025	June 2026	5.5	Construction
June 2026	September 2028	7.75	Construction Outages; Tie-ins to Existing Condensers; Testing; Commissioning

10.3.14 Costs (§122.21(r)(10)(iii))

10.3.14.1 Capital Costs

Based on the design conditions and assumptions stated herein, an AACE Class 4 capital cost estimate has been developed for the hypothetical closed-cycle cooling tower retrofit at Oconee. The capital cost estimate incorporates union wage rates specific to the Greenville, SC metropolitan area, budgetary equipment pricing obtained from major equipment suppliers, and construction standard pricing using RSMeans data (Gordian 2019). Capital costs are presented in 2019 U.S. dollars (see Appendix 10-C).

The AACE Class 4 capital cost estimate for the materials, equipment, labor, and indirect costs associated with a hypothetical closed-cycle cooling tower retrofit at Oconee is approximately $1,109.32 M (in 2019 dollars). Capital costs are detailed in Table 10-7, and include the following components:

- Demolition costs;
- Civil/site work costs, including earthwork, transmission line relocation, construction of cooling tower basins, a cooling tower blowdown settling/treatment basin, a cooling tower booster pump station, hot water piping, cold water piping, blowdown piping, and a make-up water system;
- Mechanical costs, including cooling towers and booster pumps;
- Structural costs;
- Electrical and instrumentation and controls (I&C) costs;
- Construction indirect costs, including contractor site supervision, general conditions, and general administrative costs and profit;
- Design engineering costs at 10 percent of the construction direct costs;
- Project management costs at 10 percent of the design engineering costs;
- Owner's costs; and
- Contingency.

Table 10-7. Capital Costs for a Hypothetical Closed-cycle Cooling Tower Retrofit at Oconee Nuclear Station

Capital Cost Component	Cost (2019 $Millions)
Construction Direct Costs	
Demolition	$10.4
Civil/Site work	$356.9
Mechanical	$135.5
Structural	$10.7
Electrical and Instrumentation & Controls	$19.2
Subtotal Direct Costs	$532.7
Construction Indirect Costs	
Contractor Site Supervision	$31.2
General Conditions	$100.9
General Administrative Costs & Profit	$99.7
Subtotal Indirect Costs	$231.9
Total Construction Cost	$764.6
Design Engineering	$53.3
Project Management	$5.3
Owner's Costs	$80.4
Contingency	$205.8
TOTAL	**$1,109.32**

10.3.14.2 Annual O&M Costs

Annual O&M costs for the hypothetical closed-cycle cooling tower retrofit at Oconee are estimated to be approximately $15.0 M per year (in 2019 dollars). Annual O&M costs are provided in Table 10-8, and include the following assumptions:

- On average, 16 full-time equivalent staff would provide maintenance, inspection, and monitoring of the cooling towers, pumps, and other equipment;
- Chlorine would be added to the circulating water for control of biofouling. Cooling tower blowdown would be dechlorinated prior to discharge. A dispersant and a corrosion/scale inhibitor would be added continuously at a low dose;
- Cooling tower solids collection and disposal would occur every two years, but costs are presented on an annual basis; and

- Parts repair and replacement costs are estimated to be 6 percent of mechanical equipment capital costs.

Table 10-8. Annual O&M Costs for a Hypothetical Closed-cycle Cooling Tower Retrofit at Oconee Nuclear Station

Annual O&M Cost Component	Cost (2019 $Millions)
Labor	$2.7
Chemicals for Cooling Water	$3.9
Solids Disposal	$0.6
Parts Repair and Replacement	$7.9
TOTAL	$15.0

10.3.14.3 Station-Level Compliance Cost (Annual and Net Present Value)

This evaluation assumes that the hypothetical closed-cycle cooling towers would operate continuously using water of acceptable quality, and the cooling tower fill would not require replacement for the remaining life of the station. Per the schedule presented in Table 10-6, the cooling towers would be operational in 2026 for Unit 1, 2027 for Unit 2, and 2028 for Unit 3. Table 10-9 overlays capital costs on the preliminary implementation schedule. Annual O&M costs are presented in Table 10-10.

Table 10-9. Capital Cost Outlay for a Hypothetical Closed-cycle Cooling Tower Retrofit at Oconee Nuclear Station

Task Start Date	Task End Date	Project Year (Task End Date)	Implementation Task	Cost in 2019 ($Millions)	Cost in a Given Year ($Millions)	Present Value in 2019 ($Millions)
-	December 2020	0	Submit §316(b) Information	$-	$-	$-
December 2020	December 2021	1	Final BTA Determination	$-	$-	$-
December 2021	June 2022	1.5	Site Investigations; Engineering Contract	$11.1	$11.9	$9.8
June 2022	December 2022	2	30 Percent Design; Permitting	$25.0	$26.9	$22.1
December 2022	June 2023	2.5	60 Percent Design; Permitting	$25.0	$27.6	$21.2
June 2023	December 2023	3	Procurement Contracts	$5.5	$6.1	$4.7
December 2023	June 2024	3.5	90 Percent Design	$22.2	$25.1	$18.1
June 2024	December 2024	4	Bid Construction; Contractor Selection	$22.2	$25.1	$18.1
December 2024	June 2025	4.5	General Conditions; Local Permits; Demolition	$110.9	$128.6	$86.9
June 2025	June 2026	5.5	Construction	$554.7	$659.3	$417.4
June 2026	September 2028	7.75	Construction Outages; Tie-ins to Existing Condensers; Testing; Commissioning	$332.8	$415.6	$230.9

Table 10-10. Annual O&M Cost Outlay for a Hypothetical Closed-cycle Cooling Tower Retrofit at Oconee Nuclear Station

Year[56]	Cost in 2019 ($Millions)			Cost in Given Year ($Millions)			Present Value in 2019 ($Millions)		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
2026	$0.4	$-	$-	$0.5	$-	$-	$0.3	$-	$-
2027	$5.0	$0.4	$-	$6.1	$0.5	$-	$3.6	$0.3	$-
2028	$5.0	$5.0	$1.7	$6.2	$6.2	$2.1	$3.5	$3.5	$1.2
2029	$5.0	$5.0	$5.0	$6.4	$6.4	$6.4	$3.3	$3.3	$3.3
2030	$5.0	$5.0	$5.0	$6.6	$6.6	$6.6	$3.2	$3.2	$3.2
2031	$5.0	$5.0	$5.0	$6.7	$6.7	$6.7	$3.1	$3.1	$3.1
2032	$5.0	$5.0	$5.0	$6.9	$6.9	$6.9	$3.0	$2.9	$3.0
2033	$5.0	$5.0	$5.0	$7.1	$7.1	$7.1	$2.8	$2.8	$2.8
2034	$-	$-	$5.0	$-	$-	$7.2	$-	$-	$2.7

[56] This evaluation was performed assuming Units 1 and 2 will retire in 2033, and Unit 3 will retire in 2034, in accordance with Oconee's current renewed operating license.

10.3.15 Uncertainty

There are several uncertainties associated with the evaluation of a hypothetical closed-cycle cooling tower retrofit at Oconee, including the following:

1. The hypothetical cooling tower locations are assumed to be available;
2. Capital costs of cooling tower hot and cold water pipelines are based on measurements taken from aerial images. Site-specific geotechnical or alignment evaluations have not been performed for this study;
3. The hypothetical design cooling tower range is based on the condenser ΔT of 17.2°F;
4. It is assumed that station utilization would remain unchanged after a hypothetical closed-cycle cooling tower retrofit;
5. Station operations and condenser performance assumed in this evaluation are consistent with the existing condensers;
6. It is assumed that no hazardous materials would be encountered during excavation or demolition; and
7. Specific transmission lines that need to be relocated (including lengths and connection points) would be refined during detailed design of this hypothetical technology.

10.4 Fine-mesh and Fine-slot Screen Retrofit (§122.21(r)(10)(i))

The Rule at §122.21(r)(10)(i) requires an evaluation of the technical feasibility and cost of fine-mesh and fine-slot screens with a mesh or slot size of 2.0 mm or smaller. Fine-mesh and fine-slot screens are designed to reduce entrainment relative to coarse-mesh and coarse-slot screens[57], such as those currently installed at the Oconee CWIS.

10.4.1 Existing Cooling Water Intake Structure and Screens

The cooling water intake system at Oconee withdraws from a CWIS at the end of an intake canal located on Lower Lake Keowee. A trash boom spans the width of the intake canal upstream of the CWIS and is used to prevent debris from entering the CWIS. The CWIS is divided into three units, and each has four CCW pumps (12 CCW pumps total) that withdraw cooling water through eight intake bays (24 bays total). Each intake bay has a bar rack, a trash deflector plate, and a fixed-panel coarse-mesh screen. The top deck of the CWIS is located at El. 810 ft above mean sea level (msl). The invert of the CWIS is at El. 761 ft msl. Each intake bay is 11.3 ft wide. The bar racks are located at the face of the CWIS and are used to prevent large debris from entering the CWIS. The bar racks have 6-inch by 2-ft bars spaced three inches center-to-center.

Each fixed-panel coarse-mesh screen has 3/8-inch square mesh openings and a width of 10.75 ft. Screen cleanings are performed by lifting screens with a mobile crane and spraying with high-pressure water to remove debris (Duke Energy 2013). Debris loading at the station is typically low (Duke Energy 2016).

The velocity approaching the fixed-panel coarse-mesh screens is the same for each unit, since all three units have the same flow through the screens. The TSV was estimated under the different pump operating scenarios for each unit at Oconee. Due to a condenser piping restriction (described in Section 3), the CCW pump flow per unit is reduced based on number of CCW pumps operating and number of screens utilized. It is assumed that flow is distributed equally among utilized screens. Screen area available to flow is impacted by the presence of the overhang at the CWIS (Duke Energy 2020). Cooling water is withdrawn from the bottom of the overhang elevation (781.0 ft msl) to the bottom of the CWIS elevation (761.0 ft msl).

Under one-pump operation per unit[58], two-pump operation per unit, three-pump operation per unit, and four-pump operation per unit, the design TSV at the CWIS is approximately 2.90 fps, 2.74 fps, 2.39 fps, and 2.08 fps, respectively. These estimates of TSV are calculated assuming the screens are 100 percent clean. If screen clogging were to increase, TSV would increase as well. Engineering calculations of TSV for the existing fixed-panel coarse-mesh screens at Oconee are provided in Appendix 10-D. Additional description and drawings of the existing CWIS and screens at Oconee are provided in Sections 3 and 5 of this document.

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[57] Coarse mesh usually excludes larger organisms (e.g., juvenile and adult finfish) and debris, and does not exclude smaller organisms (e.g., eggs and larval finfish).

[58] One-pump operation occurs on less than 10 days during the five-year period of record from July 1, 2014 through June 30, 2019 (Duke Energy 2019a).

10.4.2 Typical Screen Types

Fine-mesh and fine-slot screens are typically categorized in two groups: fine-mesh traveling water screens and fine-slot wedgewire screens. The suitability of one or both of these screen types depends on the source waterbody (e.g. depth near the intake, silt and debris loading, biological activity, extent of navigation) and the type and extent of the water withdrawal (e.g. the withdrawal rate, screen operating patterns). Both screen types can be effective at reducing the amount of debris and aquatic organisms that enter the cooling water system, but their design and operational characteristics are different.

Fine-mesh traveling water screens are metallic or polymer-based, and are typically approximately 10-ft wide and approximately 40-ft deep[59], with about 15-20 ft of the screen submerged. They rotate along a continuous belt, and are typically rotated and cleaned based on a timer or pressure differential (see Figure 10-16).The screens may have several rotation speeds, which can be changed as needed depending on the debris loading (Evoqua Water Technologies 2016).

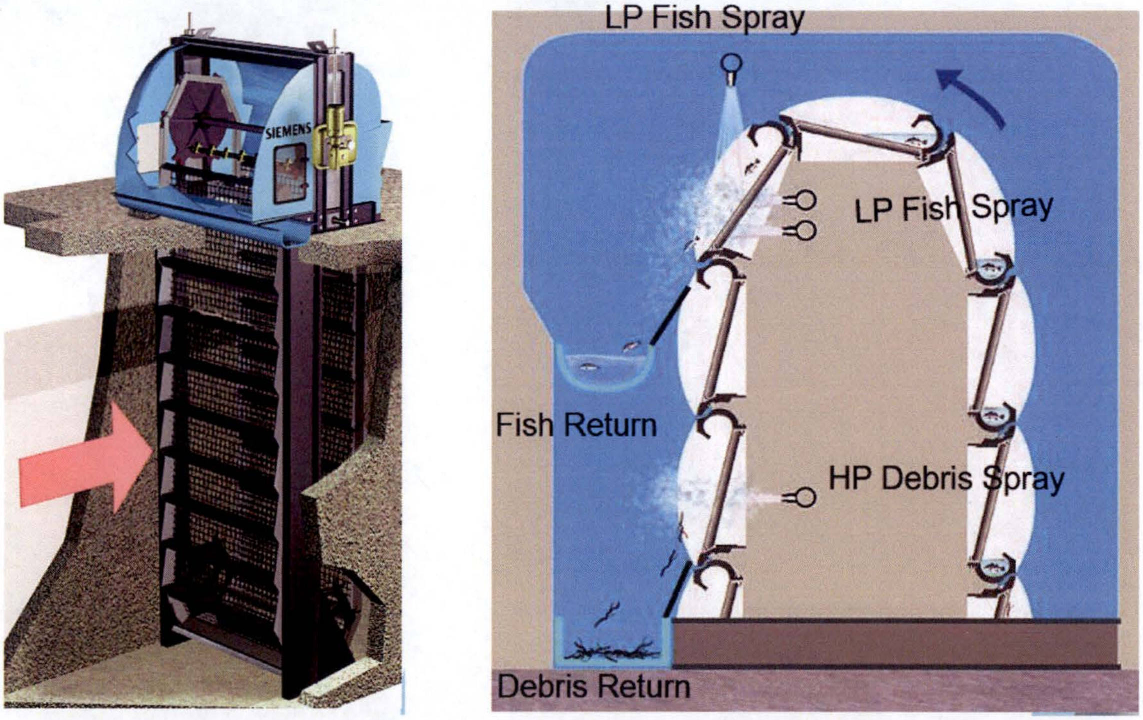

Figure 10-16. Schematic of a Traveling Water Screen (Left) and Close-Up View of Aquatic Organism Baskets, Aquatic Organism Return, and Debris Return (Right) (Evoqua Water Technologies 2016)

Fine-mesh traveling water screens are typically installed in through-flow or dual-flow alignment. Through-flow screens are oriented parallel to the face of the CWIS, whereas dual-flow screens are oriented perpendicular to the face of the CWIS. Through-flow screens utilize the front of the screens to accept the flow, whereas dual-flow screens use two sides of mesh to accept incoming flow. Dual-flow screens are particularly effective at reducing debris loading on the screens, and can result in

[59] The width and depth of traveling screens is typically dependent on station-specific needs and site conditions.

minor TSV and headloss reductions when compared to through-flow screens (Evoqua Water Technologies 2019b). However, the installation of dual-flow screens is often more difficult than the installation of through-flow screens and can require extensive CWIS modification, especially when considering a retrofit of dual-flow screens at a CWIS where through-flow screens are already in use (Evoqua Water Technologies 2019b). Fine-mesh dual-flow traveling water screens were not considered at Oconee due to the limited space available in front of and behind the existing screen guides, which would increase retrofit complexity, require extensive CWIS modification, increase costs, and potentially impact station reliability. For the purposes of this evaluation, fine-mesh through-flow traveling water screens were evaluated for installation.

Fine-slot wedgewire screens are stationary passive screens that are typically designed to maintain through-slot velocities of less than 0.5 fps. These are metallic screens that are commonly cylindrical in shape (Figure 10-17), although several other shapes are available.

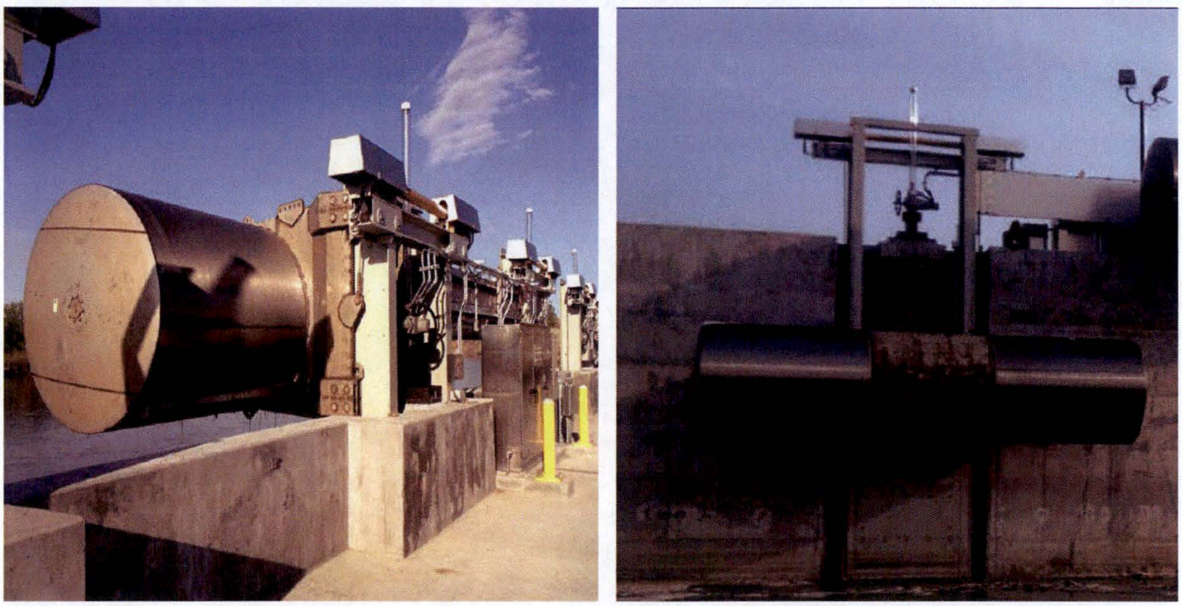

Figure 10-17. Cylindrical Wedgewire Screens (Shown Out of Water) (ISI 2016)

Both traveling water screens and wedgewire screens can utilize coarse mesh (> 2.0-mm) or fine mesh (≤ 2.0-mm). The Rule requires the evaluation of fine-mesh and fine-slot screens as potential entrainment reduction technologies. Section 10.4.3 evaluates the feasibility of installing fine-mesh traveling water screens at Oconee. Section 10.4.4 evaluates the feasibility of installing fine-slot wedgewire screens at Oconee.

10.4.3 Fine-mesh Traveling Water Screens

Fine-mesh traveling water screens provide protection from debris and aquatic organisms for pumps and condensers (USEPA 2014). These types of screens span the water column from the bottom elevation to greater than the high water elevation of the waterbody to avoid screen overtopping. Typically, screen panels are attached to a belt system and travel in a loop. The screen panels travel upward on the upstream side and travel downward on the downstream side. As the screen panels breach the water surface at the top of the screen, a high-pressure wash system sprays the screen panels to remove debris[60]. The debris is typically collected in a debris trough for disposal. Screens designed only for debris removal are typically operated on an intermittent basis to avoid screen wear and tear, and to reduce maintenance costs (USEPA 2014).

Traveling water screens modified for IM reduction are known as modified-Ristroph traveling water screens, and they remove aquatic organisms trapped against the screen and return them to the receiving waterbody (USEPA 2014). These screens are equipped with screen baskets and a dual-spray wash system to remove impinged organisms from the screen. The screen baskets on modified-Ristroph screens hold water and include a lip to reduce turbulence as the screen panel travels (Figure 10-16). Modified-Ristroph screens are required by the USEPA to rotate continuously or nearly continuously for the protection of aquatic organisms. The dual-spray wash system includes the use of a low-pressure spray wash for the gentle removal or aquatic organisms followed by the use of a high-pressure spray wash for debris removal. Aquatic organisms are returned to a suitable area in the receiving waterbody by an aquatic organism return system (USEPA 2014).

Studies of modified-Ristroph coarse-mesh traveling water screens have documented improvements in the survival of impinged organisms compared to stationary coarse-mesh screens. Available literature and experience indicate that the efficacy of modified-Ristroph fine-mesh traveling water screens is site- and screen-specific (USEPA 2014).

The Rule at §122.21(r)(10)(i) requires an evaluation of the technical feasibility and cost of fine-mesh and fine-slot screens with a mesh or slot size of 2.0 mm or smaller. The following approach was used to assess entrainment at Oconee to determine which mesh size(s) should be evaluated as a part of the analyses required in §122.21(r)(10)-(12):

1. Engage screen manufacturers to discuss commercially available FMS mesh and slot sizes, wire widths, and other design features to facilitate TSV and headloss calculations;
2. Evaluate the technical feasibility of potential mesh and slot sizes by comparing TSV, headloss, operational constraints, and other site-specific engineering factors;
3. Evaluate site-specific entrainment as discussed in Appendix 9-A; and
4. Use BPJ to select an appropriate mesh or slot size(s) for advancement in evaluations conducted in §122.21(r)(10)-(12).

10.4.3.1 Through-screen Velocity and Headloss

FMS use higher gauge (thinner) wire than coarse-mesh screens; therefore fine mesh is not as strong as coarse mesh, and a backing (approximately 1-inch square) is typically used for support. In some cases, facilities overlay fine mesh on existing coarse mesh for support. As the mesh size gets smaller, the percentage of screen open area available for water flow also gets smaller, and TSV increases, unless the total screen area at the CWIS is increased.

[60] Screens designed for aquatic organism protection also include low-pressure sprays, which remove impinged organisms into an aquatic organism return trough prior to the high-pressure spray wash, which removes debris into the debris trough.

A retrofit of existing coarse-mesh screens with FMS impacts screen performance and efficacy in two key ways:

1. It increases TSV, the velocity that larvae and juveniles would need to swim away from, and the velocity with which organisms would collide with the mesh. Exclusion and TSV both impact organism survival, and the selection of the fine mesh size needs to strike a balance between the rate of exclusion and increased mortality due to increased TSV; and
2. It increases headloss across the screens. Screens are typically designed to withstand a maximum headloss of approximately 5 to 10 ft (Argonne National Laboratory 1979). If headloss across the screens increases beyond the rated maximum value, the screens could experience damage and/or collapse. In addition, increased headloss could impact pump performance, and potentially cause pump cavitation, damage, and/or pump failure.

Figure 10-18 provides empirical relationships between TSV and headloss based on screen manufacturer data for various mesh sizes (US Filter 2016).

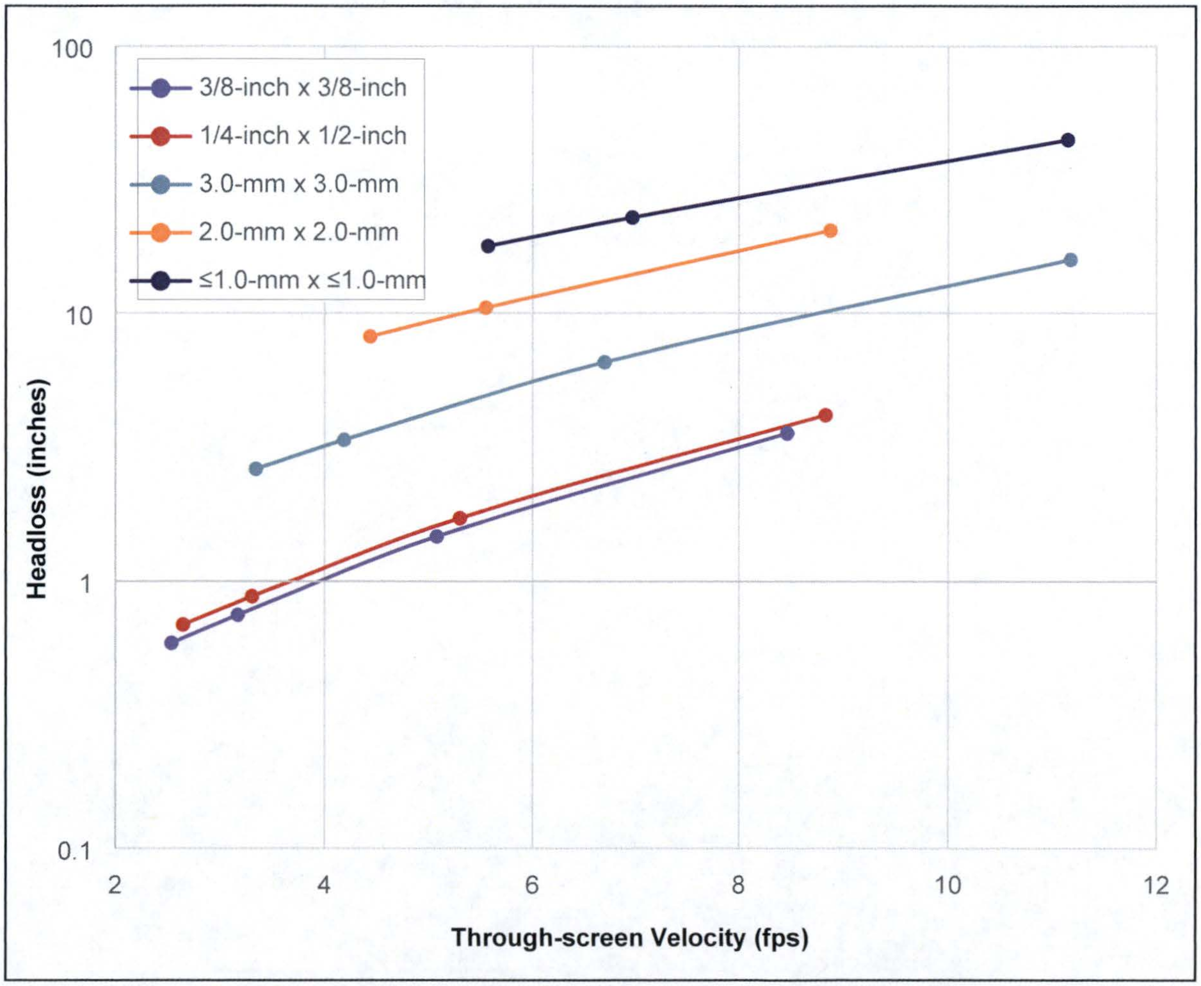

Figure 10-18. Through-screen Velocity and Headloss Curves (US Filter 2016)

10.4.3.2 Mesh Size Selection

1.0-mm fine mesh was selected for further evaluation at Oconee after analyzing the likely entrainment reduction performance of a range of screen mesh sizes (0.5, 0.75, 1.0, and 2.0-mm), as described in Appendix 10-E. The 1.0-mm mesh was determined to be potentially feasible based on expected TSV, headloss, site-specific debris loading conditions, and entrainment reduction efficacy. Table 10-11 provides estimated TSV and headloss under various levels of screen clogging for the hypothetical retrofit of the existing coarse-mesh screens with 1.0-mm FMS, the hypothetical installation of 1.0-mm FMS within a new CWIS, and the existing 3/8-inch coarse-mesh screens at Oconee. Engineering calculations of TSV and headloss for the hypothetical 1.0-mm FMS retrofit and the hypothetical 1.0-mm FMS in a new CWIS at Oconee are provided in Appendix 10-F and Appendix 10-G, respectively.

The design TSV for a hypothetical 1.0-mm FMS retrofit at the 50 percent screen clogging scenario is approximately 7.3 fps, with a headloss of approximately 24.1 inches. The design TSV for a hypothetical new CWIS with FMS at the 50 percent screen clogging scenario is approximately 2.9 fps, with a headloss of approximately 11.3 inches. For reference, the TSV for the existing coarse-mesh screens at the 50 percent screen clogging scenario is approximately 5.8 fps, with a headloss of approximately 1.8 inches.

Table 10-11. Comparison of Through-screen Velocity and Headloss for Hypothetical 1.0-mm Fine-mesh Screens and Existing Coarse-mesh Screens at Oconee Nuclear Station

Mesh Size	Support Backing	Clogging (%)	Effective Open Area (%)	Design Value	
				TSV (fps)	Headloss (inches)
1.0-mm FMS Retrofit[61]	1-inch	0	45	3.6	12.7
		15	38	4.3	14.2
		50	22	7.3	24.1
1.0-mm FMS in New CWIS[62]	1-inch	0	45	1.4	9.5
		15	38	1.7	9.8
		50	22	2.9	11.3
Existing 3/8-inch Coarse Mesh[63]	None	0	56	2.9	0.7
		15	48	3.4	0.8
		50	28	5.8	1.8

10.4.3.3 Hypothetical FMS Implementation Options

FMS could be implemented at Oconee in multiple ways, including the following:

[61] Due to a piping restriction at Oconee, the CCW pump flow per unit varies based on the number of pumps operating and the number of screens operating. It is assumed that flow is distributed equally among the operating screens. TSV for 1.0-mm FMS is presented under one-pump operation, which is the most conservative scenario. Screen

1. The retrofit of the existing coarse-mesh screen panels with new 1.0-mm FMS units, and the installation of a new aquatic organism return system;
2. The installation of 1.0-mm FMS overlays on the existing coarse-mesh screen panels on a permanent or seasonal basis; and
3. The installation of 1.0-mm FMS in a newly-constructed CWIS to facilitate lower TSV and headloss than what could be achieved in a 1.0-mm FMS retrofit in the existing CWIS, and the installation of an aquatic organism return system.

These options are discussed in more detail below.

Retrofit Existing Coarse-mesh Screen Panels with New 1.0-mm FMS Units

This FMS implementation option assumes that the existing 3/8-inch coarse-mesh fixed-panel screens would be replaced with new 1.0-mm FMS units, and a new aquatic organism return system would be constructed to safely route organisms from the new FMS units to a receiving waterbody. Because the existing screens are fixed-panel, and not traveling water screens, extensive modification or reconstruction of the existing CWIS could be required to create space for the new FMS units. Each FMS panel in the new units would include an organism collection basket, and the screens would be rotated continuously. New screen motors and drivers would be installed. A low-pressure spray wash system, including new headers and pumps, would be installed to gently wash aquatic organisms into the aquatic organism return system. A high-pressure spray wash system, including new headers and pumps, would be installed to remove debris. In total, 24 coarse-mesh fixed-panel screens (eight per unit) would be replaced with new 1.0-mm FMS units at Oconee.

1.0-mm FMS Overlay on Existing Screen Panels

This FMS implementation option assumes that new 1.0-mm FMS panels would be attached to the existing coarse-mesh screen panels, and the coarse-mesh screens would function as the necessary support backing for the FMS. The FMS panels could be attached on a permanent or seasonal basis. On a seasonal basis, the overlays would be installed prior to the entrainment season and removed afterwards. A 1.0-mm FMS overlay would have greater TSV and headloss impacts because the TSV through the "composite" mesh would be greater than the TSV through FMS with the standard 1-inch square backing. Because the existing screens at Oconee are fixed-panel and not traveling water screens, an FMS overlay would not be an effective option for impingement mortality or entrainment reduction unless the screens were reconstructed to include traveling aquatic organism baskets, a low-pressure and high-pressure spray wash systems, and an aquatic organism return system. In

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area available to flow is impacted by the presence of the overhang at the CWIS. Cooling water is withdrawn from the bottom of the overhang elevation (781.0 ft msl) to the bottom of the CWIS elevation (761.0 ft msl).

[62] The intake bays within the new CWIS at Oconee would be hydraulically connected, and it is assumed that flow would be distributed equally among all screens. TSV for 1.0-mm FMS in a new CWIS is presented under four-pump operation and maximum drawdown elevation for Lake Keowee, which is the most conservative scenario.

[63] Due to a piping restriction at Oconee, the CCW pump flow per unit varies based on the number of pumps operating and the number of screens operating. It is assumed that flow is distributed equally among operating screens. TSV for the existing 3/8-inch coarse-mesh screens is presented under one-pump operation, which is the most conservative scenario. Screen area available to flow is impacted by the presence of the overhang at the CWIS. Cooling water is withdrawn from the bottom of the overhang elevation (781.0 ft msl) to the bottom of the CWIS elevation (761.0 ft msl).

total, 1.0-mm FMS overlays would be installed on the 24 existing coarse-mesh fixed-panel screens at Oconee (eight per unit).

Installation of 1.0-mm FMS Units in a New CWIS

This FMS implementation option assumes that new 1.0-mm FMS units would be installed in a newly-constructed CWIS in the Oconee intake canal, upstream of the existing CWIS, and a new aquatic organism return system would be installed to safely route organisms from the new FMS units to a receiving waterbody. The purpose of the new CWIS would be to facilitate the installation of more FMS units than what would be able to be installed in the existing CWIS. This would increase the total screen area available to receive flow, and would decrease TSV and headloss when compared to the FMS retrofit option discussed previously. Lower TSV and headloss would help to increase FMS efficacy, and would alleviate potential engineering design concerns associated with high TSV and headloss. Construction of a new CWIS would require significant civil work and earthwork, and would result in disturbances to the intake canal and Lake Keowee. In total, 30 1.0-mm FMS units (10 per unit) would be installed in the new CWIS at Oconee. The existing coarse-mesh fixed-panel screens would remain in place to provide additional debris protection for the pumps and condensers.

10.4.3.4 Aquatic Organism Return System

A system to remove aquatic organisms from the FMS and return them to the waterbody unharmed is integral to the operation of a modified-Ristroph FMS system. The screen spray wash system would require approximately 468 gpm per screen, and another 192 gpm in total would be required as trough make-up water (Evoqua Water Technologies 2019a)[64]. The aquatic organism return system would be designed to convey approximately 6,000 gpm of water[65], and would be constructed of smooth high-density polyethylene with heat tracing to prevent freezing. The aquatic organism return system piping would be above grade.

The aquatic organism return system would begin at the CWIS and terminate in one of three potential location options (shown on Figure 10-19):

1. Option A: the aquatic organism return system would be built to travel west from the CWIS to its terminus in a cove in Lake Keowee. The terminus of Option A would be a sufficient distance from the intake canal to avoid organism re-impingement in the CWIS. Challenges associated with Option A include constructing and operating the aquatic organism return system in the close proximity of station infrastructure and across a public roadway, and designing a feasible above-grade gravity pipe system for this location, which may not be possible due to site topographic constraints.

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[64] Per Evoqua Water Technologies (2019a), each screen would require 221 gpm at 80 psi for the high-pressure spray wash system, 176 gpm at 15 psi for the low-pressure spray wash system, and 70 gpm at 7 psi for the auxiliary low-pressure spray wash system. An additional 192 gpm would be required to maintain flowing water in the aquatic organism return trough; this flow is common to all screens that discharge to the trough.

[65] This assumes that half of the screen wash water would be routed to the aquatic organism return system, and the other half would wash into the intake bays. The additional trough make-up water would continuously feed the aquatic organism return system. If a new CWIS with FMS was chosen as the entrainment BTA compliance option, the aquatic organism return system would be designed to convey approximately 7,500 gpm.

2. Option B: the aquatic organism return system would be built to travel northeast from the CWIS to its terminus in Lake Keowee northeast of the existing discharge canal. The terminus of Option B would be a sufficient distance from the discharge canal to avoid any thermal impacts to organisms, however, returned organisms might be susceptible to subsequent impingement or entrainment at the nearby Keowee hydroelectric power plant. Challenges associated with Option B (similar to Option A) include constructing and operating the aquatic organism return system in the close proximity of station infrastructure, and designing a feasible above-grade gravity pipe system for this location.

3. Option C: the aquatic organism return system would be built to travel northeast from the CWIS to its terminus in the Keowee River. Challenges associated with Option C include releasing organisms to a different waterbody than Oconee's source waterbody, which could present biological concerns and permitting issues, constructing and operating the aquatic organism return system in the close proximity of station infrastructure and across a station roadway, and designing a feasible above-grade gravity pipe system for this location.

For costing purposes, it is assumed that Option B would be utilized for the aquatic organism return system at Oconee.

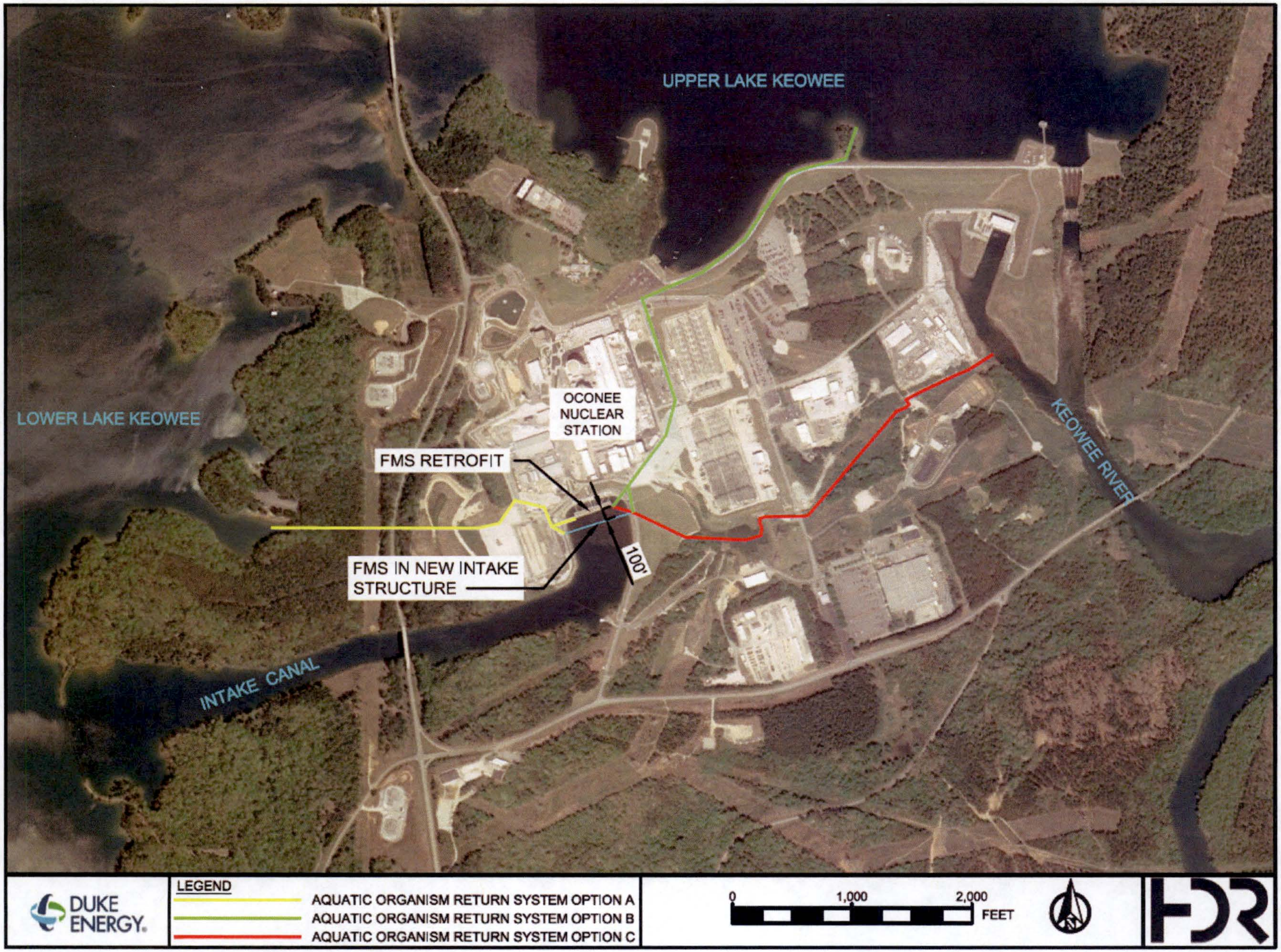

Figure 10-19. Plan View of Hypothetical Fine-mesh Screen Implementation at Oconee Nuclear Station

10.4.3.5 Retrofit Existing Coarse-mesh Screen Panels with New 1.0-mm FMS Units

Of the three hypothetical FMS implementation options discussed in Section 10.4.3.3, two are considered the most practicable at Oconee: the retrofit of the existing coarse-mesh screen panels with new 1.0-mm FMS units with the installation of an aquatic organism return system, and the installation of 1.0-mm FMS in a newly-constructed CWIS with the installation of an aquatic organism return system. The hypothetical retrofit of the existing coarse-mesh screen panels with new 1.0-mm FMS units will be discussed in this section. The installation of 1.0-mm FMS units in a newly-constructed CWIS will be discussed in Section 10.4.3.6.

Feasibility Discussion (§122.21(r)(10)(i)(D))

The key construction-related challenges related to the hypothetical retrofit of 1.0-mm FMS in the existing CWIS and the installation of a new aquatic organism return system at Oconee include the following:

1. The installation of fine-mesh traveling water screens with debris and organism collection systems in the existing fixed-panel screen slots could require significant modification, reconstruction, and demolition within the existing CWIS using heavy equipment;
2. Removal of the existing screens could be difficult depending on screen condition and accessibility within the existing CWIS;
3. The construction outage for this retrofit is expected to be approximately 2 months in total for each unit, and would include a regularly scheduled unit outage (approximately 1 month) to reduce replacement energy costs. However, Oconee is a large baseload station, and the replacement energy costs would be very significant; and
4. The aquatic organism return system would be lengthy (e.g., at least 2,800 ft)[66], and would require construction and operation in the close proximity of station infrastructure. There is the potential the aquatic organism return system would be required to cross roadways (public or private). The design of a feasible pipe system that would be above grade and gravity-fed would be challenging. The potential suitability of terminating the aquatic organism return system in a different waterbody than Oconee's source waterbody (Keowee River) would require further evaluation.

The key operations-related challenges related to the hypothetical retrofit of 1.0-mm FMS in the existing CWIS and the installation of a new aquatic organism return system at Oconee include the following:

1. The FMS retrofit would cause significant increases to TSV and headloss across the screens, which would impact the performance of the existing CCW pumps, and could potentially cause pump cavitation, damage, or failure. This could significantly impact station reliability, availability of cooling flow, and nuclear safety at Oconee, as well as the overall entrainment reduction efficacy of the FMS system;

[66] The aquatic organism return system length for Options A, B, and C, as shown on Figure 10-19, would be approximately 2,800 ft, 4,400 ft, and 4,000 ft, respectively.

2. The FMS retrofit would cause an increase in the annual energy consumption at the station due to the new screen motors and pumps, the continuous rotation of the FMS, and the impacts of increased headloss on the existing CCW pumps;
3. The likelihood of screen clogging or biofouling would increase due to the FMS retrofit, and could have significant impacts on station reliability, availability of cooling flow, and nuclear safety at Oconee; and
4. The FMS retrofit would require increased maintenance due to the continuous operation of the screens, pumps, and motors.

Overall, the hypothetical retrofit of the existing coarse-mesh screen panels with new 1.0-mm FMS units at Oconee is considered technically feasible. However, due to the construction and operational challenges detailed previously, including the potential impacts to nuclear safety due to increased TSV and headloss, the implementation of this technology is considered impractical. If a 1.0-mm FMS retrofit within the existing CWIS was determined to be BTA for entrainment reduction at Oconee, additional evaluations would be performed to confirm feasibility, particularly related to debris loading, existing CCW pump hydraulics, and nuclear safety.

Pursuant to Rule requirements, the following sections will evaluate the permitting requirements, implementation schedule, and costs of a hypothetical 1.0-mm FMS retrofit within the existing CWIS at Oconee.

Permitting Requirements

A 1.0-mm FMS retrofit within the existing CWIS at Oconee would require federal, state, and local permits, potentially including the following:

1. SCDHEC NPDES permit modification prior to commissioning new equipment;
2. USACE and FERC approvals for construction at the existing CWIS and construction of the aquatic organism return system; and
3. Local and state construction permits.

Implementation Schedule

An implementation schedule for the hypothetical 1.0-mm FMS retrofit within the existing CWIS at Oconee is provided in Table 10-12. It is assumed the FMS construction outage would be approximately 2 months in total for each unit and would include a regularly scheduled unit maintenance outage (approximately 1 month) to help reduce replacement energy costs. The anticipated commissioning of FMS would be in 2024, 2025, and 2026 for Units 1, 2, and 3 respectively.

Table 10-12. Implementation Schedule for the Hypothetical 1.0-mm FMS Retrofit within the Existing CWIS at Oconee Nuclear Station

Task Start Date	Task End Date	Project Year (Task End Date)	Implementation Task
-	December 2020	0	Submit §316(b) Information
December 2020	December 2021	1	Final BTA Determination
December 2021	June 2022	1.5	Site Investigations; Engineering Contract; Design; Permitting
June 2022	December 2022	2	
December 2022	March 2023	2.25	Select Contractor
March 2023	June 2023	2.5	General Conditions; Demolition
June 2023	December 2023	3	Install Aquatic Organism and Debris Return Systems; Procurement of Unit 1 Screens
December 2023	June 2024	3.5	
June 2024	December 2024	4	Installation and Testing of Unit 1 Screens; Procurement of Unit 2 Screens
December 2024	June 2025	4.5	
June 2025	December 2025	5	Installation and Testing of Unit 2 Screens; Procurement of Unit 3 Screens
December 2025	June 2026	5.5	Installation and Testing of Unit 3 Screens
June 2026	December 2026	6	Screen Optimization
December 2026	June 2027	6.5	
June 2027	December 2027	7	
December 2027	June 2028	7.5	

Costs (§122.21(r)(10)(iii))

CAPITAL COSTS

The capital costs of the hypothetical 1.0-mm FMS retrofit within the existing CWIS and the installation of an aquatic organism return system at Oconee (Appendix 10-H), based on an AACE Class 4 estimate, would be approximately $65.6 M in 2019 dollars. Capital costs are detailed in Table 10-13. The capital cost estimate includes the following components:

- Demolition costs;
- Civil/site work costs, including the construction of the aquatic organism return system;
- Mechanical costs, including the installation of eight 1.0-mm modified-Ristroph FMS per unit and new screen wash headers and pumps;
- Structural costs;

- Electrical and instrumentation and controls (I&C) costs;
- Construction indirect costs, including contractor site supervision, general conditions, and general administrative costs and profit;
- Two years of technology performance optimization studies, including biological monitoring (required for IM compliance);
- Design engineering costs at 10 percent of the construction direct costs;
- Project management costs at 10 percent of the design engineering costs;
- Owner's costs; and
- Contingency.

Table 10-13. Capital Costs for the Hypothetical 1.0-mm FMS Retrofit within the Existing CWIS at Oconee Nuclear Station

Capital Cost Component	Cost (2019 $Millions)
Construction Direct Costs	
Demolition	$1.4
Civil / Site Work	$7.5
Mechanical	$20.9
Structural	$1.5
Electrical and I&C	$4.2
Subtotal Direct Costs	$35.4
Construction Indirect Costs	
Contractor Site Supervision	$0.5
General Conditions	$3.0
General Administrative Costs & Profit	$5.8
Subtotal Indirect Costs	$9.4
Total Construction Cost	$44.8
Design Engineering	$3.5
Project Management	$0.4
Owner's Costs	$4.8
Contingency	$12.2
TOTAL	**$65.6**

ANNUAL O&M COSTS

Annual O&M costs for a hypothetical 1.0-mm FMS retrofit within the existing CWIS and installation of an aquatic organism return system at Oconee are estimated to be approximately $1.9 million (in 2019 dollars) (Table 10-14), assuming that:

- On average, 4 full-time equivalent staff would provide maintenance for the screens, motors, pumps, and aquatic organism return system;
- Annual parts repair and replacement would be approximately 6 percent of mechanical equipment capital costs; and
- No additional chemicals would be required.

Table 10-14. Annual O&M Costs for the Hypothetical 1.0-mm FMS Retrofit within the Existing CWIS at Oconee Nuclear Station

Annual O&M Cost Component	Cost (2019 $Millions)
Labor	$0.7
Parts Repair and Replacement	$1.2
TOTAL	**$1.9**

Environmental Mitigation Costs (From §122.21(r)(12))

There are no significant environmental mitigation measures associated with this technology.

Station-Level Compliance Cost (Annual and Present Value)

Per the technology implementation schedule presented in Table 10-12, the Unit 1 FMS and aquatic organism return system would be operational in 2024, the Unit 2 FMS would be operational in 2025, and the Unit 3 FMS would be operational in 2026. Table 10-15 overlays the estimated 1.0-mm FMS retrofit capital costs on the technology implementation schedule. Table 10-16 provides annual O&M costs for the operational period of the FMS.

Table 10-15. Capital Cost Outlay for the Hypothetical 1.0-mm FMS Retrofit within the Existing CWIS at Oconee Nuclear Station

Task Start Date	Task End Date	Project Year (Task End Date)	Implementation Task	Cost in 2019 ($Millions)	Cost in Given Year ($Millions)	Present Value in 2019 ($Millions)
-	December 2020	0	Submit §316(b) Information	$-	$-	$-
December 2020	December 2021	1	Final BTA Determination	$-	$-	$-
December 2021	June 2022	1.5	Site Investigations; Engineering Contract; Design; Permitting	$3.9	$4.2	$3.5
June 2022	December 2022	2		$3.9	$4.2	$3.5
December 2022	March 2023	2.25	Select Contractor	$0.7	$0.7	$0.6
March 2023	June 2023	2.5	General Conditions; Demolition	$2.6	$2.9	$2.2
June 2023	December 2023	3	Install Aquatic Organism and Debris Return Systems; Procurement of Unit 1 Screens	$13.1	$14.5	$11.2
December 2023	June 2024	3.5		$8.2	$9.3	$6.7
June 2024	December 2024	4	Installation and Testing of Unit 1 Screens; Procurement of Unit 2 Screens	$7.2	$8.2	$5.9
December 2024	June 2025	4.5		$3.3	$3.8	$2.6
June 2025	December 2025	5	Installation and Testing of Unit 2 Screens; Procurement of Unit 3 Screens	$10.5	$12.2	$8.2
December 2025	June 2026	5.5	Installation and Testing of Unit 3 Screens	$6.9	$8.2	$5.2
June 2026	December 2026	6	Screen Optimization	$1.3	$1.6	$1.0
December 2026	June 2027	6.5		$1.3	$1.6	$0.9
June 2027	December 2027	7		$1.3	$1.6	$0.9
December 2027	June 2028	7.5		$1.3	$1.6	$0.9

Table 10-16. Annual O&M Cost Outlay for the Hypothetical 1.0-mm FMS Retrofit within the Existing CWIS at Oconee Nuclear Station

Year[67]	Cost in 2019 ($Millions)			Cost in Given Year ($Millions)			Present Value in 2019 ($Millions)		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
2024	$0.05	$-	$-	$0.06	$-	$-	$0.04	$-	$-
2025	$0.6	$0.05	$-	$0.7	$0.06	$-	$0.5	$0.04	$-
2026	$0.6	$0.6	$0.4	$0.7	$0.7	$0.4	$0.5	$0.5	$0.3
2027	$0.6	$0.6	$0.6	$0.8	$0.8	$0.8	$0.5	$0.5	$0.5
2028	$0.6	$0.6	$0.6	$0.8	$0.8	$0.8	$0.4	$0.4	$0.4
2029	$0.6	$0.6	$0.6	$0.8	$0.8	$0.8	$0.4	$0.4	$0.4
2030	$0.6	$0.6	$0.6	$0.8	$0.8	$0.8	$0.4	$0.4	$0.4
2031	$0.6	$0.6	$0.6	$0.8	$0.8	$0.8	$0.4	$0.4	$0.4
2032	$0.6	$0.6	$0.6	$0.9	$0.9	$0.9	$0.4	$0.4	$0.4
2033	$0.6	$0.6	$0.6	$0.9	$0.9	$0.9	$0.4	$0.4	$0.4
2034	$-	$-	$0.6	$-	$-	$0.9	$-	$-	$0.3

[67] This evaluation was performed assuming Units 1 and 2 will retire in 2033, and Unit 3 will retire in 2034 in accordance with Oconee's current renewed operating license.

Uncertainty

Key uncertainties associated with the hypothetical 1.0-mm FMS retrofit within the existing CWIS and installation of an aquatic organism return system at Oconee include the following:

1. Equipment sizes, lengths, and capacities were based on preliminary design for this evaluation. Actual equipment and associated costs and impacts would be refined during detailed design if this option were selected for further BTA evaluation;
2. This evaluation assumed that a 2-month construction outage would be required for each unit, which would incorporate regularly-scheduled unit maintenance outages to help reduce replacement energy costs. The actual construction outage could differ from what was assumed in this evaluation;
3. Debris loading studies and hydraulic evaluations would be performed to quantify potential impacts of 1.0-mm FMS on the existing CCW pump performance if this option were selected for further BTA evaluation. Additionally, the TSV for 1.0-mm FMS would be much greater than the existing 3/8-inch coarse mesh screens and significantly higher than the vendor recommended 1.5 fps guidance;
4. This evaluation assumed the existing CWIS and screens would be accessible to heavy equipment for the necessary construction and screen removal in the existing CWIS; and
5. This evaluation assumed an aquatic organism return system of at least 2,800 ft in length would be feasible for construction, including in the close proximity of station infrastructure and private and public roadways.

10.4.3.6 Installation of 1.0-mm FMS Units in a New CWIS

Of the three hypothetical FMS implementation options discussed in Section 10.4.3.3, two are considered the most practicable at Oconee: the retrofit of the existing coarse-mesh screen panels with new 1.0-mm FMS units with the installation of an aquatic organism return system, and the installation of 1.0-mm FMS in a newly-constructed CWIS with the installation of an aquatic organism return system. The installation of 1.0-mm FMS units in a newly-constructed CWIS will be discussed in this section. The hypothetical retrofit of the existing coarse-mesh screen panels with new 1.0-mm FMS units is discussed in Section 10.4.3.5.

Feasibility Discussion (§122.21(r)(10)(i)(D))

The key construction-related challenges related to the hypothetical installation of 1.0-mm FMS in a newly-constructed CWIS and a new aquatic organism return system at Oconee include the following:

1. Construction of the new CWIS would require extensive civil work and earthwork, and would cause significant disturbance to the intake canal at Oconee. While it is assumed that the new CWIS could be constructed while the station is operating, it would be a large construction and permitting effort requiring extensive coordination to maintain existing station operations; and

2. The aquatic organism return system would be lengthy (e.g., at least 2,800 ft)[68], and would require construction and operation in the close proximity of station infrastructure. There is the potential the aquatic organism return system would be required to cross roadways (public or private). The design of a feasible pipe system that would be above grade and gravity-fed would be challenging. The potential suitability of terminating the aquatic organism return system in a different waterbody than Oconee's source waterbody (Keowee River) would require further evaluation.

The key operations-related challenges of the hypothetical installation of 1.0-mm FMS in a newly-constructed CWIS and a new aquatic organism return system at Oconee include the following:

1. The installation of 1.0-mm FMS in a new CWIS would result in higher headloss across the screens[69], which would impact the performance of the existing CCW pumps, and could potentially cause pump cavitation, damage, or failure. This could significantly impact station reliability, availability of cooling flow, and nuclear safety at Oconee, as well as the overall entrainment reduction efficacy of the FMS system;
2. The FMS installation would cause an increase in the annual energy consumption at the station due to the new screen motors and pumps, the continuous rotation of the FMS, and the impacts of increased headloss on the existing CCW pumps;
3. The likelihood of screen clogging or biofouling would increase due to the FMS installation, and could have significant impacts on station reliability, availability of cooling flow, and nuclear safety at Oconee; and
4. The FMS installation in a new CWIS would require increased maintenance due to the continuous operation of the screens, pumps, and motors.

Overall, the hypothetical installation of 1.0-mm FMS units in a new CWIS and a new aquatic organism return system at Oconee is considered technically feasible. However, due to the construction and operational challenges detailed previously, the implementation of this technology is considered impractical. If the installation of 1.0-mm FMS units in a new CWIS was determined to be BTA for entrainment reduction at Oconee, additional evaluations would be performed to confirm feasibility, particularly related to debris loading, existing CCW pump hydraulics, and nuclear safety.

Pursuant to Rule requirements, the following sections will evaluate the permitting requirements, implementation schedule, and costs of the hypothetical installation of 1.0-mm FMS units in a new CWIS at Oconee.

Permitting Requirements

The hypothetical installation of 1.0-mm FMS units in a new CWIS and a new aquatic organism return system at Oconee would require federal, state, and local permits, potentially including the following:

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[68] The aquatic organism return system length for Options A, B, and C, as shown on Figure 10-19, would be approximately 2,800 ft, 4,400 ft, and 4,000 ft, respectively.

[69] The installation of 1.0-mm FMS in a new CWIS would result in lower headloss across the screens compared to retrofitting the existing CWIS with 1.0-mm FMS, and would result in lower TSV when compared to both the existing coarse-mesh screens in the existing CWIS and retrofitting the existing CWIS with 1.0-mm FMS.

1. SCDHEC NPDES permit modification prior to commissioning new equipment;
2. USACE and FERC approval to construct the new CWIS and aquatic organism return system; and
3. Local and state construction permits.

Implementation Schedule

An implementation schedule for the hypothetical installation of 1.0-mm FMS units in a new CWIS and a new aquatic organism return system at Oconee is provided in Table 10-17. It is assumed that a construction outage specific to the new CWIS and FMS installation would not be required at Oconee, and that the new CWIS and FMS system would be constructed during station operations. The anticipated commissioning of the new 1.0-mm FMS units and the aquatic organism return system would be in 2026 for all three units at Oconee.

Table 10-17. Implementation Schedule for the Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Task Start Date	Task End Date	Project Year (Task End Date)	Implementation Task
-	December 2020	0	Submit §316(b) Information
December 2020	December 2021	1	Final BTA Determination
December 2021	June 2022	1.5	Site Investigations; Engineering Contract; Design
June 2022	December 2022	2	
December 2022	June 2023	2.5	Permitting; Select Contractor
June 2023	December 2023	3	General Conditions
December 2023	June 2024	3.5	Install Aquatic Organism and Debris Return Systems; Screen Procurement
June 2024	December 2024	4	
December 2024	June 2025	4.5	New FMS Intake Structure Construction
June 2025	December 2025	5	Screen Installation and Testing
December 2025	June 2026	5.5	
June 2026	December 2026	6	Screen Optimization
December 2026	June 2027	6.5	
June 2027	December 2027	7	
December 2027	June 2028	7.5	

Costs (§122.21(r)(10)(iii))

CAPITAL COSTS

The initial capital cost of constructing and implementing a hypothetical installation of a new CWIS with 1.0-mm modified-Ristroph FMSs and an aquatic organism return system at Oconee (Appendix 10-I, based on an AACE Class 4 estimate, would be approximately $122.2 million if the design, permitting, procurement, construction, installation, and biological optimization were performed in 2019 (Table 10-18). This includes the following components:

- Civil/site work costs, including the construction of the new CWIS and aquatic organism return system;
- Mechanical costs, including the installation of ten 1.0-mm modified-Ristroph FMS per unit and new screen wash headers and pumps;
- Structural costs;
- Electrical and instrumentation and controls (I&C) costs;
- Construction indirect costs, including contractor site supervision, general conditions, and general administrative costs and profit;
- Two years of technology performance optimization studies, including biological monitoring (required for IM compliance);
- Design engineering costs at 10 percent of the construction direct costs;
- Project management costs at 10 percent of the design engineering costs;
- Owner's costs; and
- Contingency.

Table 10-18. Capital Costs for the Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Capital Cost Component	Cost (2019 $Millions)
Construction Direct Costs	
Civil / Site Work	$26.8
Mechanical	$28.1
Structural	$2.6
Electrical and I&C	$5.4
Subtotal Direct Costs	$62.9
Construction Indirect Costs	
Contractor Site Supervision	$1.2
General Conditions	$8.8
General Administrative Costs & Profit	$10.9
Subtotal Indirect Costs	$20.9
Total Construction Cost	$83.8
Design Engineering	$6.3
Project Management	$0.6
Owner's Costs	$8.9
Contingency	$22.7
TOTAL	**$122.2**

ANNUAL O&M COSTS

Annual O&M costs for the hypothetical installation of 1.0-mm FMS units in a new CWIS and a new aquatic organism return system at Oconee are estimated to be approximately $2.3 million (in 2019 dollars) (Table 10-19), assuming that:

- On average, 4 full-time equivalent staff would provide maintenance for the new screens, motors, pumps, and aquatic organism return system;
- Annual parts repair and replacement costs would be approximately 6 percent of mechanical equipment capital costs; and
- No additional chemicals would be required.

Table 10-19. Annual O&M Costs for the Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Annual O&M Cost Component	Cost (2019 $Millions)
Labor	$0.7
Parts Repair and Replacement	$1.6
TOTAL	**$2.3**

Environmental Mitigation Costs (From §122.21(r)(12))

There are no significant environmental mitigation measures associated with this technology.

Station-Level Compliance Cost (Annual and Present Value)

Per the technology implementation schedule presented in Table 10-17, the new 1.0-mm FMS units and aquatic organism return system would be operational in 2026 for all three units. Table 10-20 overlays capital costs associated with the hypothetical installation of 1.0-mm FMS units in a new CWIS on the technology implementation schedule. Table 10-21 provides annual O&M costs for the operational period of the FMS.

Table 10-20. Capital Cost Outlay for the Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Task Start Date	Task End Date	Project Year (Task End Date)	Implementation Task	Cost in 2019 ($Millions)	Cost in Given Year ($Millions)	Present Value in 2019 ($Millions)
-	December 2020	0	Submit §316(b) Information	$-	$-	$-
December 2020	December 2021	1	Final BTA Determination	$-	$-	$-
December 2021	June 2022	1.5	Site Investigations; Engineering Contract; Design	$7.3	$7.9	$6.5
June 2022	December 2022	2		$7.3	$7.9	$6.5
December 2022	June 2023	2.5	Permitting; Select Contractor	$1.2	$1.3	$1.0
June 2023	December 2023	3	General Conditions	$4.9	$5.4	$4.2
December 2023	June 2024	3.5	Install Aquatic Organism and Debris Return Systems; Screen Procurement	$18.3	$20.7	$15.0
June 2024	December 2024	4		$18.3	$20.7	$15.0
December 2024	June 2025	4.5	New FMS Intake Structure Construction	$30.5	$35.4	$23.9
June 2025	December 2025	5	Screen Installation and Testing	$12.2	$14.2	$9.6
December 2025	June 2026	5.5		$12.2	$14.5	$9.2
June 2026	December 2026	6	Screen Optimization	$2.4	$2.9	$1.8
December 2026	June 2027	6.5		$2.4	$3.0	$1.8
June 2027	December 2027	7		$2.4	$3.0	$1.8
December 2027	June 2028	7.5		$2.4	$3.1	$1.7

Table 10-21. Annual O&M Cost Outlay for the Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Year[70]	Cost in 2019 ($Millions)			Cost in Given Year ($Millions)			Present Value in 2019 ($Millions)		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
2026	$0.4	$0.4	$0.4	$0.5	$0.5	$0.5	$0.3	$0.3	$0.3
2027	$0.8	$0.8	$0.8	$0.9	$0.9	$0.9	$0.6	$0.6	$0.6
2028	$0.8	$0.8	$0.8	$1.0	$1.0	$1.0	$0.5	$0.5	$0.5
2029	$0.8	$0.8	$0.8	$1.0	$1.0	$1.0	$0.5	$0.5	$0.5
2030	$0.8	$0.8	$0.8	$1.0	$1.0	$1.0	$0.5	$0.5	$0.5
2031	$0.8	$0.8	$0.8	$1.0	$1.0	$1.0	$0.5	$0.5	$0.5
2032	$0.8	$0.8	$0.8	$1.1	$1.1	$1.1	$0.5	$0.5	$0.5
2033	$0.8	$0.8	$0.8	$1.1	$1.1	$1.1	$0.4	$0.4	$0.4
2034	$-	$-	$0.8	$-	$-	$1.1	$-	$-	$0.4

[70] This evaluation was performed assuming Units 1 and 2 will retire in 2033, and Unit 3 will retire in 2034 in accordance with Oconee's current renewed operating license.

Uncertainty

Key uncertainties associated with the hypothetical installation of 1.0-mm FMS units in a new CWIS and a new aquatic organism return system at Oconee include the following:

1. Equipment sizes, lengths, and capacities were based on preliminary design for this evaluation. Actual equipment and associated costs and impacts would be refined during detailed design if this option were selected for further BTA evaluation;
2. This evaluation assumed that the new CWIS could be constructed during station operations and a construction outage would not be required. The actual construction outage could differ from what was assumed in this evaluation;
3. Debris loading studies and hydraulic evaluations would be performed to quantify potential impacts of 1.0-mm FMS in a new CWIS on the existing CCW pump performance if this option were selected for further BTA evaluation; and
4. This evaluation assumed an aquatic organism return system of at least 2,800 ft in length would be feasible for construction, including in the close proximity of station infrastructure and private and public roadways.

10.4.4 Fine-slot Wedgewire Screens

10.4.4.1 Description of Technology

A wedgewire screen is considered a passive intake technology because the screen is designed to filter water drawn through it as a result of the hydraulic head differential between the waterbody and a wet well from which the CCW pumps take suction. Unlike traveling water screens that must remove organisms that are already withdrawn at the CWIS, wedgewire screens prevent entrainment by excluding organisms from withdrawn water. Thus, wedgewire screens do not require an organism return system.

While mesh openings for conventional traveling water screens are usually square and punched into the screen face or woven using metal wire, wedgewire screens are constructed with wedge-shaped or V-shaped wires welded onto an internal frame. The screens are fabricated using a single continuous wire wrapped around an array of internal support rods in a spiral fashion, producing a strong cage-like structure. The spaces between the wires, referred to as slots, are long openings that run lengthwise along the screen or form a spiral along its axis. The maximum distance between adjacent wires is referred to as the slot size (USEPA 2014). Wedgewire screens can be manufactured with various slot sizes and various cylinder diameters and lengths to accommodate flow requirements while maintaining low TSV. Screens often have a debris deflector on the upstream side of the screen and are typically placed in parallel with the direction of waterbody current (USEPA 2014). The wedgewire screen structure (i.e., wedgewire screens and associated intake piping) is typically submerged in the waterbody (USEPA 2014).

Depending on site-specific conditions, wedgewire screens may be located near the water surface or near the bottom of the waterbody. Submerged structures, such as wedgewire screens, require proper delineation and permitting to minimize interference with activities in the source waterbody (USEPA 2014).

10.4.4.2 Screen Cleaning Systems

Due to the potential for debris accumulation, routine wedgewire screen cleaning is recommended. Screens are often installed with an automated cleaning system. Manual screen cleaning would typically be performed by divers. Two common automated wedgewire screen cleaning systems are air-bursting and mechanical brushing. The air-burst cleaning system includes air compressors, an accumulator (also known as a receiver), controls, a distributor, and air piping that generates a burst of air from within each screen. The force produced by the air-burst system inside the screen dislodges accumulated debris. The mechanical brush cleaning system removes debris while the wedgewire screen is rotated. During a screen rotation, an external fixed brush cleans the outer screen surface, while an internal rotating brush cleans the internal screen surface. Water jets can also be used to remove debris. Automated screen cleanings can actuate on a timer or on pressure differential across the screens[71].

10.4.4.3 Screen Material

Wedgewire screens are typically constructed of stainless steel. Other metals and alloys, such as nickel or copper, can be utilized depending on site-specific requirements to reduce biofouling (USEPA 2014).

10.4.4.4 Sweeping Velocity

Regardless of the screen cleaning method used (manual, air-bursting, mechanical brushing), the flow of water in a source waterbody is critical to effectively move debris and organisms away from the screens. The velocity associated with this flow is referred to as the sweeping velocity, which should be roughly parallel to the screen face. The sweeping velocity creates a "bow wave" at the upstream end of the screen that causes debris and organisms to be diverted away from the screen slots. This diversion is known as hydraulic bypass and can reduce entrainment significantly. In order to maximize debris and organism exclusion, the sweeping velocity should be greater than the TSV and approach velocity. The sweeping velocity has a significant impact on wedgewire screen efficacy, and must be considered during screen design.

10.4.4.5 Wedgewire Screen Types

Tee-style Screens

Tee-style wedgewire screens are cylindrical with an outlet flange on one side. Water flows through the screens on either side of the flange to a wet well or common intake bay. Tee-style screens are installed parallel to flow in the source waterbody to maximize the sweeping velocity. These screens often utilize debris deflectors, which can be installed on one or both ends of the screens. A generalized schematic of a tee-style screen is shown in Figure 10-20.

[71] Improvements in the air-burst cleaning system have largely reduced the use of timed cleaning cycles in favor of pressure differential cleaning cycles (USEPA 2014).

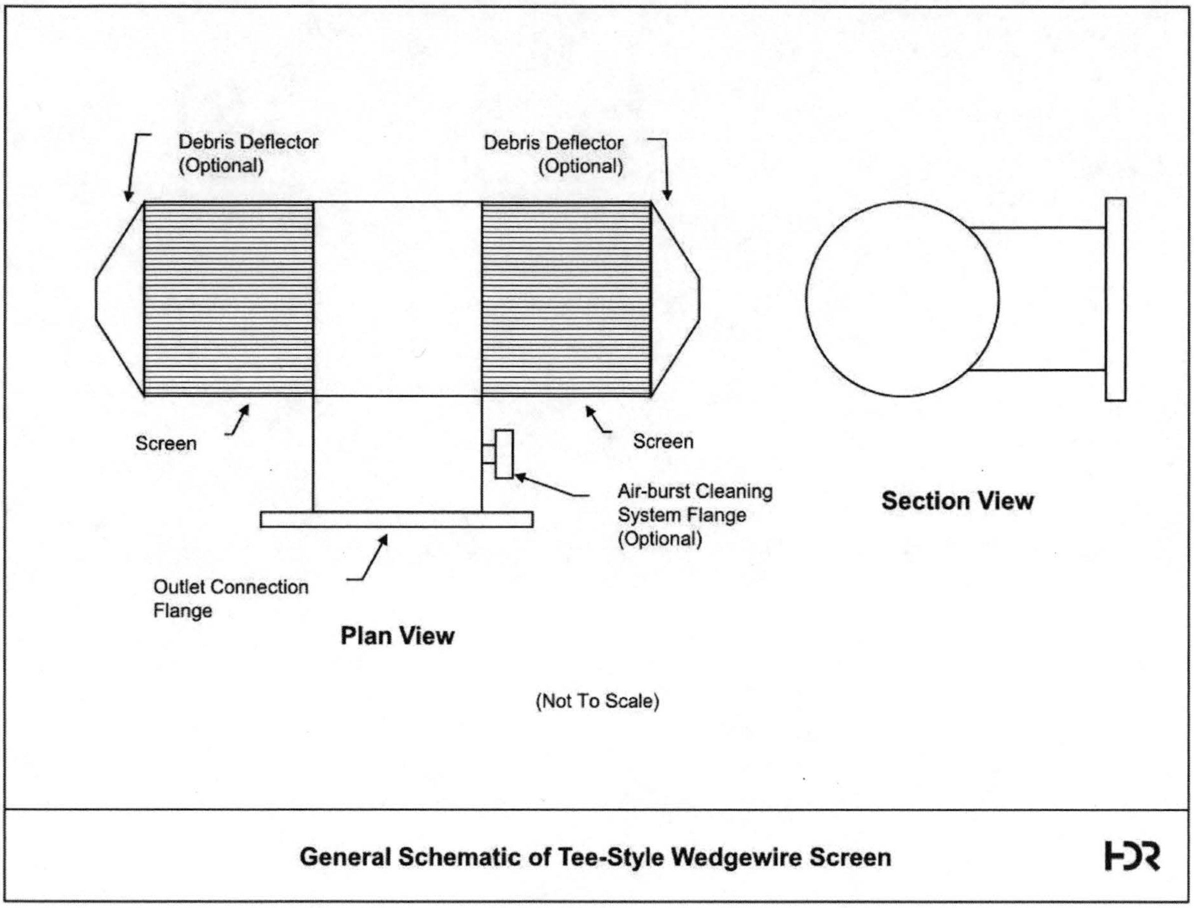
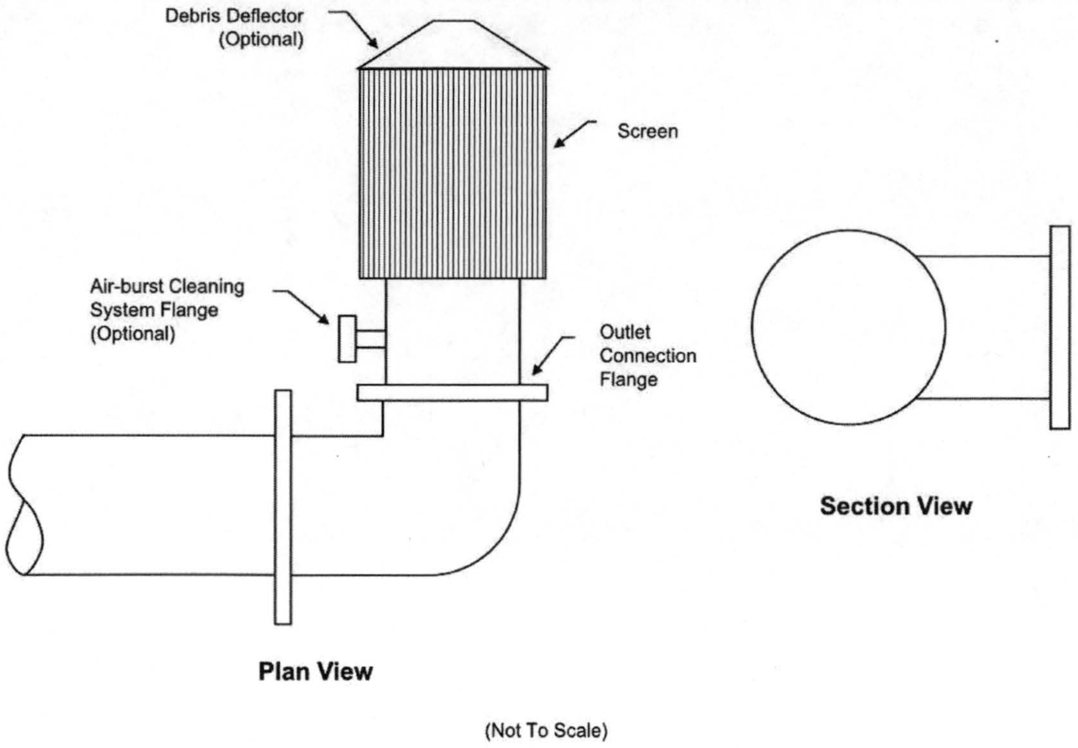


Figure 10-20. General Schematic of a Tee-style Wedgewire Screen

Drum-style Screens

Drum-style wedgewire screens are also cylindrical, with the outlet flange at one end of the cylinder. Drum-style screens are typically larger in diameter than tee-style screens and protrude farther into the waterbody, requiring more water depth to avoid navigational hazards. Drum-style screens can be installed vertically in a waterbody to reduce debris accumulation, and can be utilized in waterbodies with low sweeping velocity. A general schematic of a drum-style wedgewire screen is shown in Figure 10-21.



General Schematic of Drum-Style Wedgewire Screen

Figure 10-21. General Schematic of a Drum-style Wedgewire Screen

Other Screen Types

Half wedgewire screens can operate with less available water depth than standard tee-style and drum-style wedgewire screens, requiring only a half-diameter clearance around the screen (Aqseptence Group 2017). Thus, half wedgewire screens are typically used for shallow water depth applications. Additionally, there are other less common screen types that are available on a design-build basis, with site-specific customization options.

10.4.4.6 Wedgewire Screen Conceptual Design

The Rule requires the evaluation of fine-mesh screens with 2.0-mm or smaller openings for entrainment reduction. FMS or fine-slot screens can reduce entrainment by preventing small organisms, such as eggs and larvae, from entering the cooling system. The slot size is typically selected based on site-specific data regarding the dimensions of entrainable organisms at a facility (USEPA 2014). A slot size of 1.0-mm was selected for evaluation at Oconee.

The number of screens required for a particular design flow rate is inversely proportional to the screen slot size, assuming the same screen diameter and length. The number of screens required is also related to the desired TSV. In the Rule, one of the IM reduction compliance alternatives is maintaining a TSV of less than 0.5 fps. The number of screens required at Oconee was calculated based on this 0.5 fps TSV threshold.

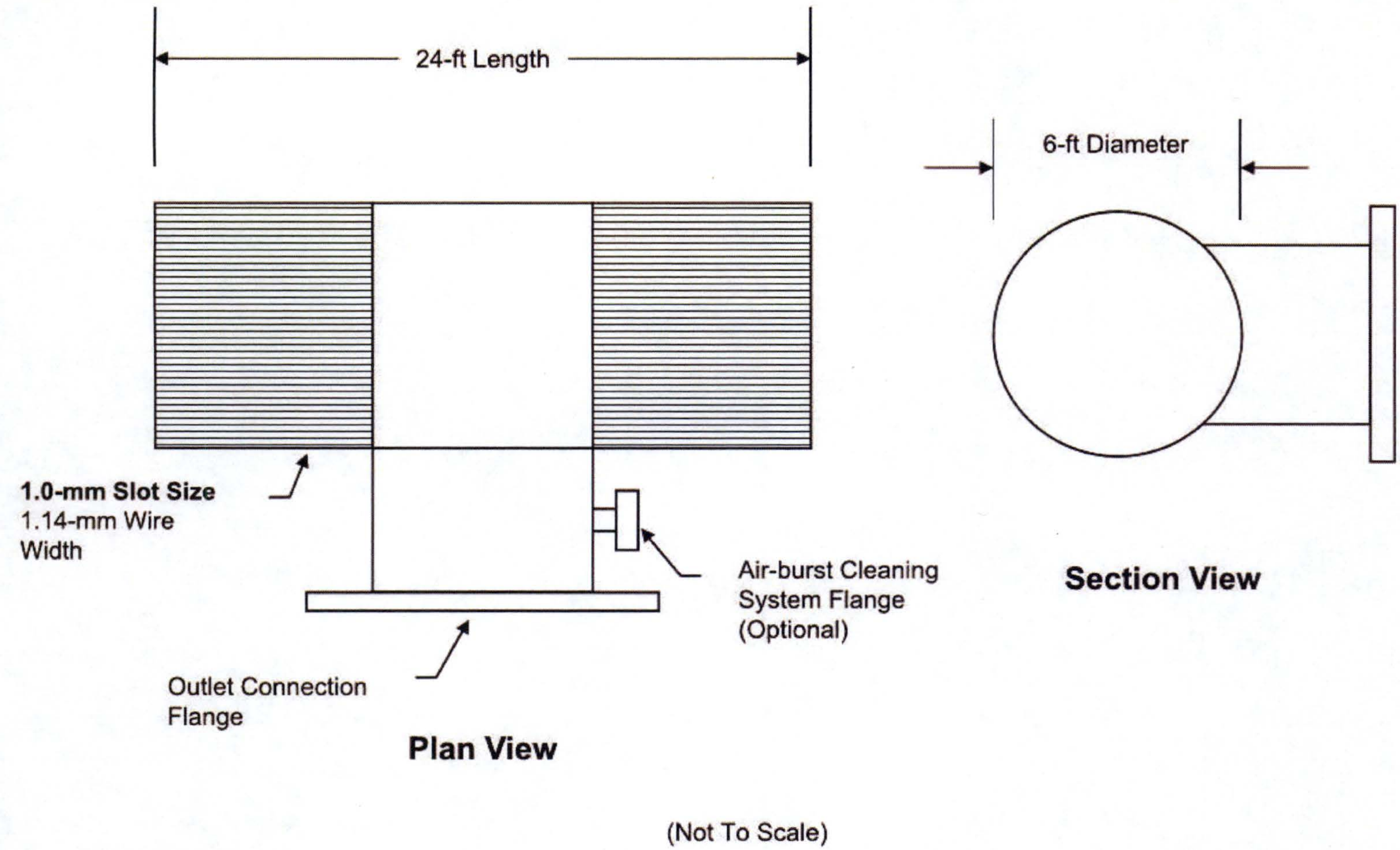
Hypothetical 1.0-mm fine-slot tee-style cylindrical wedgewire screens would be installed within the existing intake canal, in front of the existing CWIS at Oconee. In the vicinity of the CWIS, the intake canal bottom elevation is at El. 760 ft msl, and the water depth under the maximum drawdown elevation is 30 ft. The design criteria for the hypothetical 1.0-mm fine-slot wedgewire screen installation at Oconee are provided in Table 10-22.

Table 10-22. 1.0-mm Fine-slot Wedgewire Screen Design Criteria per Unit for Oconee Nuclear Station

Parameter	Value Per Unit	Value for Entire Station	Units
Design Flow Rate	708,000	2,124,000	gpm
Number of Screens	28	84	-
Design TSV	0.40	-	fps
Maximum TSV	0.50	-	fps
Screen Percent Open Area	46.7	-	%
Required Screen Open Area	3,944	-	square ft
Slot Size	1.0	-	mm
Wire Width	1.14	-	mm
Screen Diameter	6	-	ft
Screen Total Length	24	-	ft
Length of Screen Available to Withdraw Water	16	-	ft

84 fine-slot wedgewire screens (28 per unit) would be required to maintain a maximum TSV of less than 0.5 fps. A design TSV of 0.4 fps was used as a design contingency, which would eliminate the need for redundant screens. A screen diameter of 6 ft was selected. A typical 6-ft diameter wedgewire screen with a 1.0-mm slot size is shown on Figure 10-22.

Debris deflectors would likely not be required because the intake canal would provide protection from debris in Lake Keowee. The wedgewire screens would connect to a concrete manifold structure via intake pipes, as shown on Figure 10-23. The manifold structure would provide structural support for the screens and would include a screen bypass system in the event of screen clogging or maintenance. With a water depth in the vicinity of the CWIS of 30 ft, 6-ft diameter wedgewire screens could be doubly-stacked vertically in the water column (Figure 10-23). This would include a separation distance of 6 ft between the intake canal bottom and the bottom screens, 6 ft between screens (horizontally and vertically), and 6 ft between the top screen and the water surface at the maximum drawdown elevation. Using this design basis, the screens would be consistently submerged to minimize impacts on station reliability and nuclear safety.



Wedgewire Screen Dimensions	Unit 1 Flow:	708,000 GPM (28 Screens)
Oconee Nuclear Station	Unit 2 Flow:	708,000 GPM (28 Screens)
	Unit 3 Flow:	708,000 GPM (28 Screens)

Figure 10-22. 1.0-mm Wedgewire Screen Dimensions for Screen Installation at Oconee Nuclear Station

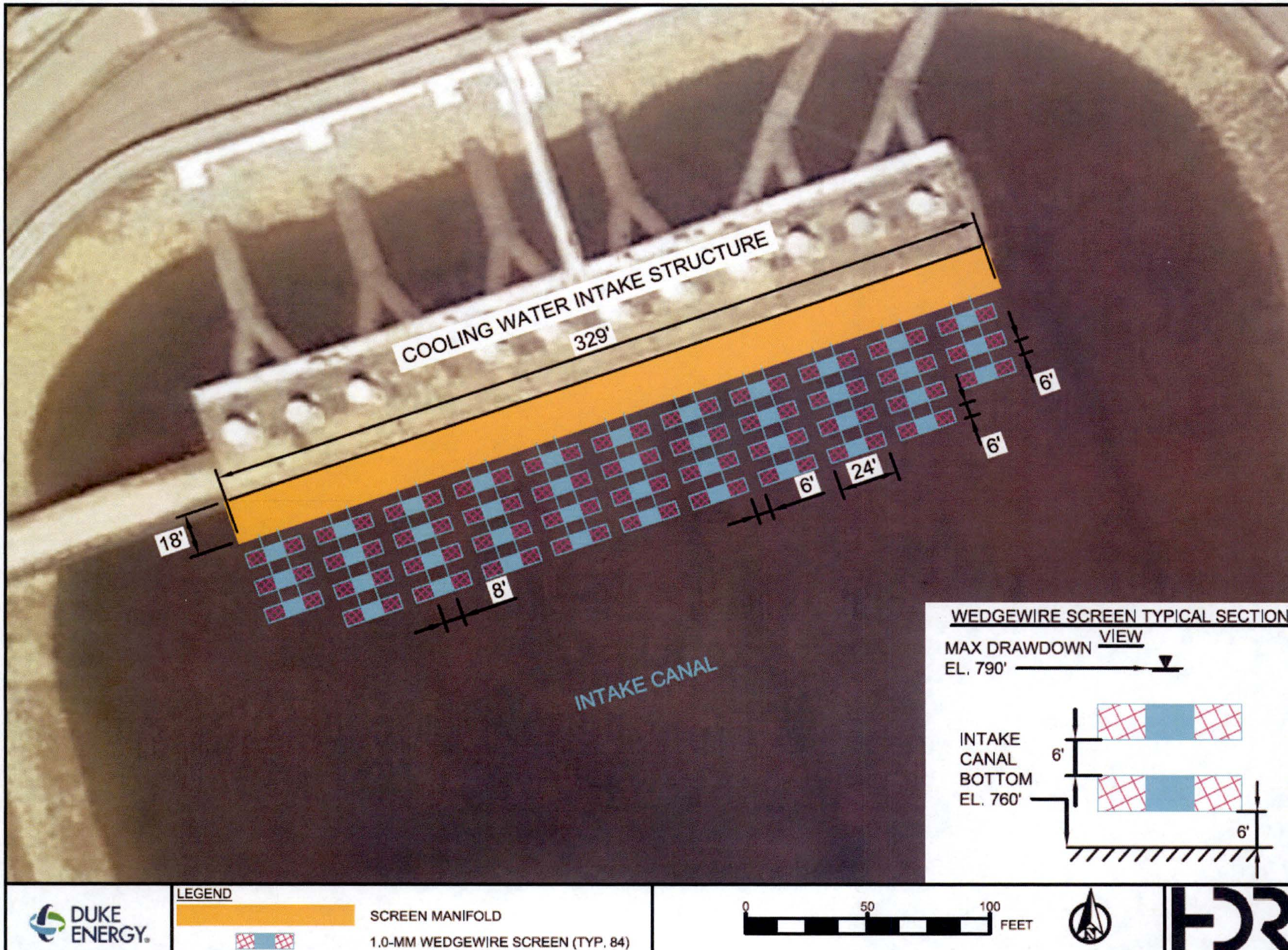


Figure 10-23. Plan View of the Hypothetical 1.0-mm Fine-slot Wedgewire Screen Installation at Oconee Nuclear Station

10.4.4.7 Feasibility Discussion

The key challenges associated with a hypothetical 1.0-mm fine-slot cylindrical wedgewire screen installation at Oconee include the following:

1. The hypothetical wedgewire screen installation within the intake canal would likely have inadequate sweeping velocity to effectively move organisms and debris away from the screens. This would impact cleaning requirements, but more importantly would impact the overall entrainment reduction efficacy of the screen system;
2. Construction and installation of 84 wedgewire screens and the concrete manifold would cause significant disturbance to the intake canal, and would have significant capital costs;
3. The screens and manifold could have significant structural impacts on the existing CWIS. Extensive structural analysis and design review would be required;
4. The hypothetical wedgewire screen installation could require a lengthy construction outage, which would significantly disrupt station operations and carry significant energy replacement costs;
5. The potential for significant impacts to station reliability, availability of cooling flow, and nuclear safety due to wedgewire screen clogging or damage;
6. The additional headloss associated with wedgewire screen installation could impact performance of the existing CCW pumps at Oconee, including additional energy consumption, pump damage, or pump cavitation. Impacts to the existing CCW pumps could affect station reliability, availability of cooling flow, and nuclear safety;
7. The potential for frequent and significant dredging operations near the screens in the intake canal to remove sediment buildup due to screen operation; and
8. Significant screen cleaning and maintenance requirements for station personnel.

Based on these challenges related to construction, installation, and operation of hypothetical 1.0-mm fine-slot wedgewire screens at Oconee, this technology is considered infeasible. This technology will not be further evaluated.

10.5 Summary of Social Costs for MDCTs, FMS, and FMS in a New CWIS

The first step in estimating social costs is to determine whether the entrainment reducing technology costs will result in the station becoming uneconomic to operate. A premature shutdown of the station would have social costs related to loss of jobs, loss of income and expenditures, loss of tax base, increased electricity costs because of generation being dispatched at a higher price from less efficient plants, and increased infrastructure costs to maintain grid reliability. Oconee is an important asset in Duke Energy's generating portfolio and supplies approximately 11 percent of the total generation portfolio (Duke Energy 2019b). However, an extraordinarily expensive conversion requirement could lead to premature station closure. For the purposes of this analysis, it is assumed that Duke Energy will incur the entrainment reduction compliance costs and continue to operate Oconee (Veritas 2020).

The social costs of installing entrainment reduction technologies are estimated by determining the capital costs of the evaluated technologies along with the O&M, power system, externality, and permitting costs. The analysis assumes that all compliance costs would be passed on to Duke Energy's electric customers. Table 10-23 summarizes the results of this evaluation and its implication for social costs.

Following the requirements of the Rule, Table 10-23 evaluates social costs under two discount rates: 3 and 7 percent (79 FR 158, p. 48428). As the first column of Table 10-23 shows, the top half of the table presents the present value of social costs discounted at 3 percent, and the bottom half presents the social costs discounted at 7 percent. The next column of the table presents each of the feasible technologies evaluated at Oconee. The third and fourth columns present the compliance costs estimated for each feasible technology. The third column presents the estimated capital costs, and the fourth column presents the annual O&M costs for each feasible technology.

The remaining columns in the table present the individual categories of social costs developed for this analysis: electricity price increases from compliance and power system costs, externality costs, and government regulatory costs. The analysis discounts the future stream of each of these social costs at the relevant discount rate and sums them over the years when they are specified to occur to develop the Total Social Cost estimate presented in the penultimate column. The table concludes by presenting the Annual Social Cost estimate for each technology. The annual estimate divides the Total Social Cost by the number of years the analysis is conducted.

Table 10-23. Total Compliance and Social Costs of Feasible Entrainment Reduction Technology Options at Oconee Nuclear Station

Discount Rate	Technology	Compliance Costs[a]		Social Costs[b]					
		Total Capital Costs	Annual O&M Costs[c]	Electricity Price Increases From: Compliance Costs	Electricity Price Increases From: Power System Costs	Externality Costs	Government Regulatory Costs	Total Social Costs[d]	Annual Social Costs
3%	Closed-cycle Cooling Tower Retrofit	$1,109.32M	$15.0M	$901.54M	$326.73M	$11.85M	$0.186M	$1,240.30M	$137.81M
	1.0-mm FMS Retrofit in the Existing CWIS	$65.62M	$1.9M	$64.66M	$36.45M	N/A	$0.012M	$101.13M	$9.19M
	1.0-mm FMS Installation in a New CWIS	$122.20M	$2.3M	$103.53M	$2.06M	N/A	$0.020M	$105.61M	$11.73M
7%	Closed-cycle Cooling Tower Retrofit	$1,109.3M	$15.0M	$600.23M	$227.44M	$8.68M	$0.148M	$836.49M	$92.4M
	1.0-mm FMS Retrofit in the Existing CWIS	$65.62M	$1.9M	$45.00M	$28.98M	N/A	$0.010M	$73.99M	$6.73M
	1.0-mm FMS Installation in a New CWIS	$122.20M	$2.3M	$68.93M	$1.52M	N/A	$0.016M	$70.47M	$7.83M

[a] Compliance costs are presented undiscounted and in 2019 dollars. These costs were developed as part of the engineering studies for Oconee and are represented in millions (M) of dollars.
[b] Social costs associated with each technology are discounted at 3 and 7 percent using the specifications outlined in Table 10-24. These costs are represented in M of dollars. Numbers may not sum due to rounding. Source: Veritas 2020; Appendix 10-J.
[c] O&M costs vary by year, annual O&M costs represent the average for each technology.
[d] For the Cooling Tower retrofit scenario, the relatively high power system costs offset the effect of the 3 percent discount rate such that the Total Social Costs are greater than values provided under Compliance Costs. For the FMS installation in a new CWIS scenario, the relatively low power systems costs do not offset the effect of the 3 percent discount rate, and as a result, the Total Social Cost is lower than the values provided under Compliance Costs. Under the 7 percent discount rate, the difference between Compliance Costs and Total Social Costs are slightly different due the effect of using a higher discount rate.

Assumptions regarding the timing of regulatory document submittals and technology implementation (i.e., permitting, design, and construction) are provided in Table 10-24 for the hypothetical closed-cycle cooling tower retrofit, the hypothetical 1.0-mm FMS retrofit in the existing CWIS, and the hypothetical 1.0-mm FMS installation in a new CWIS. It is assumed that O&M costs begin during the final year of the technology implementation period. Based on these assumptions, and the anticipated unit retirement dates, compliance costs would continue for an additional 9 years for both the cooling tower retrofit and the FMS installation in a new CWIS scenarios, and 11 years for the FMS retrofit scenario (Veritas 2020).

Table 10-24. Social Cost Modeling Timing for Feasible Entrainment Reduction Technologies at Oconee Nuclear Station[a]

Technology	Regulatory Documents Submitted	Modeled Technology Implementation Period	Modeled O&M Costs Begin	Modeled Years of Operation Before Retirement[b]
Closed-cycle Cooling Tower Retrofit	2020	2021–2025	2026	9
1.0-mm FMS Retrofit in the Existing CWIS	2020	2021–2023	2024	11
1.0-mm FMS Installation in a New CWIS	2020	2021-2025	2026	9

[a] Timelines are from Duke Energy's PROSYM model.
[b] Anticipated station retirement date. Oconee's USNRC operating licenses expire at midnight on the following dates for each unit: Unit 1 – 2/6/2033, Unit 2 – 10/6/2033, and Unit 3 – 7/19/2034.

As Table 10-23 shows, the social costs of each technology include the expected electricity price increases associated with each technology, the additional power system costs that would be incurred with each technology, the externality costs of each technology, and the governmental regulatory costs. As previously noted, the analysis specifies that all compliance costs are passed on to Duke Energy's rate payers resulting in increased electricity prices. To develop the electricity price increases, the capital costs are allocated over the modeled technology implementation time periods presented in Table 10-24. Modeled O&M costs are then added for each year the technology is operational, and the future streams of those costs are discounted by 3 and 7 percent to develop the present value estimate for each discount rate. Social costs are discussed in more detail in Appendix 10-J (Veritas 2020).

Power system costs represent the additional power needed to operate the new technologies and the additional fuel needed from running less efficient units during installation construction outages. The power system costs are developed from evaluating backpressure and auxiliary load effects, capacity losses from each of the technologies with estimated outage times, and electricity consumption associated with each technology.

Externality costs represent the environmental impacts associated with the installation of entrainment reducing technologies. For example, operation of a closed-cycle cooling system would create a visible plume from the cooling towers, which has the potential to affect nearby property values. More detail is provided in Appendix 10-J.

Governmental regulatory costs include the total costs associated with permitting, monitoring, administering, and enforcing the technology selection and installation. Costs are incurred by the government as the permitting and review process is undertaken. These vary with the type of technology, as certain technologies require substantially more permitting. These costs are initially borne by the government, but ultimately paid by taxpayers.

Further information can be found in the Veritas Economic Consulting, LTD (Veritas) (2020) report: *Social Costs of Purchasing and Installing Entrainment Reduction Technologies: Oconee Nuclear Station* (see Appendix 10-J).

10.5.1 Property Value Effects

The viewshed near Oconee would be affected by a visible plume. The height of the hypothetical MDCTs is estimated at 60 ft and the tower plume could extend several hundred feet above the towers. Based on the Electric Power Research Institute's (EPRI) (2011) study, a 6-mile radius around Oconee was assumed to have potential viewshed impacts. The approximately 3,366 residential properties associated with the census tracts within the 6-mile radius are collectively valued at approximately $776.2 million (Veritas 2020). EPRI (2011) used the results from Anstine (2003) to infer that plumes from a closed-cycle cooling retrofit are likely to result in a 1.8 percent reduction in affected property values due to viewshed impacts; therefore, this analysis applies the 1.8 percent impact from EPRI (2011) to the $776.2 million in properties within six miles of Oconee (Appendix 10-J). Results indicate a potential negative property value impact of approximately $13.97 million within six miles of Oconee. Discounted at 3 percent and 7 percent, this gives a present value of $11.03M and $8.13M, respectively.

10.5.2 Water Consumption Effects

The hypothetical closed-cycle MDCTs used in this evaluation rely on evaporation to cool water and evaporative losses would be made up though withdrawals from Lake Keowee. This would result in reduced water levels in Lake Keowee, thereby affecting the availability of water for other uses. The estimated net increase in water consumption resulting from operation of the MDCTs at Oconee is approximately 6,771.8 million gallons per year (MGY) based on the period July 1, 2014 through June 30, 2019. The estimated annual lost system hydroelectric generation resulting from the loss of this water ranges from $540,024 (7 percent discount rate) to $811,115 (3 percent discount rate), which equals approximately 2.535 percent of the annual generation at the Keowee Development (see Appendix 10-J).

10.5.3 Winter Fishery Effects

Heated water discharged into Lake Keowee from Oconee creates favorable habitat conditions during colder winter months by forming a warm water refuge which supports a substantial winter fishery for recreational anglers. Under closed-cycle cooling operation, there would be a social cost related to loss of this fishery. The Recreational Angling Demand Model developed to estimate the benefits of entrainment reductions was also used to evaluate the potential changes in Oconee's discharge and the effect on recreational anglers. Within the model, winter catch estimates were modified to represent recreational catch rates and values if the thermal discharge was eliminated. The Recreational Angling Demand Model considered potential impacts to anglers located in ZIP codes within a 50-mile radius of Oconee. The model was applied from 2026 (the year the MDCTs would be operational, thus eliminating the heated discharge) to 2034 (the assumed retirement of Oconee). Over this 9-year period, the present value estimate of the social cost ranges from a loss of approximately $5,727 (7 percent discount rate) to approximately $8,602 (3 percent discount rate).

10.6 Alternate Cooling Water Sources [§122.21(r)(10)(i)(C)]

Alternate cooling water sources, including groundwater, potable water, and grey water, have been evaluated for potential use to supplement the cooling water needs at Oconee. These potential sources were evaluated by first comparing the distance and available flow of the potential source to the location of the station, and then by determining its practicability. Table 10-25 provides the flow criteria for potential alternate water sources located within 5 miles of the station. Alternate water sources that are more than 5 miles from the station were not considered due to the prohibitive construction and permitting challenges that these sources would present, including stream and wetlands crossings, rail and roadway crossings, numerous rights-of-way required over private properties, and significant capital and O&M costs. The challenges of utilizing an alternate water source would increase with increased distance from the station. As such, this evaluation assumes that a potential source at a greater distance from the station would be required to be able to provide a greater percentage of the station DIF to be considered for further evaluation.

Table 10-25. Alternate Cooling Water Source Flow Criteria

Distance from Station	Percentage of Station DIF	Approximate Minimum Target Flow Rate for Further Evaluation
On-site	Any	Any
0 to 1-mile	5%	153 MGD
1 to 2-mile	10%	306 MGD
2 to 3-mile	15%	459 MGD
3 to 4-mile	20%	612 MGD
4 to 5-mile	25%	765 MGD
Station DIF = 3,059 MGD		

10.6.1 On-site Water Reuse

On-site water use at Oconee primarily consists of condenser cooling water, screen backwash water, and service water, which includes uses for the low-pressure and high-pressure service water systems, and station equipment cooling. If possible, on-site water reuse at Oconee would include service water and/or screen backwash water to support condenser cooling. Screen backwash water is not suitable for reuse, as it is intended to remove screen debris. Design service water flow (129.6 MGD) is approximately 4.4 percent of the station DIF (see Table 10-26). However, as shown on Figure 3-5, the majority of this flow serves as non-contact service water, which is routed back to Lake Keowee (via Outfall 001) and, therefore, is available for reuse at the station. Contact service water is currently routed through Chemical Treatment Pond 3 prior to being discharged to the Keowee River via Outfall 002. Re-routing contact service water back to the CWIS would require installation of pumps, piping, and associated electrical supply. Given the relatively small flow (1.8 MGD on average), reuse of contact service water is considered impractical.

Table 10-26. On-site Water Reuse Evaluation at Oconee Nuclear Station

Unit	Design Condenser Cooling Water Flow (MGD)	Design Service Water Flow (MGD)[72]	Service Water as a Percentage of Condenser Cooling Water Flow	Candidate for Further Evaluation
Unit 1	976.3	43.2	4.4%	No
Unit 2	976.3	43.2	4.4%	No
Unit 3	976.3	43.2	4.4%	No
Total	**2,929**	**129.6**	**4.4%**	**No**

Source: Duke Energy 2019a, Duke Power Company 1970

10.6.2 Grey and Potable Water Sources

The Witty Adkins Water Treatment Plant is located within 5 miles of Oconee and is identified on Figure 10-24. As shown in Table 10-27, the flow potentially available from this water treatment plant is equivalent to 2 percent of the DIF at Oconee. As such, the Witty Adkins Water Treatment Plant is not considered a candidate for further evaluation as a potential alternate cooling water source.

Table 10-27. Grey and Potable Water Alternate Water Source Evaluation at Oconee Nuclear Station

Water Source	Distance From Station	Design Flow (MGD)	Percent of Station DIF	Candidate for Further Evaluation	References
Witty Adkins Water Treatment Plant	2 to 3-Miles	60	2.0%	No	Greenville Water 2019

[72] The design service water flow rate was calculated by subtracting the design condenser flow rate from the station DIF.

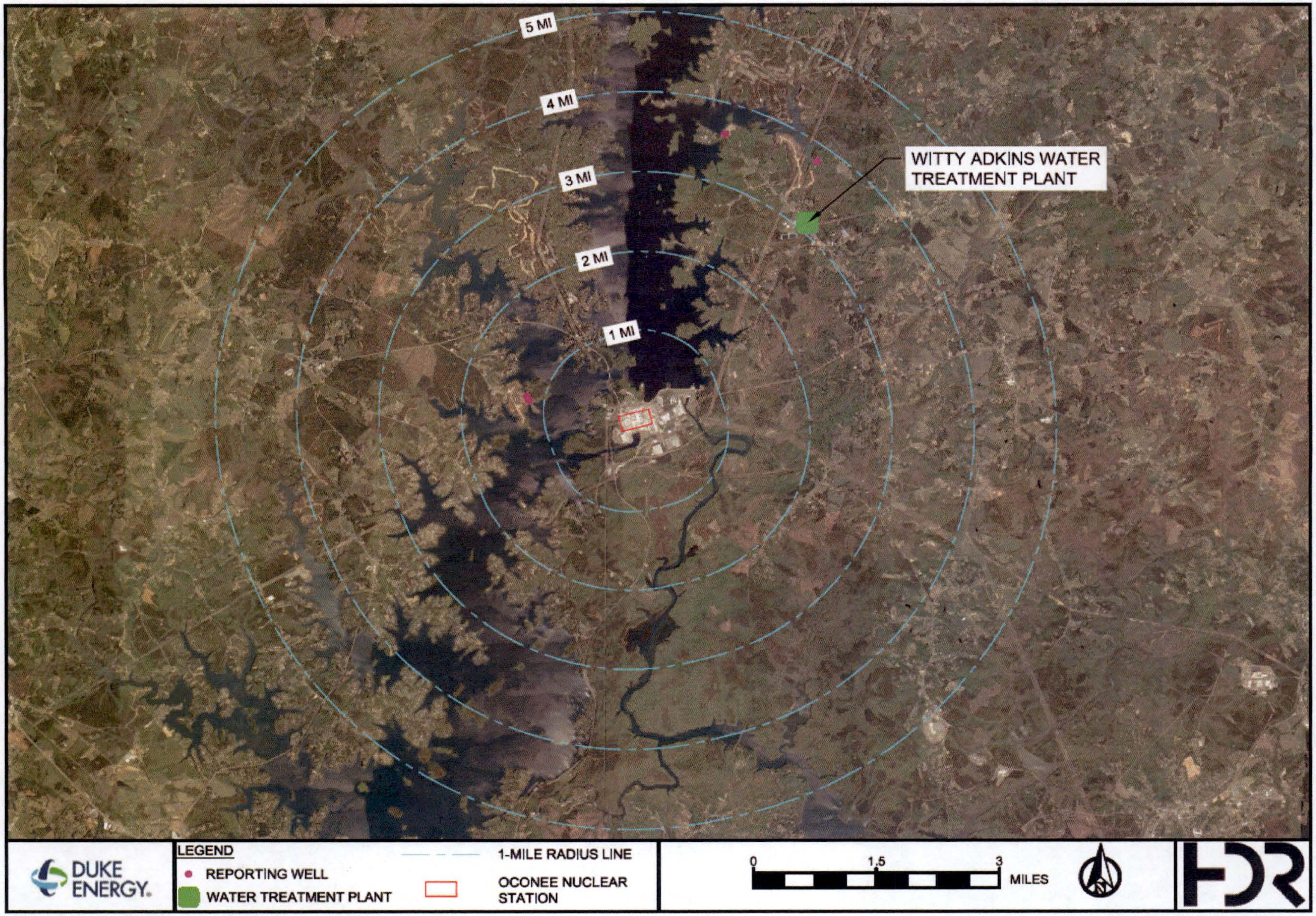


Figure 10-24. Groundwater Wells and Water Treatment Plants within a 5-mile Radius of Oconee Nuclear Station (Greenville Water 2019, SCDHEC 2018)

10.6.3 Groundwater Sources

10.6.3.1 On-site Groundwater Wells

Oconee has a network of on-site groundwater monitoring wells that were installed as a result of Duke Energy's Groundwater Protection Initiative (S&ME 2011). The Groundwater Protection Initiative was developed in response to the Nuclear Energy Institute's approval of a voluntary initiative to monitor tritium to improve the industry's management of groundwater protection issues. Oconee's on-site groundwater monitoring wells produce no yield and would not be viable as an alternate cooling water source, and are not considered for further evaluation.

The installation of new on-site radial wells was considered as a potential alternate source of cooling water at Oconee. However, due to geologic constraints, radial wells generally work best in riverine settings and their effectiveness is reduced at facilities adjacent to man-made reservoirs. In addition, the magnitude of flow required at Oconee would not be feasible to obtain from radial wells; therefore, this technology is not considered for further evaluation.

10.6.3.2 Off-site Groundwater Wells

Groundwater wells within 5 miles of the station have been identified on Figure 10-24 and listed in Table 10-28. The reporting wells that were identified have no provided yield (SCDHEC 2018). As such, off-site groundwater wells are not considered for further evaluation.

Table 10-28. Off-site Groundwater Wells within 5 Miles of Oconee Nuclear Station

Distance from Station	Number of Reporting Wells	Number of Dry or Non-Reporting Wells	Total Number of Wells
0 to 1-Mile	0	0	0
1 to 2-Mile	2	0	2
2 to 3-Mile	0	0	0
3 to 4-Mile	2	0	2
4 to 5-Mile	0	0	0

Source: SCDHEC 2018

10.7 Summary of Findings

This evaluation considered the following technologies as potential entrainment reduction measures at Oconee to comply with the Rule, as summarized in Table 10-29:

- Closed-cycle cooling systems;
- Modified-Ristroph FMS with an aquatic organism return system;
- Fine-slot wedgewire screens; and
- Alternate cooling water sources and on-site water reuse options.

Table 10-29. Summary of Findings

Technology	Feasibility Finding	Reasoning
Closed-cycle Cooling		
NDCTs	Feasible, but impractical	This technology is considered technically feasible (if designed with a large cooling tower approach and range), but extremely challenging and impractical due to current USNRC operating license terms, site footprint constraints, and significant capital costs. NDCTs are typically designed and implemented at new facilities with long expected life, which does not fit Oconee.
MDCTs	Feasible, but impractical	The technology is considered technically feasible but extremely challenging and impractical due to site footprint constraints, significant construction and requirements for station redesign, lengthy construction outage, significant annual energy penalty, the potential for annual station de-rates due to wet-bulb temperature exceedances, and significant capital costs.
Hybrid, Multi-cell, and Plume-abated Cooling Towers	Feasible, but impractical	This technology is considered technically feasible but extremely challenging and impractical due to the lack of stringent water consumption restrictions, the lack of critical infrastructure in the immediate vicinity of the station where visible plume would be a concern, site footprint constraints, increased annual energy penalty, and significant capital costs.
Dry Cooling System	Infeasible	This technology is considered infeasible due to site footprint constraints, likelihood of significant required station redesign, significant annual energy penalty, lengthy construction outage, and significant capital costs.
FMS		
Retrofit of the Existing Coarse-mesh Fixed-panel Screens with New 1.0-mm FMS Units and Installation of a New Aquatic Organism Return System	Feasible, but impractical	The technology is considered technically feasible but impractical due to the potential for significant modification, reconstruction, and demolition within the existing CWIS, the need for a lengthy construction outage, and the significant length required for an effective aquatic organism return system. In addition, increases to TSV and headloss could impact the existing CCW pumps, which could affect station reliability, availability of cooling flow, nuclear safety, and the overall entrainment reduction efficacy of the technology.
1.0-mm FMS Overlay of Existing Coarse-mesh Fixed-panel Screens	Feasible, but impractical	This technology is technically feasible but impractical due to significant TSV and headloss through the overlay composite mesh, which could impact the existing CCW pumps and affect station reliability, availability of cooling flow, nuclear safety, and the overall entrainment reduction efficacy of the technology. In addition, the existing screens at Oconee are not traveling screens, nor do they have an aquatic organism return system, so the IM and entrainment reduction efficacy of the overlay system would be decreased without these elements.

Technology	Feasibility Finding	Reasoning
Installation of 1.0-mm FMS Units in a New CWIS and Installation of a New Aquatic Organism Return System	Feasible, but impractical	This technology is considered technically feasible but impractical due to extensive civil work and earthwork, and the significant length required for an effective aquatic organism return system. In addition, increases to TSV and headloss could impact the existing CCW pumps, which could affect station reliability, availability of cooling flow, nuclear safety, and the overall entrainment reduction efficacy of the technology.
Installation of 1.0-mm Fine-slot Wedgewire Screens	Infeasible	This technology is considered infeasible due to inadequate sweeping velocity in the intake canal, which would impact the entrainment reduction efficacy. Screen installation would cause significant disturbance to the intake canal, would have significant capital costs, and could require a lengthy construction outage. Screen clogging or damage could have significant impacts to station reliability, availability of cooling flow, and nuclear safety. Increased headloss could impact the existing CCW pumps, which could affect station reliability, availability of cooling flow, and nuclear safety. There would also be the potential for frequent and significant dredging requirements near the screens, and significant screen cleaning and maintenance requirements.
Alternate Cooling Water Sources		
Reuse Existing On-site Water Sources	Infeasible	This technology is considered infeasible because the magnitude of service water flow is not significant when compared to the design circulating water flow, which would limit any potential entrainment reduction benefits. In addition, a portion of service water at Oconee has an associated heat load due to use in equipment cooling and could require cooling and/or treatment prior to reuse. Rerouting of the service water discharge at this nuclear power plant would be challenging from a cost and engineering perspective.
Replace or Supplement Existing Surface Water Source with Alternate Water Sources	Infeasible	This technology is considered infeasible because there is insufficient quantity of potential grey and potable water sources in the vicinity of the station. In addition, Oconee's on-site groundwater wells are monitoring wells that produce no yield, and reporting groundwater wells in the vicinity of the station did not provide a yield.

Based on the summary of findings provided in Table 10-29, the technologies that have been retained for a benefits valuation study (Section 11) and a non-water quality and other environmental impacts study (Section 12) at Oconee are listed in Table 10-30.

Table 10-30. Technologies Retained for Further Evaluation

Technology	Retained for Further Evaluation
NDCTs	No
MDCTs	Yes
Hybrid, Multi-cell, and Plume-abated Cooling Towers	No
Dry Cooling Systems	No
Retrofit of the Existing Coarse-mesh Fixed-panel Screens with New 1.0-mm FMS Units and Installation of a New Aquatic Organism Return System	Yes
1.0-mm FMS Overlay of Existing Coarse-mesh Fixed-panel Screens	No
Installation of 1.0-mm FMS Units in a New CWIS and Installation of a New Aquatic Organism Return System	Yes
Installation of 1.0-mm Fine-slot Cylindrical Wedgewire Screens	No
Use of Alternate Cooling Water Source(s) to Supplement or Replace Cooling Water Needs	No

10.8 Section 10 References

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11 Benefits Valuation Study [§122.21(r)(11)]

The information required to be submitted per §122.21(r)(11), *Benefits Valuation Study*, is outlined as follows:

(i) *Incremental changes in the numbers of individual species and life stages of fish and shellfish*[73] *lost due to impingement mortality and entrainment as defined at §125.92;*

(ii) *Description of basis for any estimates of changes in the stock sizes or harvest levels of commercial and recreational fish or shellfish species, or forage fish species;*

(iii) *Description of basis for any monetized values assigned to changes in the stock size or harvest levels of commercial and recreational fish or shellfish species, forage fish, and to any other ecosystem or nonuse benefits;*

(iv) *A discussion of mitigation efforts completed prior to October 14, 2014, including length of implementation and level of effect on fish abundance and ecosystem viability in the CWIS area of influence;*

(v) *Discussion, with quantification and monetization where possible, of any other benefits expected to accrue to the environment and local communities, including but not limited to improvements for mammals, birds, and other organisms and aquatic habitats; and*

(vi) *Discussion, with quantification and monetization where possible, of benefits expected to result from any reductions in thermal discharges from entrainment technologies.*

Under §122.21(r)(11) of the Rule, "the owner or operator of the facility must submit a detailed discussion of the benefits of the candidate entrainment reduction technologies evaluated in §122.21(r)(10) and using data in the Entrainment Characterization Study in §122.21(r)(9). Each category of benefits should be described narratively, and when possible benefits should be quantified in physical or biological units and monetized using appropriate economic valuation methods."

Each of these requirements is addressed in the following subsections:

- Sections 11.1 and 11.2 describe the methodology used to determine the incremental changes in entrainment and impingement under baseline and candidate technologies;
- Sections 11.3 and 11.4 describe the methodology used to determine the annualized benefits and to monetize those benefits;
- Sections 11.5 and 11.6 present the technology-specific biological modeling results in terms of losses and the annualized benefits and their economic values;
- Section 11.7 provides a discussion of uncertainty in the benefit valuation study;

[73] The Rule requires a characterization of the annual IM and entrainment for fish and shellfish. Shellfish were not collected in the recent or historical impingement studies; thus no impacts to shellfish are assumed.

- Section 11.8 discusses the potential benefits resulting from reduced thermal discharges;
- Section 11.9 discusses mitigation efforts made prior to the Rule; and
- Section 11.9.3 provides a summary and discussion of the information presented in Section 11.

11.1 Determining Entrainment and Impingement Losses under Baseline and Candidate Technologies

This Benefits Valuation Study provides a summary of the ecological and monetary benefits of select entrainment reduction technologies and operational measures evaluated for Oconee per the requirements listed at §122.21(r)(10) (see Section 10). The benefits of reductions in entrainment and impingement losses of early life stage fish are best evaluated by translating losses to an ecological or human-use context, and assessing differences in total losses among compliance technology scenarios discussed in Section 10. Relationships between entrainment/impingement losses, equivalent adults and production foregone estimates, and quantifiable benefit reductions are depicted in Figure 11-1.

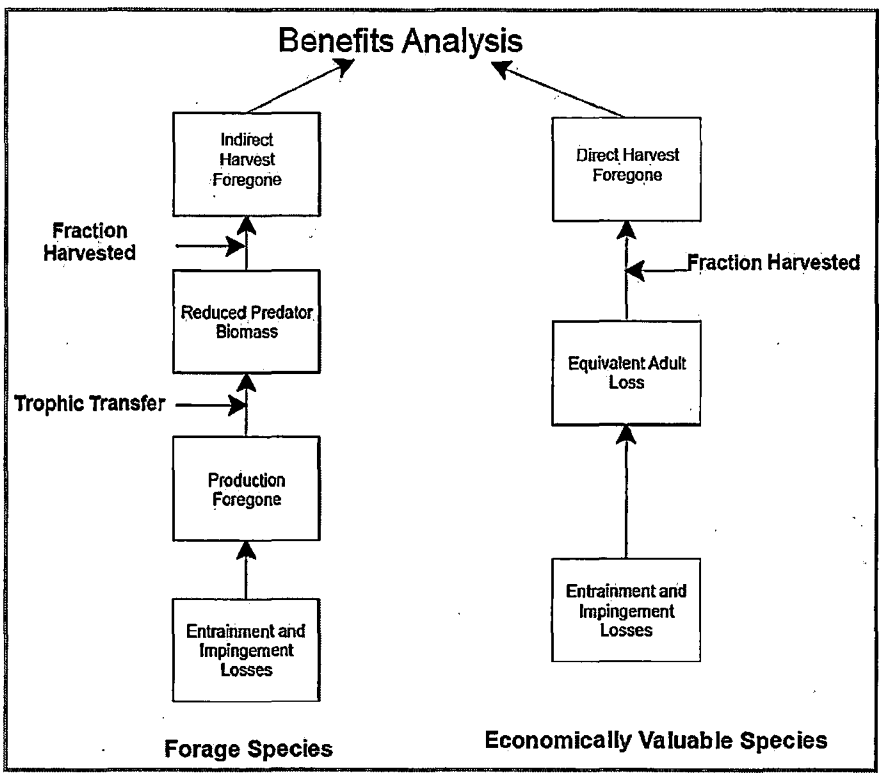

Figure 11-1. Conceptual relationship of equivalent adult estimates and production Foregone estimates to economic benefit analysis (EPRI 2004a)

The estimation of benefits was accomplished using a multistep process:

1. Estimate taxa and life-stage specific losses of fish and shellfish to entrainment and impingement mortality under each technology scenario evaluated in Section 10;

2. Convert losses using commonly applied and accepted methods including the equivalent adult, production foregone, and equivalent yield models[74];
3. Calculate the benefits (reduction in estimated annual losses) of candidate technologies as recreational yield by incorporating trophic transfer of production foregone biomass (forage species) and fishing pressure to commercial/recreational taxa;
4. Monetize the changes in recreational yield resulting from implementation of candidate technologies (benefit) and subsequent reductions in entrainment and impingement at Oconee.

This process was followed to calculate the baseline losses as well as benefits (reductions in entrainment and impingement) for the two feasible technologies identified in Section 10:

- Closed-cycle cooling in the form of mechanical draft cooling towers (MDCTs); and
- Installation of a fish-friendly FMS[75] with 1.0-mm mesh and an aquatic organism return.

As noted in Section 10, alternative water supplies were determined to be infeasible and were not carried forward to the Benefits Valuation Study.

11.1.1 Baseline Loss Estimates for Fish and Shellfish

Site-specific data from the recent Entrainment Characterization Study (Study) (see Section 9, Appendix 9-A) and previous impingement study (discussed in Section 4) were extrapolated to annual entrainment and impingement loss estimates using actual water withdrawal volumes reported for Oconee in 2016 and 2017.

11.1.1.1 Entrainment Loss Estimates

Ichthyoplankton were sampled at Oconee encompassing the spawning season (i.e., March to October) during 2016 and 2017, as described in Section 9. Mean density values were extrapolated based on CWIS flows to estimate the total annual entrainment at Oconee based on actual water withdrawals in 2016 and 2017. An estimated 36.1 million and 37.5 million ichthyoplankton were entrained in 2016 and 2017, respectively.

Fragile species (e.g., Blueback Herring, Alewife, Gizzard and/or Threadfin Shad) were the most abundant taxa identified during the Study, representing 98.6 percent (2016) and 100 percent (2017) of the number entrained each year. Sunfish species (*Lepomis* spp.) was the only recreational taxa entrained, representing 1.4 percent of estimated annual entrainment for 2016; however, none were entrained during sampling in 2017. Only egg and larval life stages were entrained during both years with eggs comprising 92.3 and 86.5 percent of ichthyoplankton during 2016 and 2017, respectively. As described in Section 7 of this report, the low number and diversity of the estimated entrainment losses is attributed to the efficacy of the curtain wall because it helps to reduce the number of ichthyoplankton susceptible to entrainment at the CWIS, while facilitating the withdrawal of cooling water from the lower portion of the water column.

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[74] The equivalent yield model is used to convert the estimated losses under evaluated technologies to the equivalent biomass of harvest foregone.

[75] An additional FMS option that includes expanding the CWIS to achieve a TSV of 1.5 fps or below is also evaluated for monetized benefits; however, the estimated changes in stock and harvest are the same as FMS retrofit.

11.1.1.2 Impingement Mortality Loss Estimates

Loss estimates for IM in 2016 and 2017 were developed using data from a representative impingement sampling study performed at Oconee in 2006 and 2007 (ASA 2008) and actual water withdrawals at Oconee during 2016 and 2017. The biological models are based on species-specific life history information for individual life stages, therefore the annual losses for a species must be incorporated for each life stage, separately. Impinged fish from the 2006-2007 study were classified as "YOY" or "adult/juvenile", while the available life history information for the model requires fish to be aged as either adults or juveniles. To facilitate the use of the existing data into the modeling effort, Blueback Herring, Threadfin Shad, Bluegill, and Alabama Bass were classified as adults or juveniles using available length-frequency distributions and species-specific length data from the literature. The remaining species were classified using BPJ based on history characteristics, abundance, and collection dates, or they were considered juveniles. This assumes that adult fish susceptible to impingement due to TSV were likely of younger age, as the reduced swimming ability of smaller fish increases their susceptibility to impingement.

Based on the ASA (2008) impingement study (summarized in Section 4) and actual water withdrawals at Oconee during 2016 and 2017, annual IM was estimated to be 46,437 and 45,399 fish, respectively (Tables 11-A1 and 11-A2 in Appendix 11-A). The estimated annual IM losses were dominated by fragile species (over 95 percent), driven by impingement of Threadfin Shad and Blueback Herring[76]. Bluegill had the third largest number of IM losses and accounted for 2.9 to 3.1 percent of the total estimated annual IM; the remaining 8 species each accounted for less than 1 percent of IM losses.

Although the impingement study data are over 10 years old, withdrawal rates and screen operations at Oconee have remained consistent since the data were collected. Additionally, recent studies by Duke Energy (2007, 2013) demonstrate that Lake Keowee in the vicinity of Oconee has shown a persistent and stable fish community since the impingement study was conducted with only minor changes due to introduced species such as Alabama Bass and Flathead Catfish. Therefore, the impingement data collected during the 2006-2007 study are considered representative of existing conditions and were used to represent current baseline impingement at Oconee.

11.1.2 Loss Estimates under Candidate Entrainment and Impingement Reduction Technology Scenarios

Several facility configurations and operational scenarios were evaluated as potential retrofit compliance options at Oconee (Section 10) and a select list of candidate compliance technologies were retained for further evaluation (Table 11-1). The total estimated entrainment and impingement losses expected to occur under each of the evaluated technologies were used to calculate the estimated reduction benefits of those technologies in comparison to baseline conditions at Oconee.

Table 11-1. Summary of Candidate Technology Scenarios for the Benefits Valuation Study

Scenario	Description	Configuration and Operation Assumption	Compliance Applicability	
			Entrainment	Impingement
FMS[1]	Fine-Mesh Screens (FMS) at actual water withdrawals	1.0-mm fine mesh Ristroph screens with an aquatic organism return system at actual water withdrawals	Yes	Yes[2]

30 percent impingement survival.

Post-IM BTA	Post-Impingement BTA compliance at actual water withdrawals	3/8-inch mesh Ristroph screens with an aquatic organism return system at actual water withdrawals	No	Yes
MDCT	Mechanical Draft Cooling Towers (MDCT) at actual water withdrawals	MDCT at actual water withdrawals based on preliminary design presented in Section 10	Yes	Yes

[1]Note that replacement of the existing fixed panel screens with traveling screens would incur substantial electrical and other costs as noted in Section 10.
[2]FMS is intended to address entrainment but would also satisfy the impingement criteria (with appropriate measures such as an aquatic organism return, entrapment prevention, etc.).

11.1.2.1 Determining Losses with Fine-Mesh Screens and an Aquatic Organism Return System

Data were modeled under the FMS technology scenario assuming the installation of 1.0-mm fine-mesh Ristroph traveling water screens with an aquatic organism return system. An aquatic organism return system includes continuously rotating traveling water screens with fish-friendly buckets designed to minimize turbulence, a guard rail/barrier to prevent organisms from escaping the collection bucket, and smooth, woven or synthetic mesh (79 FR 158, 48337). The system would use a low-pressure wash to remove aquatic organisms from the screens to a transfer trough designed to avoid avian and animal predation (79 FR 158, 48346). Organisms would be returned to the source waterbody at a location a sufficient distance from the CWIS to reduce risk of repeated impingement on the FMS.

Installation of traveling water screens with a mesh size smaller than the current configuration inherently results in an increase in the impingement of organisms. Ichthyoplankton with head depths equal to or greater than 1.0 mm, which would have otherwise been entrained through 3/8-inch coarse-mesh screens or 2.0-mm FMS, would be impinged on the 1.0-mm FMS (i.e., "converted" from entrainment to impingement). Early life stage organisms typically lack scales and well-developed body musculature, thus not all ichthyoplankton may survive impingement on a FMS (EPRI 2010a). Therefore, converted organisms were also adjusted for on-screen survival using values identified from multiple historical survival studies and meta-analyses (EPRI 2003, 2004b, 2006, 2010b, 2013). Additional losses were calculated by applying on-screen survival rates to determine the number of convert losses due to impingement on the FMS; the convert losses were then added to the entrainment mortality loss estimates (79 FR 158, 48330). Applied on-screen survival values are discussed further in Section 11.2.3.

In addition to the impact of on-screen survival to organisms converted to impingement on FMS, survival of larval fish in the organism return system can be variable depending on the species and life stage of the organism. A study by EPRI (2010c) demonstrated that survival of organisms through an aquatic organism return system following impingement on an FMS was dependent on the life stage of the fish, particularly whether it was yolk-sac versus post yolk-sac larvae or older- as compared to the configuration (i.e., length, drops, bends) or velocity of the fish return system. However, due to the limited amount of species-specific survival information, as related to the return system, and uncertainty of this information at the time of document development, estimates presented under this scenario conservatively assume 100 percent survival through the aquatic organism return system (which results in a greater estimate of benefits).

11.1.2.2 Determining Losses under Post-IM BTA Compliance

The Post-Impingement (Post-IM) BTA candidate technology represents the installation of 3/8-inch coarse-mesh modified fish-friendly (i.e., Ristroph) screens, a low-pressure spray wash, and an aquatic organism return system. All early life stage organisms would be entrained through the coarse mesh and are assumed to experience 100 percent mortality (79 FR 158, 48318); therefore, this compliance option offers no entrainment reduction from the annual estimates presented in Section 11.1.1.2. Similar to the FMS candidate technology, on-screen survival data were used to model the effects of survival under this scenario. Although survival of juvenile fish through fish return systems is expected to be greater than 90 percent (EPRI 2010c), estimates presented under this scenario conservatively assume 100 percent survival through the aquatic organism return system (which results in a greater estimate of benefits).

11.1.2.3 Determining Losses with Mechanical Draft Cooling Towers

Closed-cycle cooling system retrofits typically result in a significant reduction to the total volume of cooling water withdrawn by the facility. In Section 10, a site-specific hypothetical retrofit with MDCTs was designed for Oconee that is conservatively estimated to reduce cooling water withdrawals by as much as 97.4 percent. This value was used to reduce the actual water withdrawal volumes reported for 2016 and 2017, which were then used to determine the incremental entrainment losses under the MDCT candidate technology scenario. Since MDCTs are considered closed-cycle cooling systems, they also qualify as impingement BTA and provide a corresponding reduction in IM losses.

11.1.3 Summary of Incremental Losses under Entrainment and Impingement Reduction Scenarios

The existing curtain wall at Oconee effectively reduces entrainment at Oconee by 90 percent under current operations, and results of the 2017 Curtain Wall Study (summarized in Section 4) were supported by the relatively low ichthyoplankton densities documented in the entrainment characterization study (HDR 2018) and the resulting annual entrainment estimates presented in Section 9. Thus, the entrainment reduction estimates for the technologies presented in Section 11.1.2, and summarized below, represent the further reduction in entrainment that could potentially occur with the installation of an additional entrainment reduction technology.

The baseline configuration and conditions (coarse-mesh fixed screens and no aquatic organism return system) represents the greatest total losses for entrainment and IM (Table 11-2 and Table 11-3) under actual operations. The installation of FMS with a fish return system may reduce entrainment losses by 68.3 to 76.8 percent (compared to existing conditions). Approximately 98.6 percent of organisms estimated in 2016 and 100 percent of organisms in 2017 were classified as fragile species, therefore the efficacy (exclusion of organisms and subsequent survival of those organisms) of FMS is not expected to be as high as it would be if robust species were entrained.

The Post-IM BTA candidate technology would provide a reduction in IM of 8.0 to 8.1 percent (Table 11-3). The efficacy of this candidate technology is limited due to the high number of fragile species estimated under existing conditions (greater than 95 percent; see Appendix 11-A). Because convert mortalities are accounted for under entrainment estimates, the estimated IM is the same with 3/8-inch coarse mesh or 1.0-mm fine-mesh modified Ristroph screens.

Apart from the complete elimination of entrainment and impingement at Oconee, installation of MDCTs would result in the greatest reduction in fish entrainment and IM (Table 11-2 and Table 11-3). While a proportional reduction of 97.4 percent through flow decrease was applied for the purposes of this modeling effort (79 FR 158, 48331), it is possible that an even greater reduction in impingement would be achieved under this scenario due to a lower TSV. Incremental losses by species and life stage for entrainment and impingement are provided in Tables 11-A3 through 11-A6 of Appendix 11-A.

Table 11-2. Summary of Potential Incremental Reductions in Entrainment Losses by Candidate Technology Scenario for 2016 and 2017

Scenario	2016		2017	
	Total No. Lost[1]	Percent Reduction	Total No. Lost[1]	Percent Reduction
Baseline[2]	36,102,094	--	37,534,245	--
FMS[3,4]	8,361,087	76.8	11,881,297	68.3
MDCT	938,654	97.4	975,890	97.4

[1] Total No. Lost were rounded to the nearest whole number.
[2] Baseline condition represents the current system of technologies consisting of the intake canal curtain wall and submerged weir, CWIS overhang, 3/8-inch coarse-mesh fixed-panel water screens and no aquatic organism return system. This scenario represents the losses that would be eliminated under the "Without-Entrainment" scenario.
[3]Total FMS losses include convert mortalities.
[4]Total number lost and percent reduction for the FMS scenario includes convert mortalities. These values likely represent a conservative representation of technology benefits as this scenario is based on the assumption of 100 percent survival of the egg life stage. The on-screen survival values used to develop these estimates are provided in Appendix 11-B.

Table 11-3. Summary of Potential Incremental Reductions in Impingement Losses by Candidate Technology Scenario for 2016 to 2017

Scenario	2016		2017	
	Total No. Lost[1]	Percent Reduction	Total No. Lost[1]	Percent Reduction
Baseline[2]	46,437	--	45,399	--
Post-IM BTA	42,714	8.0	41,709	8.1
MDCT	1,208	97.4	1,181	97.4

[1]Total No. Lost were rounded to the nearest whole number.
[2] Baseline condition represents the current system of technologies consisting of the intake canal curtain wall and submerged weir, CWIS overhang, 3/8-inch coarse-mesh fixed-panel water screens and no aquatic organism return system. This scenario represents the losses that would be eliminated if Oconee's units were retired and impingement was eliminated.

11.2 Estimating Changes in Stock Size or Harvest Levels

To facilitate the quantification and comparison of technology-specific benefits, the annual incremental entrainment losses of recreational taxa were extrapolated using equivalent adult and production foregone models. Equivalent adult losses are the number of fish (and biomass) that would have survived to some future age (based on age of equivalence), but were removed from the harvestable population due to entrainment or impingement (EPRI 2004a). The Forward Projection (EPRI 2012) approach of the equivalent adult model was used for Oconee, as described in the Oconee Entrainment and Impingement Calculation Appendix (Appendix 9-C). This model approach uses taxa-specific life history information (e.g., growth and survival rates, weights-at-age) to estimate the number and biomass of individuals surviving to the age of equivalence. For recreational taxa, the age of equivalence was defined for each species/life history table as the age of 100 percent vulnerability to the fishery (summarized in Appendix 11-B, Table 11-B1).

To account for forage species (non-recreational taxa), the Rago approach (EPRI 2012) was used to extrapolate prey and non-game biomass losses to an age of equivalence. This model includes the expected future growth of forage species prior to their consumption by predators. Because the production foregone model quantifies the forage biomass lost to entrainment and impingement, they were excluded from the equivalent adult model to avoid redundancy. The age of equivalence for forage species was the age of reproductive maturity of female taxa (summarized in Appendix 11-B, Table 11-B1).

Assumptions and BPJ decisions employed during the development of the equivalent adult and production foregone models are described below and are summarized in Appendix 11-B.

11.2.1 Life History and Model Parameter Development

Available site-specific (or region-specific) life history information from a variety of sources were compiled to create species-specific life history summary tables. Parameters used in the modeling effort include life stage duration, stage-specific weights, natural mortality, fishing mortality and vulnerability (for recreational species), fecundity, and others. Data were obtained from numerous resources (Tables 11-B2 and 11-B3 in Appendix 11-B), however the majority of information was drawn from the following documents:

- EPRI Final Report 1008471 “Extrapolating Impingement and Entrainment Losses to Equivalent Adults and Production Foregone” (EPRI 2004a);
- EPRI Technical Report 1023103 “Fish Life History Parameter Values for Equivalent Adult and Production Foregone Models: Comprehensive Update” (EPRI 2012); and
- Environmental Protection Agency EPA-821-R-04-007 “Regional Benefits Analysis for the Final Section 316(b) Phase II Existing Facilities Rule” (USEPA 2006).

Modeling fish survival into the future through the equivalent adult and production foregone models warrants the incorporation of natural mortality into the analyses. Natural mortality can be the result of starvation, competition, predation, disease, natural senescence, or other factors. Early life stage fish experience high natural mortality rates of up to 96.4 to 99.9 percent depending on whether it is a freshwater or marine ecosystem (Fuiman and Werner 2009). Therefore, it is important to consider natural mortality in estimated losses given the vast majority of eggs and larvae would not have survived to adulthood in the natural environment even without entrainment and/or impingement effects. In addition to natural mortality, fishing mortality is also applied in calculations of harvest foregone for recreational taxa, as categorized in Table 11-B4 in Appendix 11-B.

Life history tables were adjusted to achieve approximately zero net growth per generation to assume that all populations are stable throughout the model projections (EPRI 2004a). This adjustment was referred to as life history table “balancing” and was applied to all species life history tables. Natural and fishing mortality, stage-specific maturity, population gender ratio, and fecundity were used for the balancing process, where natural mortality rates were adjusted to result in zero cumulative egg production over the life of the fish. This approach limits the magnitude of the biases that can occur in model projections when parameters are compiled from different studies that were performed at different times using various methods for different life stages and populations (EPRI 2004a).

11.2.2 Life History Information

Fish and shellfish life history information (e.g., life stage duration, weight-at-death, natural mortality rates, fishing mortality rates, as illustrated in Table 11-4) has not been developed for all species and life stages or for all U.S. waterbodies. Information on stock status (e.g., spawning stock biomass, standardized catch-per-unit-effort, recruitment) is generally only available for harvested species, which represent a minor fraction of impingement and entrainment losses (USEPA 2006). In fact, only 23 percent of U.S. managed fish stocks have been fully assessed (U.S. Ocean Commission 2002). Therefore, site-specific, region-specific, or species-specific data were not readily available for each of the species and life stages collected at Oconee and reported in this benefits valuation analysis (i.e., all species collected during the entrainment and impingement studies). Life history information previously developed by EPRI (2004a, 2012) and the USEPA (2006) was used.

Table 11-4. Example of Species Comparison for Life History Table Mapping

Characteristic	Alabama Bass	Smallmouth Bass
Maximum Length (centimeter)	63.5	69.0
Common Length (centimeter)	30.0	35.5
Maximum Weight (kg)	4.7	5.4
Diet	Insects, crayfish, frogs, worms, grubs, and small fish	Fish, crayfish, and aquatic insects
Trophic Level	3.56	4.09
Habitat Preferences	Streams, lakes and reservoirs	Shallow, rocky areas of lakes; clear, gravelly runs and pools of rivers
Classification[1]	Recreational	Recreational

Source: Rohde et al. 2009; SCDNR 2015, Froese and Pauly 2019
[1]Classificiation: a site-specific classification of economic role in the fishery as either recreational, commercial, or forage.

When species-specific life history data were unavailable, information from a surrogate species was applied. Surrogate species were ideally a species from the same genus or family exhibiting the greatest similarity in body size and growth-rate. The process of substituting life history data from a surrogate species is referred to as "mapping" the collected species to the life history information of a surrogate species. For example, no existing life history table information was available for the Alabama Bass. Therefore, Smallmouth Bass was selected as a surrogate species for Alabama Bass. Both species are members of the *Micropterus* genus and exhibit similar life history characteristics and ecosystem functions (Rohde et al. 2009; SCDNR 2015; Froese and Pauly 2019), and are likely to experience comparable fishing pressure in Lake Keowee. A summary of life history table mapping selections and BPJ mapping decisions is provided in Appendix 11-B.

Not all organisms could be identified to species level; therefore, some BPJ decisions were based on data that were collected during previous entrainment or impingement studies (e.g., periodicity, morphometrics) or data collected during the Duke Energy CWA §316(a) monitoring (species composition and abundance within the vicinity of Oconee). In instances where species identification was to the genus level (i.e., *Dorosoma* spp. or *Alosa* spp./*Dorosoma* spp.) and there was potential for selecting from more than one existing life history table, a BPJ decision was made based on morphometrics, periodicity of occurrence, or relative abundance. For example, unidentified eggs were "mapped" to the Blueback Herring life history table based on the abundance of Blueback Herring eggs that were collected during the study as compared to other taxa.

Some parameters of the life history tables did not include all of the necessary data required to develop equivalent adult and production foregone models. These data were developed based on BPJ decisions following EPRI guidelines. Parameter-specific BPJ decisions made during life history table development are summarized in Appendix 11-B. For example, where median weight data were unavailable, the midpoint (i.e., average) between starting weights of successive life stages was calculated using formulas provided in EPRI 2004a.

11.2.3 On-screen Survival

On-screen survival data from multiple historical survival studies were compiled and summarized by species, life stages, and screen mesh types, sizes, and configurations (EPRI 2003, 2004b, 2006, 2010b, 2013). Due to limitations on availability of species-specific information, the compiled data were grouped based on three life stages (larvae, juvenile, and adult) and species vulnerability (fragile vs. robust). Additionally, very little information is available on the survivability of egg impingement on a FMS; therefore, the on-screen survival applied for eggs was considered 100 percent as a conservative measure (in order to assume a greater reduction in losses and therefore greater estimate of benefits). On-screen survival data were used to adjust the entrainment losses estimated under the FMS with aquatic organism return and the Post-IM compliance scenario.

Fragile species are defined as those with an impingement survival rate of less than 30 percent[77]. For this facility, fragile species consisted of taxa within the Clupeidae family. Robust species were considered non-fragile species, or species with an impingement survival rate of greater than 30 percent. Based on the accepted IM standard acknowledged by the USEPA (79 FR 158, 48321), a 76 percent survival rate was applied for robust age 1+ fish species. Species classifications and associated on-screen survival values are summarized in Table 11-B6 of Appendix 11-B.

11.3 Basis for Determining Annualized Reduction Benefits

To analyze the benefit of each feasible technology, the total losses that would still be incurred under each Reduced-Entrainment scenario (Post-IM BTA [for impingement], FMS, and MDCT) were converted to net benefits as compared to the With-Entrainment scenario (baseline/existing conditions). For comparison purposes, an additional scenario (Without-Entrainment) was calculated as the total additional recreational taxa that would occur with the complete elimination of entrainment at Oconee, and was calculated using the assumption of 100 percent reduction based on baseline entrainment data at actual water withdrawal volumes documented at Oconee over the 2-year Study.

Benefits of entrainment reduction technologies were analyzed by creating age-structured transition (i.e., Leslie) matrices (Leslie 1945, 1948; Caswell 2001). These dynamic matrix models were

[77] CFR Section §125.92(m) includes Alewife and Gizzard Shad on the list of fragile species; however, Threadfin Shad also exhibit similar characteristics and are a member of the same taxonomic family (Clupeidae). Therefore, Threadfin Shad should be considered a fragile species at this facility and were treated as such for this analysis.

developed incorporating survival rates and biomass by age, simulated through the remaining useful plant life to identify changes in forage or recreational fish stocks for each evaluated compliance technology.

11.3.1 Trophic Transfer

A comprehensive approach to benefit analysis requires, in addition to input parameter values for the equivalent adult and production foregone models, a variety of assumptions (or data) concerning trophic transfer efficiencies to mimic biomass flow pathways within source waterbodies (EPRI 2004a). Monetizing impacts to forage species is accomplished by converting them to an equivalent number and biomass of recreational and commercial species via the "trophic-transfer" method (EPRI 2004a). Although a trophic transfer efficiency of 10 percent is widely referenced and utilized in the ecological community (including the Regional Benefits Analysis for the Final Section 316(b) Phase III Existing Facilities Rule by the USEPA [2006]), it is also generally acknowledged that this value is an oversimplification of the complex ecosystems and food web relationships within a given waterbody (Burns 1989; USEPA 2006). Therefore, trophic transfer efficiencies were developed for the benefits analysis based on the fish community observed in environmental monitoring in the vicinity of Oconee to better represent the predator-prey relationships and the potential benefits of entrainment reduction via prey biomass transfer to economically valuable (recreational) taxa.

The percentage of biomass transferred (trophic transfer efficiency) was developed using a matrix with species-specific trophic levels and species relationships. Trophic levels were obtained from FishBase (Froese and Pauly 2019), a widely-accepted online fisheries database. Trophic transfer efficiency was dependent upon the percent allocation of the harvestable species and the trophic level relationship between harvestable and forage/non-game species (paired). While the trophic-transfer method provides a means for "accounting for" all entrained species, it lacks a way to consider complex food web dynamics (Burns 1989). It also does not incorporate the effects of entrainment reductions on species not included in the analysis, i.e., species within the vicinity of Oconee that were not entrained.

The abundance and diversity of ichthyoplankton collected at Oconee during the entrainment characterization study (Section 9) were relatively low and sunfish ichthyoplankton were the only recreational fish collected, and they were only collected in 2016. To more accurately represent natural food web dynamics in Lake Keowee, a BPJ decision was made to allocate trophic transfer of forage biomass to Alabama Bass, a recreational species that occurs in Lake Keowee, as well as sunfish (for 2016 only). As a top predator in Lake Keowee, the Alabama Bass is more likely to consume a larger portion of the additional forage biomass and was thus used in Section 11 to demonstrate the trophic transfer of forage biomass and potential implications to recreational yield of the technologies evaluated for Oconee.

11.3.2 Assumptions

Like all model approaches, there are assumptions inherent to the equivalent adult and production foregone models used to develop the comparative scenario outputs. These models do not assume density-dependent effects in the unaffected populations, such as faster growth rates and/or greater survival of fish not entrained or impinged due to reduced competition or predation. Additionally, both models assume that "losses" are equivalent to complete removal of the biomass from the system (total carbon removal and no longer available as an energy resource). Equivalent adult models also assume stock equilibrium, i.e., that an adult female fish will produce enough eggs during her lifetime to replace herself and one male (Goodyear 1978). As a result, these models are intrinsically conservative in loss and benefit valuations.

11.3.3 Quality Assurance/Quality Control Procedures

The life history table development and modeling process included QC and documentation to ensure the quality of model inputs and outputs. A general overview of the quality QC procedures implemented through the biological modeling process is summarized in Table 11-5.

Table 11-5. QC Procedures for the Oconee Benefits Valuation Biological Modeling Process

Model Development Step	QA/QC Procedure
General	• Data converted from PDF to Excel where possible • Data copied and pasted as values preferred over manual data entry • All BPJ decisions documented
Species mapping decisions	• Reviewed by a Senior Fish Biologist
Data compilation	• Data inputs reviewed for integrity (sources), applicability (e.g., regional-specific data, surrogate species, etc.), and calculation or transcription errors
Life history table balancing	• Data inputs reviewed for data integrity, applicability, and transcription errors • Review of formula accuracies and balancing methodology
On-screen survival	• Review of species selections, data analyses, and value finalization
Modeling	• Formulas reviewed for accuracy, trends in survival, growth rates, etc. evaluated for consistency • Modeling process described by EPRI (2004a, 2012) was replicated to ensure model accuracy • Checksums performed on time series modeling for data accuracy
Trophic transfer matrix	• Step-wise matrix building reviewed for accuracy of trophic level values and formulas for trophic transfer efficiencies

11.4 Basis for Monetized Values Assigned to Changes in Stock Size and Harvest Levels

Projected changes in fish stocks (Appendix 11-C) were used to develop the potential reductions in entrainment and impingement mortality (i.e., candidate technology benefits; Appendix D), which were incorporated to the monetization of benefits summarized in the Entrainment Reduction Benefits Valuation Study for Oconee (Veritas 2020; Appendix 11-E). The study results are summarized in this section, while Appendix 11-D provides the study report detailing the assumptions, methodologies, and results. Calculation of benefits on a taxa-life stage basis are provided in Appendix 11-E.

11.4.1 Interpreting Benefits Valuation Figures

Figure 11-2 and associated text in this section provides example output from the benefits valuation process with notes on interpreting the subsequent figures. In this example, the change in recreational yield is shown for a technology that becomes operational in 2024 (illustrated by the first arrow) and remains operational until the plant is scheduled to close (2043 as indicated by the second arrow). The example indicates that the estimated difference in recreational yield over this time period would be much greater under Reduced-Entrainment conditions (i.e., with a technology installed) than under the With-Entrainment (baseline) conditions[78]. Benefits of technology conclude once the plant retires or ceases to operate.

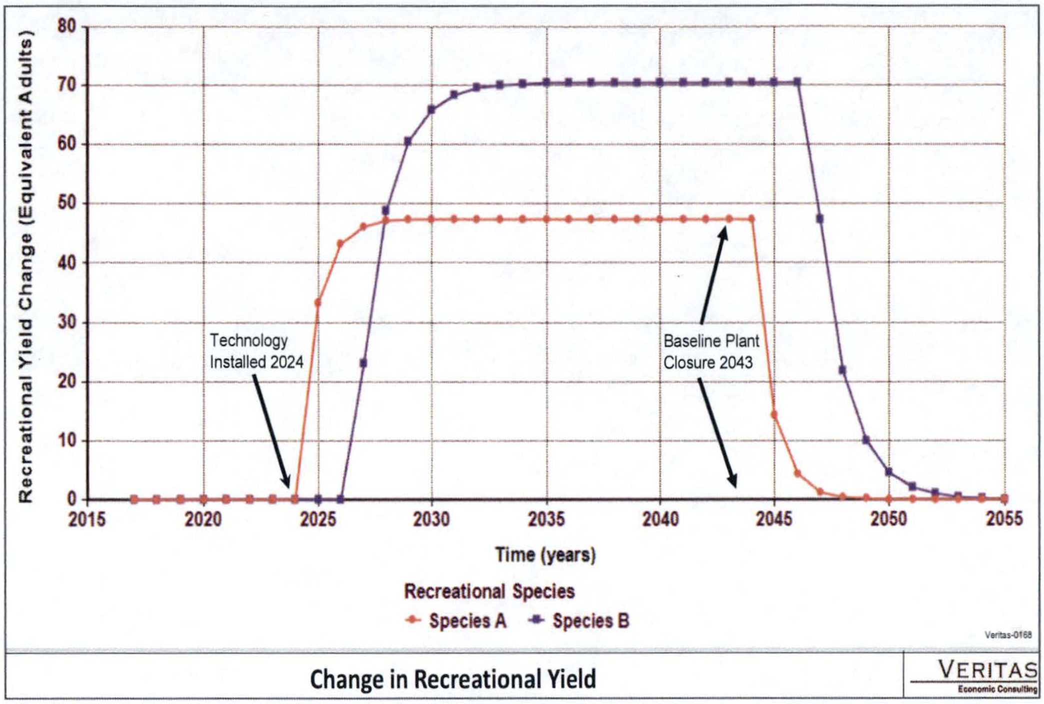


Figure 11-2. Change in Recreational Yield with Technology Installation (Example)

[78]For expositional purposes, Figure 11-2 presents the metric of recreational yield. The concepts described in the text accompanying Figure 11-2 can also be applied to the additional metrics presented throughout this section including number of recreational adults, forage species biomass, change in expected catch, change in number of trips, and welfare difference.

The example on Figure 11-2 depicts the recreational yield changes for two species. Species A is recruited to the fishery quickly and has a relatively short lifespan—approximately six years. Species B is recruited to the fishery more slowly and has a longer lifespan—approximately 25 years. For both species, although entrainment is reduced in 2024, the juveniles that are spared are not yet eligible to be caught in 2024; therefore, there is no increase in yield.

- In 2025, the juveniles of Species A that were not entrained in 2024 become vulnerable to fishing gear and there is an increase in yield of 32 fish for Species A.
- In 2026, additional juveniles of Species A become vulnerable to fishing gear. However, the change in yield for Species A does not double from 2025 to 2026 because the fish caught in 2025 and those that died naturally are removed from the fishery. Thus, the yield of Species A increases to 43, consisting of:
  - 32 one-year-olds that were not entrained in 2025; and
  - 11 two-year-olds that were not entrained in 2024.
- In 2027, the yield of Species A increases by a total of 47, consisting of:
  - 32 one-year-olds that were not entrained in 2026;
  - 11 two-year-olds that were not entrained in 2025; and
  - 4 three-year-olds that were not entrained in 2024.

As the fishery evolves, the yield of Species A reaches a steady state around 2030 when the fish not entrained in 2024 have either been caught or have died naturally and are no longer part of the fishery. This steady state continues one year past the scheduled baseline plant closure in 2043. After 2043, there is no difference between With- and Without-Entrainment Conditions because the plant is scheduled to cease operations. The 32 recruits to the fishery that would not have been entrained in 2044 with the technology in operation are no longer included in the analysis because the plant is no longer operating; therefore, the increase in recreational yield change starts to decline (15 caught fish in 2045).

In 2046, only fish spared before 2043 are caught (i.e., age three and older), reducing the change in recreational yield further (five fish in 2046). This decline in the recreational yield change continues until there are no more fish in the fishery that have a maximum lifespan of six years and would have otherwise been entrained in 2043. Yield changes for Species B are similar; however, the curve has a slightly different position because Species B takes two years longer to be recruited to the fishery and lives longer. As a result, Species B yield changes begin in 2026, do not begin to drop off until 2047, and take longer to dissipate than Species A.

The results in Figure 11-2 are presented for one year of theoretical entrainment data. The following figures presented throughout this section depict results using two years of collected entrainment data (2016 and 2017) at Oconee. The simulated model results using each year are presented individually so the effects that interannual variation have on each component of the benefit estimation process are transparent.

Presenting the results for the multiple entrainment reduction technologies evaluated at Oconee adds additional complexity to the benefit reduction figures. To simplify interpretation of the benefits figures, an additional scenario is used to demonstrate the maximum potential entrainment reduction benefit (i.e., a 100 percent reduction), referred to as the "Without Entrainment" scenario. A summary of the estimated monetized benefits of each entrainment reduction technology evaluated for Oconee are presented in Table 11-12 at the end of this section.

11.4.2 Estimating Entrainment Reduction Benefits

Estimating the benefits of entrainment reductions requires assessing the relationship between entrainment, its corresponding changes to the relevant fishery, and the impact that fishery changes have on people. For example, properly assessing recreational values requires understanding how entrainment at Oconee affects recreational fishing catch rates and how those changed catch rates affect the well-being of anglers located in the vicinity of the plant.

Age-structured changes in stock using survival parameters were developed and linked to the site-choice simulation model through fishery-specific catch and effort rates. This forms a bio-economic equilibrium (i.e., yield, trips, and expected catch are integrated) for the With-Entrainment representation of the Lake Keowee fishery expected to be affected by entrainment at Oconee. The integrated partial equilibrium models are used to simulate conditions under With-Entrainment (baseline) and Without-Entrainment conditions, and the monetized welfare differences between these two conditions determine the benefits of entrainment reductions. Equilibrium modeling using the With- and Without-Impact approach is central to benefit estimation and regulatory impact analysis (USEPA 2016). The analysis also considers the benefits that would result from reduced entrainment scenarios based on the feasible reduction technologies that were evaluated at Oconee.

Anticipated implementation timelines presented in Section 10 were used to estimate the dates when the station would start accruing operation and maintenance costs and entrainment reduction benefits for each feasible technology or compliance approach. All modeled technology scenarios assumed 2034 as the end of useful plant life.[79] Due to the complexity of retrofitting an existing nuclear station and nuances of minimizing and balancing station downtime requirements with regional power grid stability, the implementation of alternative technologies would occur incrementally over an extended period of time. Therefore, when modeling costs, a BPJ decision was made to begin accruing costs once the technologies were installed and operational at all of Oconee's units.

However, to maximize the estimated entrainment reduction benefits of each technology, a BPJ decision was made to begin accruing fisheries benefits after the installation of the technologies on the first of the units was completed, thus providing a longer timeline for the accrual of benefits before retirement in 2034. Table 11-6 presents the timelines used to model entrainment reduction benefits for each technology or compliance approach.

[79] The end of useful life for Oconee is based on the expiration date of the current operating license issued by the USNRC. The operating license for Units 1 and 2 expire in 2033 and the operating license for Unit 3 expires in 2034.

Table 11-6. Timeline Assumptions Used to Estimate Entrainment Reduction Benefits of Feasible Technologies or Compliance Approaches at Oconee Nuclear Station

Entrainment Reducing Technology or Compliance Approach	Technology Benefit Start Date	Technology End Date[1]	Years of Operation[2]
Without-Entrainment Scenario[3]	2026	2034	9
Reduced-Entrainment Scenarios			
FMS Retrofit of Existing CWIS	2024	2034	11
FMS with New CWIS	2026	2034	9
MDCT	2026	2034	9

[1] Anticipated station retirement date.
[2] Timelines represent anticipated date of first operation of the technology through station retirement.
[3] Assumes station retirement in 2026 in lieu of entrainment reduction technology installation.

11.4.2.1 Estimating Non-Recreational Benefits (Forage Species)

Monetizing impacts to forage species is accomplished by converting them to an equivalent number and biomass of recreational taxa via the trophic-transfer method. As typically applied, this approach multiplies forage/non-game biomass (i.e., production forgone) by a conversion factor dependent on differences in trophic level indices between the paired forage/non-game taxa and recreational taxa. This approach is further described in the Entrainment and Impingement Calculation Appendix (Appendix 9-C).

11.4.2.2 Estimating Recreational Benefits

Changes in recreational yield (which affects anglers) could occur at recreational sites throughout Lake Keowee, and includes anglers residing in counties within 50 miles of Oconee (Figure 11-3). Substitute sites were also considered, which were defined as sites where anglers can fish that are not affected by entrainment at Oconee (generally within 100 miles of the affected site). The change in expected catch per unit effort (i.e., catch per trip) of each recreationally harvested species in Lake Keowee is presented in Figure 11-4.

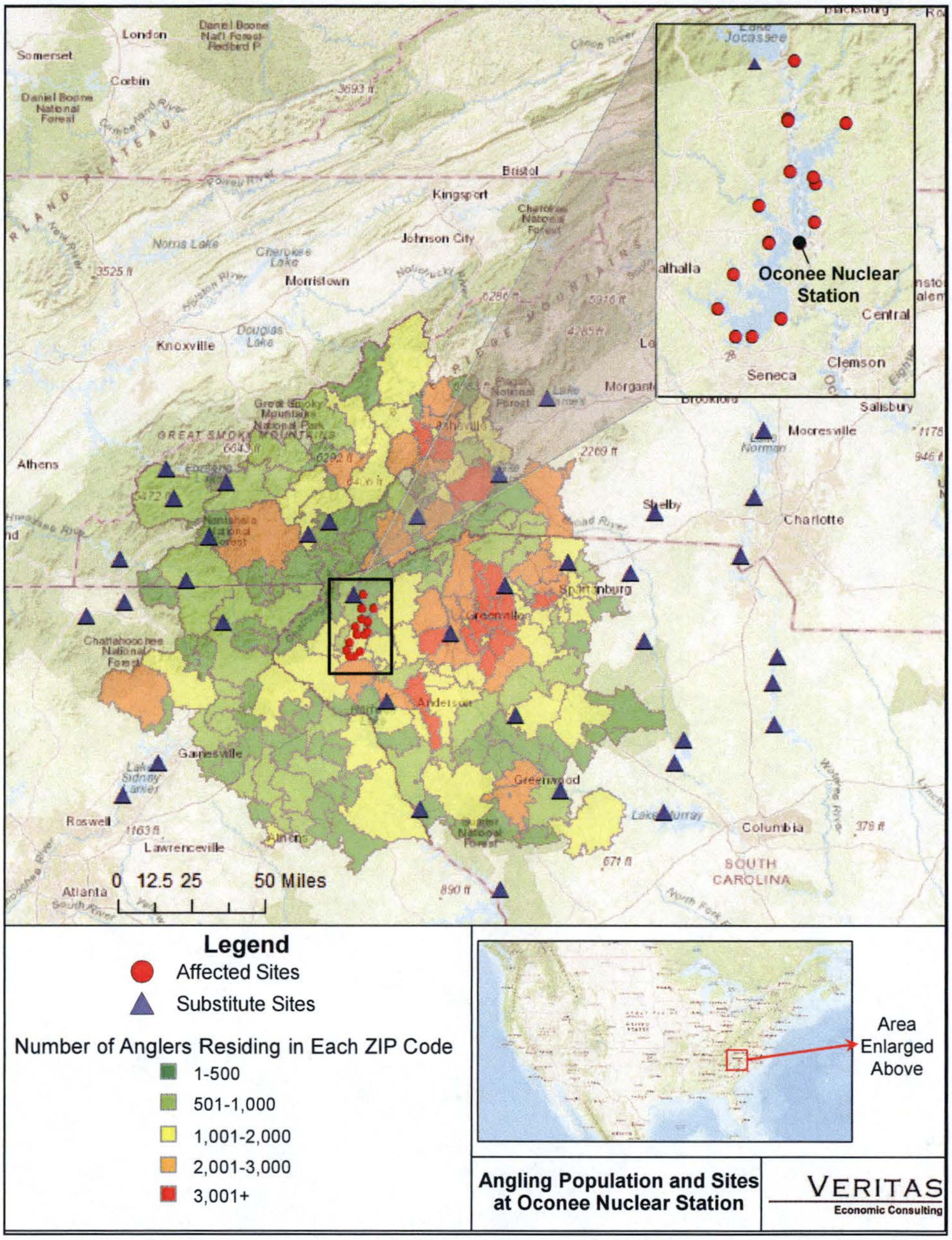


Figure 11-3. Location of Sites with Affected Catch Rates, Location of Substitute Sites, and the Concentration of Anglers (Veritas 2020)

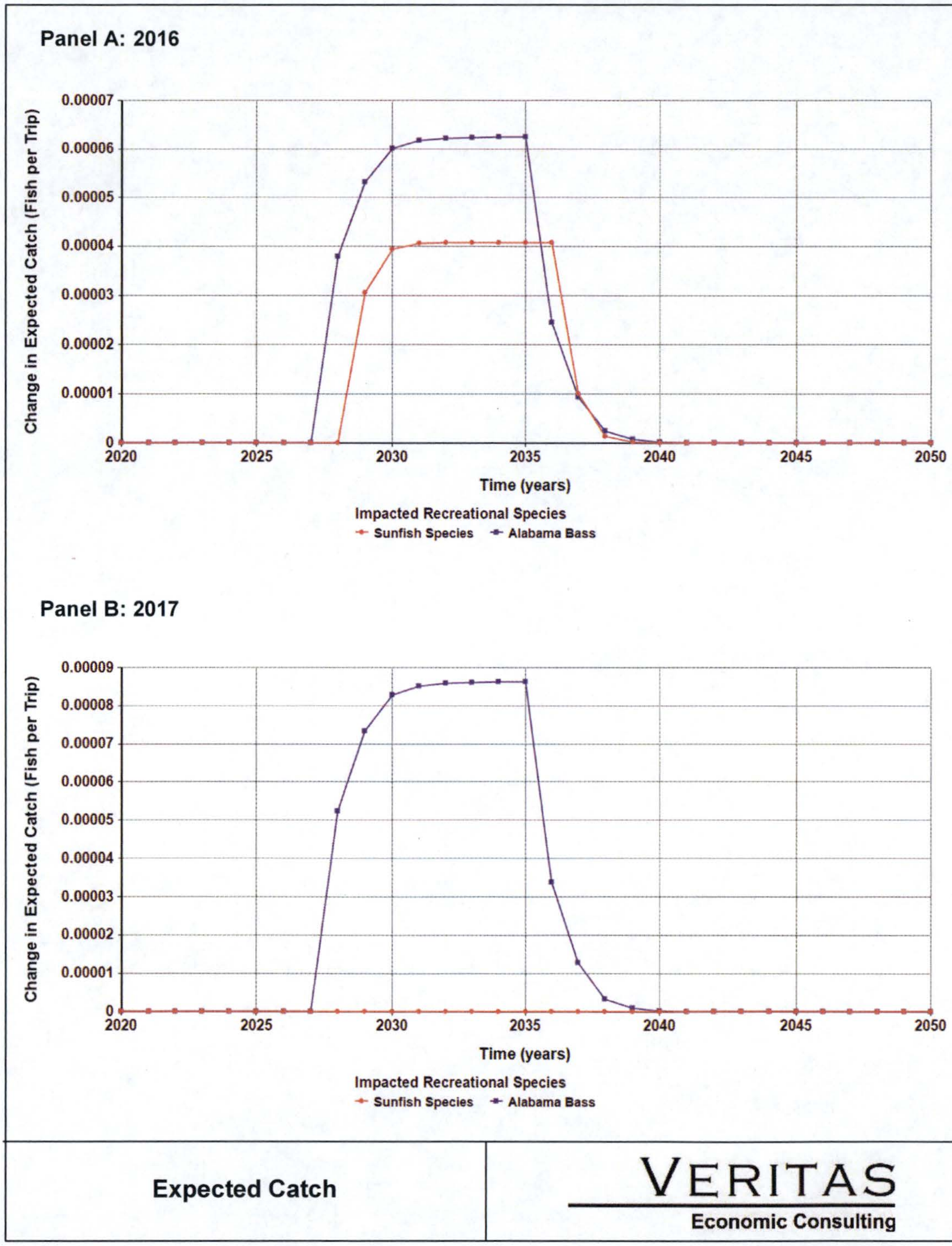


Figure 11-4. Change in Expected Catch per Trip by Species in Lake Keowee (Veritas 2020)

Based on expected catch changes, equations from welfare economics were used to identify annual changes in trips and economic benefits (based on changes in expected catch for all affected species). Changes in consumer surplus that arise from changes in site demand are the primary metrics for assessing economic benefits. This methodology is consistent with economic theory and adheres to rule discussion with respect to considering the "the availability of alternative competing water resources for recreational usage (alternative substitute sites), and the resulting estimated change in demand for use and value of the affected water resources" (79 FR 158, 48371). Figure 11-5 depicts the total change in trips to affected sites where catch rate changes are specified to occur based on the complete elimination of entrainment at Oconee.

The expected change in number of fishing trips to Lake Keowee (affected sites) based on the benefits of eliminating entrainment losses were estimated to be between 1.1 trips (2016) and 1.5 trips (2017) in 2034, at the station's assumed retirement date (Figure 11-5). The increased number of fishing trips would result in minimal welfare value, estimated between $50 and $70 at peak levels (Figure 11-6).

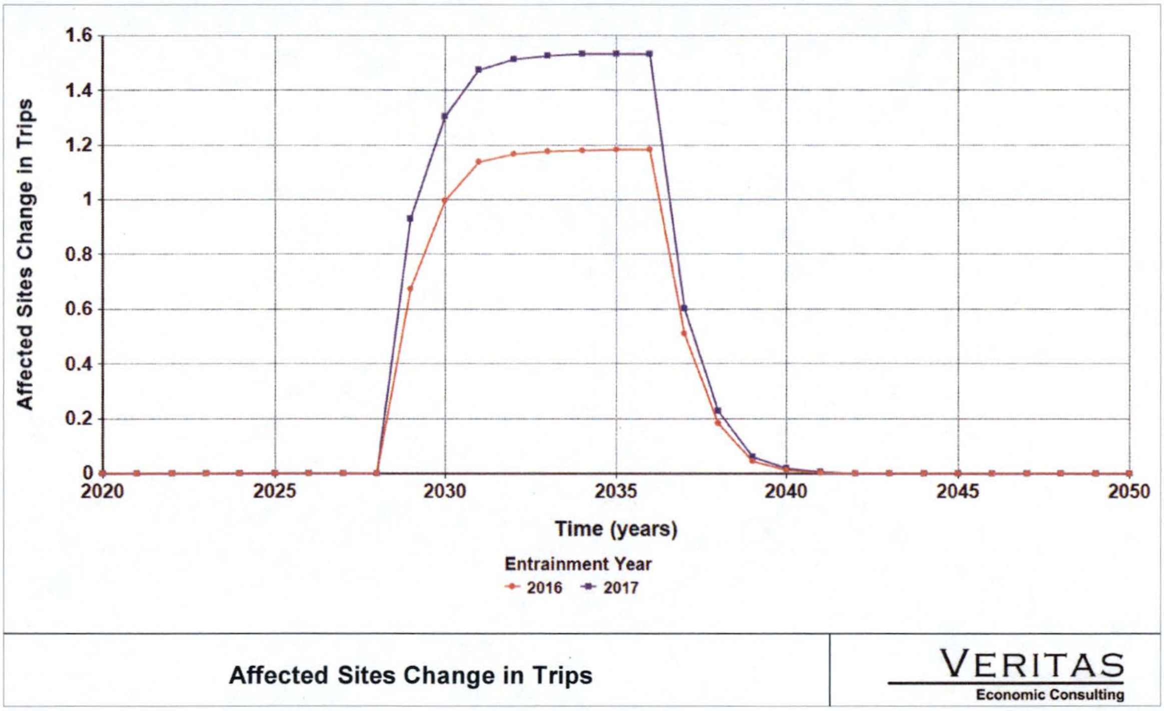


Figure 11-5.Estimated Trip Change with Elimination of Entrainment at Oconee (Veritas 2020)

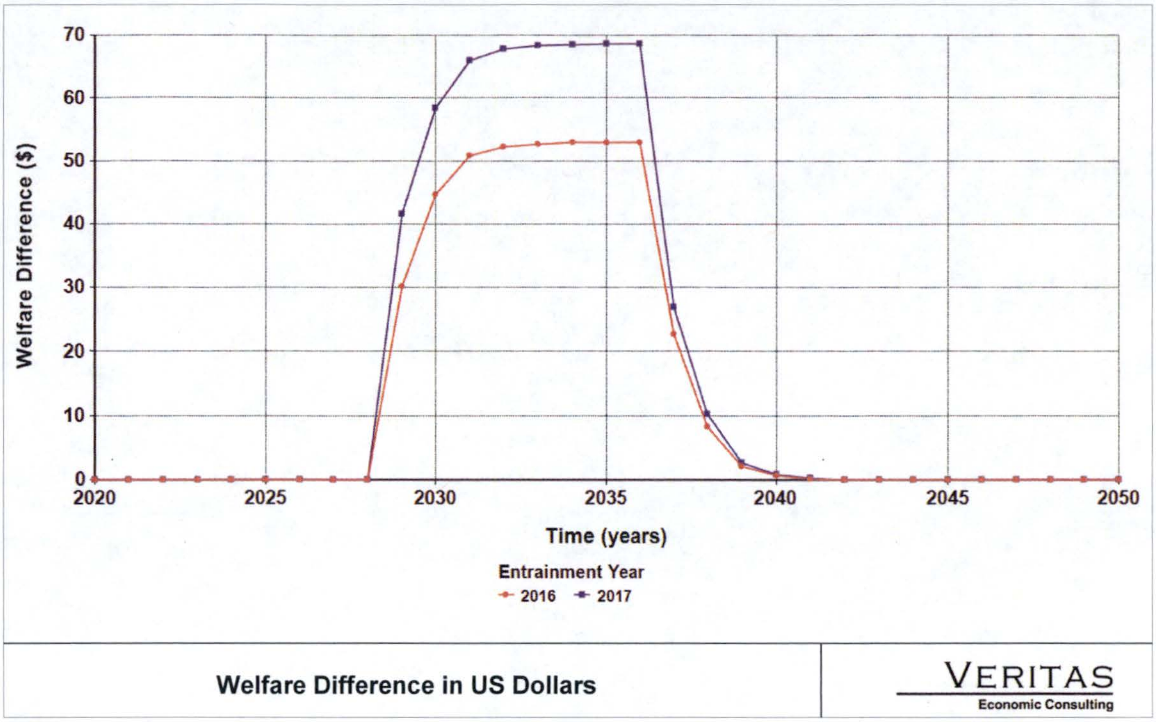


Figure 11-6. Change in Welfare with Elimination of Entrainment at Oconee (Veritas 2020)

11.4.2.3 Estimating Nonuse Benefits

The final category of benefits that could be monetized is nonuse benefits. Krutilla (1967) presented the original philosophical underpinning for nonuse values, arguing that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote:

> "when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (Krutilla 1967, p. 779).

Important components of Krutilla's original concept are that nonuse values are related to the continuing existence of unique resources. Under this framework, common resources suffering from limited injury do not generate significant nonuse values. The economic literature emphasizes the relationship between nonuse values and both the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman et al. 2014; Freeman 2003). Freeman (2003) summarizes this relationship as follows:

> "…economists have suggested that there are important nonuse values in …preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes" (Freeman 2003, p. 156).

Common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse value (Freeman 2003). Entrainment sampling indicates that no threatened or endangered species are being entrained at Oconee, and all of the estimated increased recreational yield are Sunfish Species and Alabama Bass, which are not unique and not expected to experience irreversible losses. Therefore, reductions in Oconee's entrainment are not likely to generate significant nonuse values.

While experts tend to agree on the existence of nonuse values, there is a high degree of debate on the ability to develop reliable estimates of nonuse benefits (Barnthouse et al. 2016). There is also uncertainty regarding what population can hold nonuse values for an individual facility and whether individuals with no prior knowledge of a resource can hold nonuse values (Johnson and Bingham 2001). Nonuse values have therefore not been quantified as part of this effort.

Given these constraints, nonuse values were considered qualitatively. Provided the estimated entrainment reduction costs and benefits, reliably measured nonuse benefits are not expected to impact a BTA determination that considers benefits and costs.

11.5 Estimated Fishery Benefits by Technology

11.5.1 Estimated Changes in Stock and Harvest

The estimated changes in stock and harvest under existing conditions in pounds (lbs) and evaluated entrainment and impingement reduction technologies are summarized in Table 11-7 and Table 11-8. Results are provided on a taxa-life stage basis in Tables 11-C1 through 11-C4 in Appendix 11-C. A summary of technology-specific results are presented in the following sections.

Table 11-7. Annual Entrainment Loss Estimates by Candidate Technology Scenario for 2016 and 2017 at Oconee Nuclear Station[1]

Scenario	Equivalent Adults (No.)[4]	Equivalent Adults (lbs)[4]	Production Foregone (lbs)[4]	Harvest Foregone (lbs)[4]
2016				
Baseline[2]	40	8	2,423	3
FMS[3]	25	5	988	2
MDCT	1	<1	63	<1
2017				
Baseline[2]	--	--	3,178	--
FMS[3]	--	--	1,791	--
MDCT	--	--	83	--

[1]Numbers were rounded to the nearest whole number. [2] Baseline condition represents the current system of technologies consisting of the intake canal curtain wall and submerged weir, CWIS overhang, 3/8-inch coarse-mesh fixed-panel water screens and no aquatic organism return system. [3]FMS losses include convert mortalities.

[4] Both recreational and forage taxa were collected in 2016, thus estimates by technology are provided for equivalent adults, production foregone, and harvest foregone. However, only forage taxa were collected in 2017 allowing only production foregone to be estimated. Equivalent adult and harvest foregone estimates are only provided for entrainment losses of recreational taxa.
(--) Indicates no organisms were collected during the Study thus model outputs were not available".

The degree of interannual variation in equivalent adults, production foregone, and harvest foregone estimates documented in Table 11-7 demonstrates the potential annual variation in benefits that can be anticipated for fishery stocks in Lake Keowee near the Oconee CWIS under an entrainment reduction technology. Furthermore, it is important to consider how non-operational factors (e.g., year class strength, annual precipitation and flow changes, annual temperature patterns and fluctuations) can influence fishery stocks and annual entrainment estimates. Therefore, it is important to note that annual entrainment estimates and potential entrainment reduction benefits are intended to be generally representative of potential conditions at Oconee and are not intended to represent minimum or maximum scenarios.

Table 11-8. Annual Impingement Loss Estimates by Candidate Technology Scenario for 2016 and 2017 at Oconee Nuclear Station[1]

Scenario	Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Harvest Foregone (lbs)
		2016		
Baseline[2]	571	116	3,550	52
Post-IM BTA	139	29	3,463	13
MDCT	15	3	92	1
		2017		
Baseline[2]	589	120	3,512	54
Post-IM BTA	143	29	3,427	14
MDCT	15	3	91	1

[1]Numbers were rounded to the nearest whole number. [2] Baseline condition represents the current system of technologies consisting of the intake canal curtain wall and submerged weir, CWIS overhang, 3/8-inch coarse-mesh fixed-panel water screens and no aquatic organism return system. . This technology represents the losses that would be eliminated if Oconee's units were retired and impingement was eliminated.

11.5.1.1 Without-Entrainment Condition

Entrainment

Based on the Without-Entrainment Scenario, up to 40 equivalent adults with total biomass of 8 lbs may be returned to the fishery under the Without-Entrainment scenario (100 percent elimination of entrainment) (Table 11-7). Recovered production foregone would return between 2,423 lbs and 3,178 lbs of forage biomass to the fishery. The total potential effect to the recreational fishery by eliminating entrainment at Oconee would be between 0 and 3 lbs of harvest foregone. The low values for equivalent adult, production foregone, and harvest foregone were driven by the low species richness and densities entrained due to the existing curtain wall, resulting in low annual estimates (Section 9). Only forage species were entrained during 2017, resulting in no harvest foregone estimated (Appendix 11-C, Tables 11-C1 and 11-C2).

The estimated benefits of the Without-Entrainment scenario were annualized across the remaining useful plant life (Figure 11-6) for recreational species (sunfish) and forage species (clupeids,) entrained at the CWIS (Figure 11-7 and Figure 11-8), and based on the assumption that the station would be retired in December 2025, 5-years after the anticipated submittal (December 2020) of the

NPDES renewal application and CWA §316(b) compliance package. Maximum direct benefits to recreational species over the time period were estimated to be approximately 19 equivalent adults in 2016, and zero for 2017. No direct benefits to recreational species were estimated for 2017 because no recreational species were collected in entrainment samples that year. Direct benefits to forage species were similar between the two years, with up to 1,700 pounds of forage species biomass returned to the fishery in 2016 and up to 1,500 pounds of biomass in 2017 with elimination of entrainment at Oconee. Direct benefits to forage species contributed to all clupeid species and species groups.

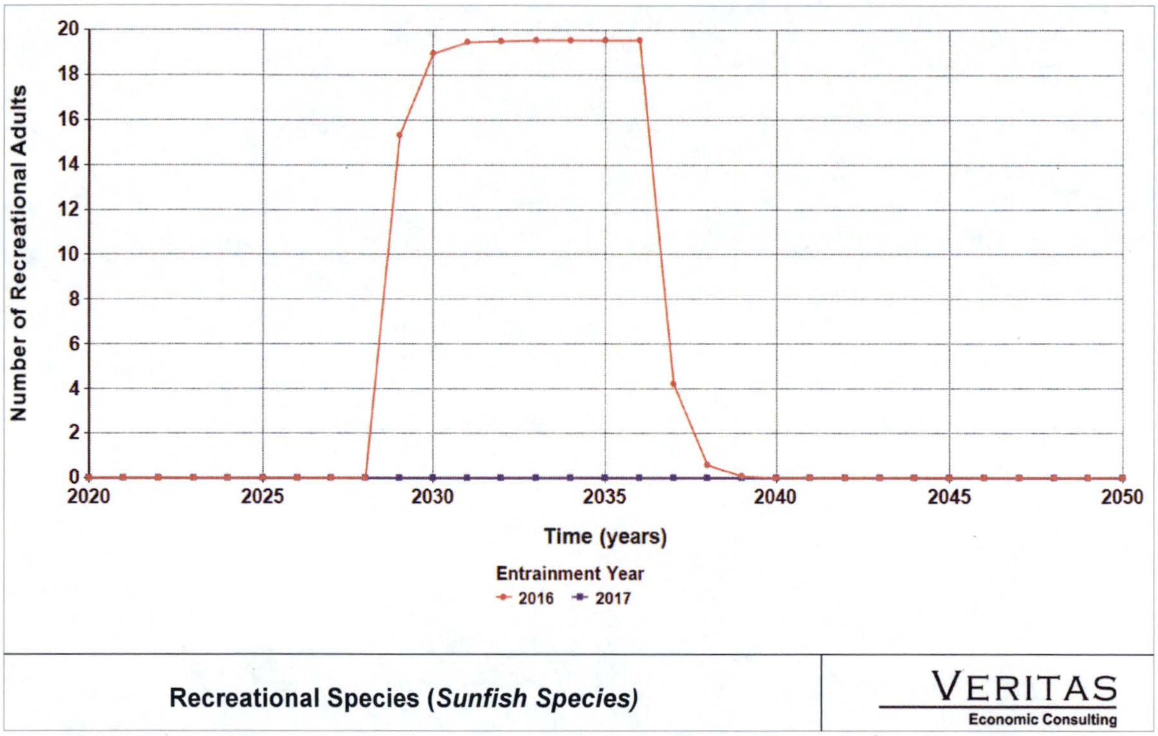


Figure 11-7. Direct Changes in Recreational Fish Stocks as Equivalent Adults with Elimination of Entrainment at Oconee (Source: Veritas 2020)

The benefits of reducing biomass losses of forage species were captured through the trophic transfer of this biomass (lbs) to the recreational taxa during the development of the annualized benefits data. In the absence of a predatory recreational species, Alabama Bass was used as a surrogate species to assume the majority of forage species biomass transfer, since it is more likely that Alabama Bass use clupeids as a food resource than Sunfish Species. The trophic transfer-based changes to predator stock as a result of changes in forage biomass is illustrated in Figure 11-9.

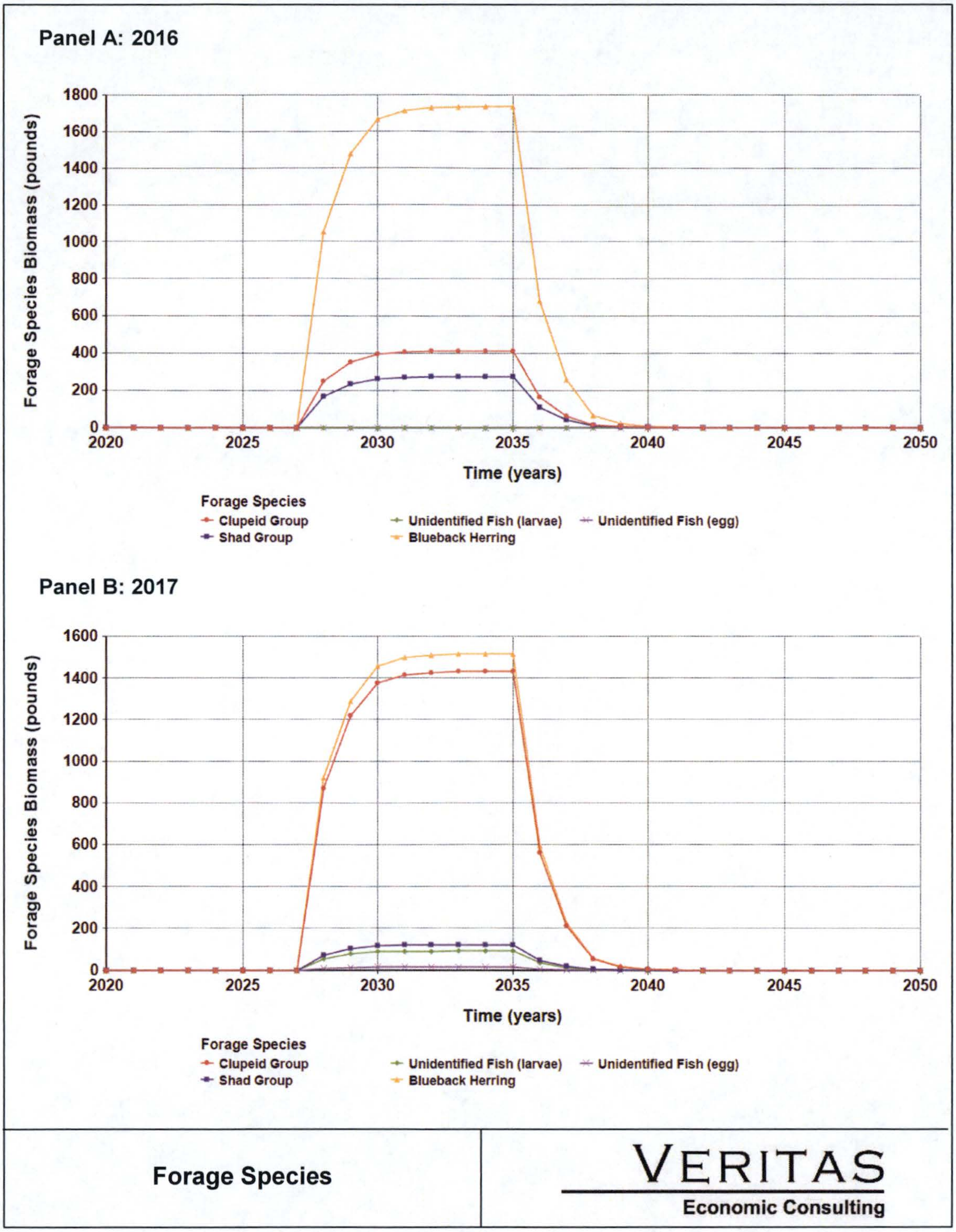
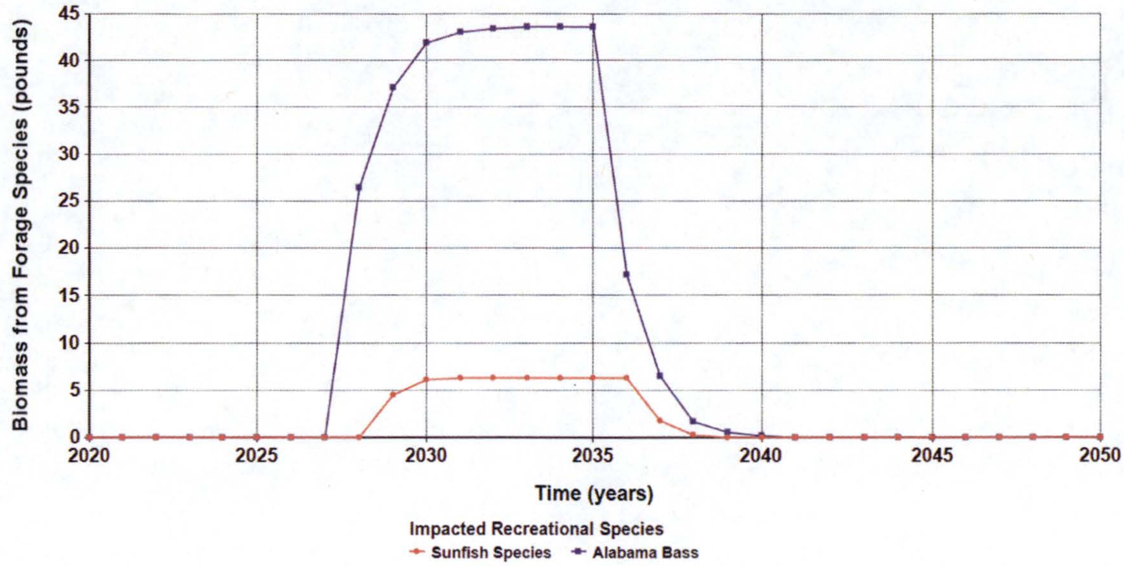
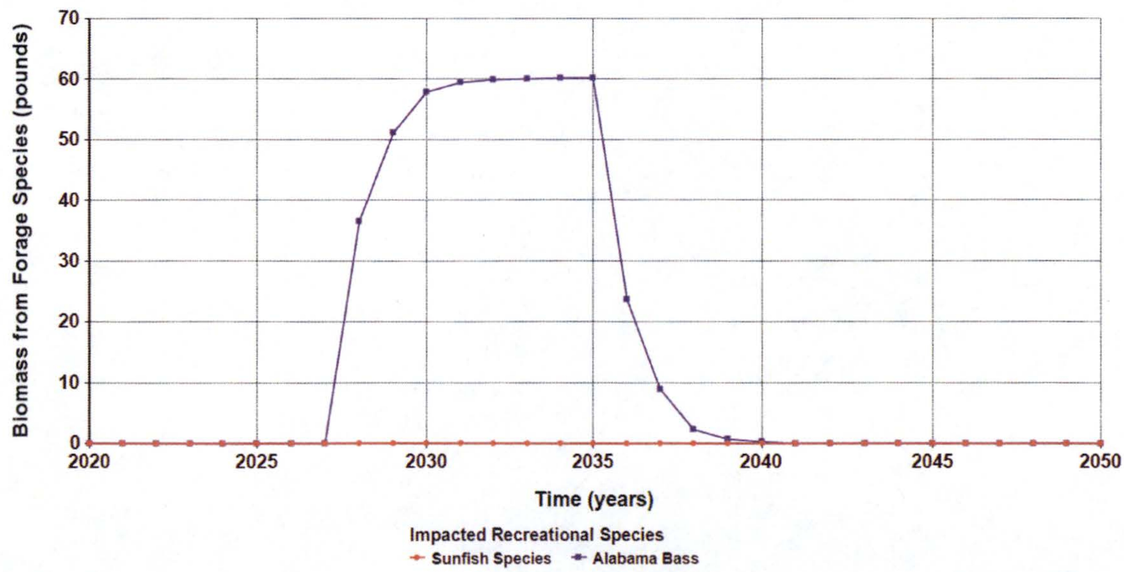


Figure 11-8. Direct Changes in Forage Fish Stocks as biomass (lbs) with Elimination of Entrainment at Oconee (Source: Veritas 2020)

Panel A: 2016



Panel B: 2017



Biomass from Forage Species

VERITAS
Economic Consulting

Figure 11-9. Trophic Transfer-Based Changes in Pounds of Biomass with Elimination of Entrainment at Oconee (Source: Veritas 2020)

To identify the recreational yield changes associated with changes in stocks, harvest rates are applied to stock changes. When possible, these harvest rates are based on fishery stock assessments of the source waterbody. When stock-specific recreational harvest rates are not available, they are developed based on species-specific harvest rates provided in the literature (USEPA 2006; EPRI 2004a, 2012) with adjustments based on BPJ. Using this information, the maximum estimated annual increase in recreational yield in the absence of entrainment is modest, from 3.9 to 8.2 equivalent adults depending on species and year, as illustrated in (Figure 11-10).

These low equivalent adult estimates reflect the existing system of technologies, CWIS AOI and its small footprint relative to the total surface area of Lake Keowee (18,357 acres), and the potential fish habitat it provides. Further, as the only recreational taxa collected in entrainment samples, centrarchids are the primary contributors to the number of equivalent adult losses estimated for Oconee. Yet, the most recently available fishery monitoring data (2013 through 2018, Duke Energy 2018) demonstrated that populations of centrarchids in Lake Keowee have been increasing, despite increasing fishing pressure (Duke Energy 2007) and continued operations at Oconee.

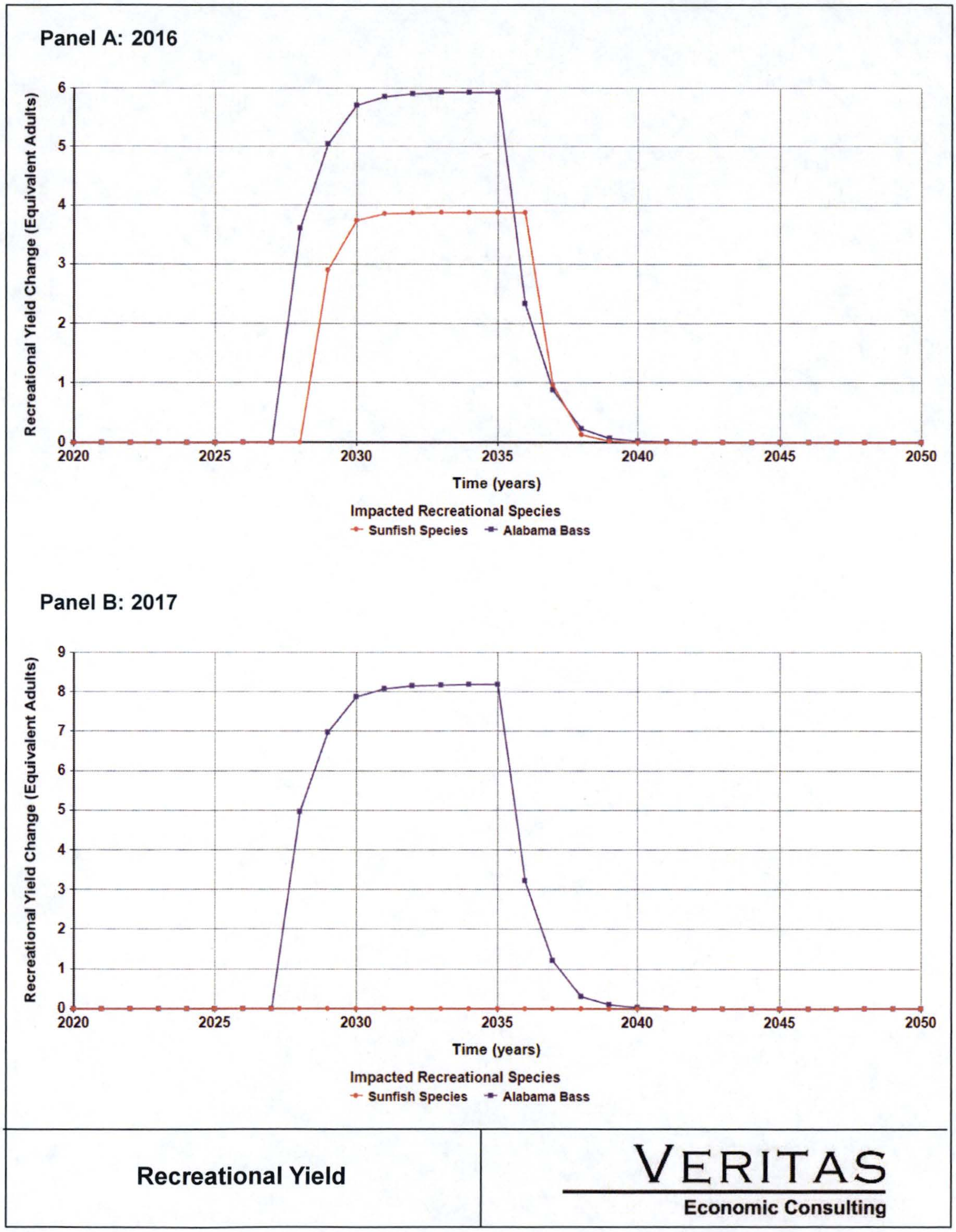


Figure 11-10. Total (Direct and Indirect) Changes in Recreational Yield with Elimination of Entrainment at Oconee (Source: Veritas 2020)

Impingement

Under baseline (existing) conditions, the changes in recreational and forage fish stocks would vary annually between an additional 571 (116 lbs) and 589 (120 lbs) equivalent adults returned to the fishery (Table 11-8). Recovered foregone production would return between 3,512 lbs and 3,550 lbs of forage biomass to the fishery, consisting primarily of Threadfin Shad and Blueback Herring. The total potential effect to the recreational fishery by eliminating impingement at Oconee would be a recovery of 52 to 54 lbs of harvest foregone returned to the fishery. Because annual IM estimates were made based on one year of data and extrapolated based on actual water withdrawals for 2016 and 2017, variation between years in individual species estimates were minor (Tables 11-C3 and 11-C4 in Appendix 11-C).

11.5.1.2 Estimated Changes with Fine-Mesh Screens and an Aquatic Organism Return System Scenario

Entrainment

The losses that would still be incurred with the installation of FMS would reduce the total losses in to the fishery in 2016 to 25 equivalent adults with a biomass of 5 lbs (Table 11-9). No equivalent adult losses were estimated for 2017 since no recreational taxa were entrained that year. Production foregone would be reduced to 988 to 1,791 lbs of forage biomass. With the installation of FMS, the recreational fishery would experience a loss of zero to two pounds of harvest foregone, annually, limited by the low number of harvestable species estimated to be entrained annually (Tables 11-C1 and 11-C2 in Appendix 11-C).

Overall losses of equivalent adults, production foregone, and harvest foregone were low due to the low numbers entrained (Sections 9 and 11.2.3) as mitigated by the presence of the curtain wall at the mouth of the intake canal (Section 7; HDR 2018a).

Table 11-9. Estimated Entrainment Losses with Fine Mesh Screens at Oconee Nuclear Station[1]

Scenario	Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Harvest Foregone (lbs)
2016				
1.0-mm FMS	--	--	988	--
Convert Mortalities	25	5	--	2
FMS Total Mortalities	25	5	988	2
2017				
1.0-mm FMS	--	--	1,332	--
Convert Mortalities	--	--	459	--
FMS Total Mortalities	--	--	1,791	--

[1]Numbers were rounded to the nearest whole number
(--) Indicates no organisms were collected during the Study thus model outputs were not available".

Impingement

The FMS scenario assumes a mesh size smaller than that modeled for the Post-IM BTA compliance scenario. The same fish impinged under the Post-IM BTA scenario (generally juveniles and adults) would also be impinged on the FMS. Moreover, converted organisms are accounted for under the entrainment mortalities and are not counted toward IM (79 FR 158, 48431). Therefore, this scenario presents the same impingement loss estimates as the Post-IM BTA discussed in the next section.

11.5.1.3 Estimated Changes under Post-IM BTA Compliance Scenario

The Post-IM BTA scenario is included as an additional scenario in the benefits evaluation process to provide a reference point to which entrainment BTA scenarios can be compared. This scenario is based on the assumption that traveling water screens with a fish return system would be the next least expensive compliance technology for addressing impingement compliance at a facility in comparison to the existing condition or a site-specific determination by the Director of *de minimis* rate of impingement. This information is not intended to represent a 'selected or preferred' IM reduction compliance approach for Oconee.

Entrainment

This scenario assumes the operation of 3/8-inch coarse mesh traveling water screens and an organism return system. Under this scenario, the screen mesh size remains the same as those currently installed at the facility and through which certain-size organisms remain susceptible to entrainment. Therefore, the entrainment loss estimates remain the same as those calculated for the baseline (existing) condition and this scenario does not offer any entrainment loss reduction benefit.

Impingement

Based on the installation of fish-friendly traveling water screens (such as Ristroph) and an organism return system, the reduced losses in recreational and forage fish stocks would total 139 (29 lbs) to 143 (29 lbs) equivalent adults (Table 11-8). Production foregone losses would be reduced to 3,427 to 3,463 lbs of forage biomass. The reduced impact to the recreational fishery by the addition of an organism return system at Oconee is between 13 and 14 lbs of harvest forgone, which consists solely of Blueback Herring and Threadfin Shad. Estimated losses by species and life stage can be found in Table 11-C3 and 11-C4 of Appendix 11-C.

11.5.1.4 Estimated Changes under Mechanical Draft Cooling Towers Scenario

Entrainment

Aside from the Without-Entrainment scenario, the MDCT scenario represents the largest reduction in entrainment. Under this scenario, losses still incurred with this technology would be up to one equivalent adult (of less than 1 lb of biomass) (Table 11-7). Production foregone losses would be reduced to between 63 and 83 lbs. Total impact to the recreational fishery would amount to less than 1 lb of harvest foregone biomass lost annually. As stated in Section 11.1.2.3, the installation of MDCTs would result in a 97.4 percent reduction in total numbers lost, equivalent adult numbers and biomass, production foregone biomass, and harvest foregone reductions from the baseline condition.

Impingement

Similar for entrainment reduction, IM estimated for 2016 under the MDCT scenario represents the greatest reduction in impingement and potential benefit to the fishery outside of the Without-Entrainment scenario, with a reduced loss of approximately 15 (3 lbs) equivalent adults estimated for both years (Table 11-8). Production foregone losses were estimated between 91 and 92 lbs. Total impact to the recreational fishery would be one pound of harvest foregone biomass.

11.5.2 Summary and Monetization of Benefits for Candidate Measures

11.5.2.1 Entrainment

A 2017 efficacy study (HDR 2018a) of the existing curtain wall demonstrated a reduction in entrainment of approximately 90 percent that extended to the CWIS; thus, the information for alternative entrainment reduction technologies summarized here represents potential additional incremental reduction benefits. Decreasing water withdrawals via MDCT retrofit would result in the greatest overall reduction in entrainment losses with a reduction of 97.4 percent in equivalent adults, production foregone, and equivalent yield (Table 11-10). Installation of modified Ristroph 1.0-mm fine mesh screens with an aquatic organism return system may reduce entrainment losses by up to 37.5 percent for equivalent adults and 33.3 percent for equivalent yield. However, interannual variation due to the composition and abundance of species and life stages within entrainment samples (i.e., no recreational species were collected) resulted in no equivalent adults or harvest foregone losses estimated for 2017, therefore there are no reductions and benefits calculated for that year (Table 11-D2 Appendix 11-D). With the installation of FMS, reductions in production foregone were estimated to be up to 59.2 percent in 2016 and 43.6 percent in 2017. A greater reduction was estimated for 2016 due to a greater entrainment of clupeid larvae during 2017, resulting in a greater reduction and benefit.

Table 11-10. Percent Reductions under Entrainment Compliance Technology Scenarios Relative to the Baseline Condition at Oconee Nuclear Station

Scenario	Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Equivalent Yield (lbs)
2016 Annual Percent Entrainment Loss Reduction				
Existing Condition[1]	--	--	--	--
FMS[2]	37.5	37.5	59.2	33.3
MDCT	97.4	97.4	97.4	97.4
2017 Annual Percent Entrainment Loss Reduction				
Existing Condition[1]	--	--	--	--
FMS[2]	--	--	43.6	--
MDCT	--	--	97.4	--

[1] Entrainment reduced by approximately 90% with the existing curtain wall.
[2] FMS scenario includes convert mortalities.

11.5.2.2 Impingement

Reduced IM with the installation of fish friendly, modified-Ristroph coarse mesh screens and an aquatic organism return system were estimated to be up to 75.8 percent for equivalent adults and equivalent yield for 2016 and 2017 (Table 11-11). However, similar to the FMS scenario for entrainment reductions, declines in production foregone were less substantial (2.4 to 2.5 percent) due to higher mortality rates of fragile forage species (i.e., clupeids), which represented 100 percent of the estimated production foregone. As with entrainment, IM estimates exhibit a proportional reduction through the application of decreased flows by 97.4 percent for the installation of MDCTs, and represents the technology with the greatest IM reduction.

Table 11-11. Percent Reductions under Impingement Compliance Technology Scenarios Relative to the Baseline Condition at Oconee Nuclear Station

Scenario	Equivalent Adults (No.)	Equivalent Adults (lbs)	Production Foregone (lbs)	Harvest Foregone (lbs)
2016 Annual Percent Impingement Loss Reduction				
Existing Condition	--	--	--	--
Post-IM BTA	75.7	75.0	2.5	75.0
MDCT	97.4	97.4	97.4	97.4
2017 Annual Percent Impingement Loss Reduction				
Existing Condition	--	--	--	--
Post-IM BTA	75.7	75.8	2.4	74.1
MDCT	97.4	97.4	97.4	97.4

[1]Baseline condition represents the current configuration of 3/8-inch coarse-mesh fixed panel water screens after withdrawal via the curtain wall and no organism return system. This technology represents the losses that would be eliminated if Oconee's units were retired and impingement was eliminated.

11.5.2.3 Summary of Monetized Benefits

The results below demonstrate the monetized values for the estimated recreational benefits of a complete reduction in Oconee's entrainment (Table 11-12). In addition to a 100-percent reduction scenario (station retirement), the analysis also considers the benefits that would result from the entrainment reduction alternatives evaluated at Oconee. To develop the present value estimates, the benefits estimated for each feasible alternative are discounted at 3 and 7 percent annually and summed over the specified time period used in the analysis (Table 11-6). Additional details on the development of monetized benefits is included in the study report provided in Appendix 11-E.

Table 11-12. Summary of Monetized Commercial and Recreational Social Benefits of Entrainment Reduction Alternatives at Oconee (Veritas 2020)

Discount Rate	Technology	2016 Entrainment Data		2017 Entrainment Data	
		Present Value	Annual Value	Present Value	Annual Value
3%	Without-Entrainment (100% Reduction)[1]	$279	$35	$362	$45
	Reduced Entrainment (With Technology)				
	MDCT	$272	$34	$353	$44
	FMS	$211	$21	$204	$20
	FMS with new CWIS	$164	$20	$158	$20
7%	Without-Entrainment (100% Reduction)[1]	$165	$21	$214	$27
	Reduced Entrainment (With Technology)				
	MDCT	$160	$20	$209	$26
	FMS	$130	$13	$126	$13
	FMS with new CWIS	$97	$12	$93	$12

[1]Maximum potential benefit achievable by facility retirement and complete elimination of entrainment at the CWIS.

Given the annual entrainment loss estimates documented at Oconee for 2016 and 2017, the potential entrainment reduction benefits (both ecological and economic) are minimal under each of the scenarios presented in Table 11-12, even in comparison to potential benefits that could be realized if Oconee were to retire and validates the efficacy of the existing installed curtain wall. Regardless of technology, year of estimated loss, or discount rate assumptions, the present value of reductions in entrainment were estimated to range between $93 and $353 (MDCT in 2017) and the annual value was estimated to range between $12 and $44.

Barnthouse (2013) notes that the available peer-reviewed literature does not support a conclusion that entrainment reductions will produce measurable improvements in recreational or commercial fish populations. The social benefits estimated for Oconee based on entrainment reduction scenarios is consistent with this position, as there are minimal potential economic benefits that could be realized at Oconee.

11.5.3 Discussion, with Quantification and Monetization where Possible, of Other Benefits

Benefits (recreational, commercial, or both) from entrainment reductions arise from changes in catch rates and therefore accrue to people who use the affected resource. Another benefit category, nonuse benefits, results from changes in values that the public may hold for a resource, independent of their use of the resource. These can arise for a number of reasons: they may be pleased that other people can use the resource, they may want it to be available for use in the future, or they may believe the resource has some inherent right to exist.

Examples of nonuse benefits from the reduction or elimination of entrainment and impingement include ecosystem effects such as population resilience and support, nutrient cycling, natural species assemblages, and ecosystem health and integrity; aesthetic value; benefits to threatened or endangered species; or benefits to migratory species (79 FR 158, 48371). The fisheries benefits study does not evaluate or monetize other non-use values or effects which may occur in the absence of entrainment or impingement. For example, the non-native, invasive Flathead Catfish is among the species impinged at Oconee. The elimination or reduction of impingement of Flathead Catfish could result in this species increased abundance in Lake Keowee, leading to additional impacts to non-use values (i.e., reduced habitat availability and increased predation of native fish, increased competition for food resources, etc.) and to recreational use values due to lost fishing opportunities.

11.6 Social Cost to Social Benefit Comparison

When determining the BTA for reducing entrainment at a particular facility, the Director must consider the social costs and benefits of evaluated entrainment compliance options (§125.98 (f)(2)(v)). In a benefit-cost analysis with multiple alternatives, those with higher costs must also have higher benefits. Those that do not meet this criterion are inferior and are eliminated from further consideration. When the remaining technologies are ordered by costs, net benefits (benefits minus costs) increase, reach a maximum, and then decrease.

11.6.1 Illustration of Social Cost to Benefit Concept

An example of the social costs to benefits comparison is illustrated in Figure 11-11. The top panel presents the social benefits and costs of alternatives and the bottom panel presents the net benefits, or the difference between the benefits and the costs. Net benefits are positive for Alternatives 1, 2, and 3, and are maximized in Alternative 2. Net benefits are zero for Alternative 4 (i.e., social costs and social benefits are equal), and are negative for Alternative 5. Alternatives 1 through 4 are economically efficient (i.e., benefits are greater than or equal to costs). Decision-making on benefit-cost criteria leads to selecting the alternative with the maximum net benefits (Alternative 2). Alternative 5 would be eliminated from consideration because it has negative net benefits.

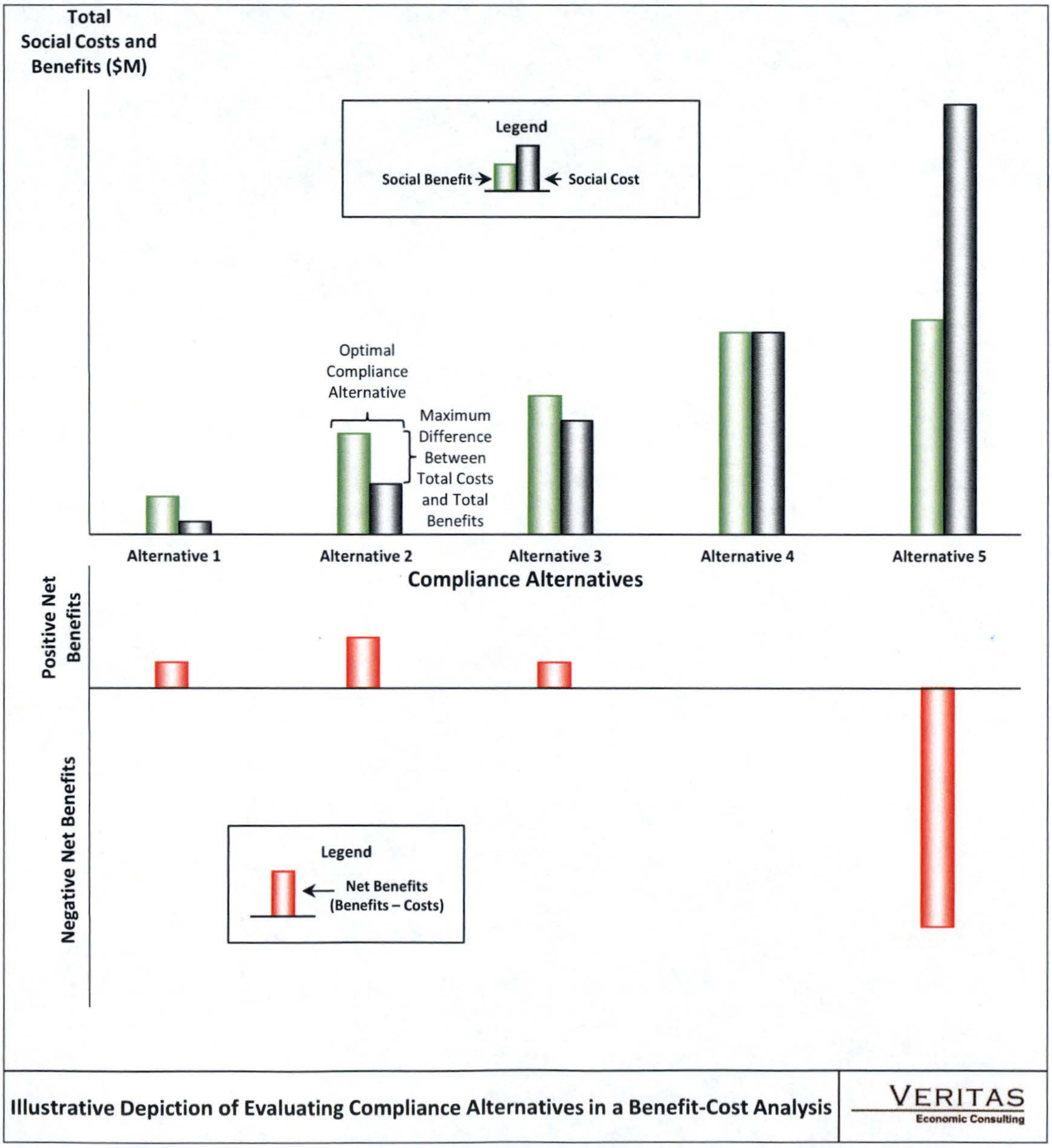


Figure 11-11. Determining the Optimal Compliance Alternative in a Benefit-Cost Analysis (Example) (Veritas 2020)

11.6.2 Social Cost to Benefit Comparison of Entrainment and Impingement Mortality Technology Options

The social costs and social benefits for each compliance technology option evaluated for Oconee are summarized in Section 10, and provides the present value estimates discounted at 3 and 7 percent based on the 2016 and 2017 entrainment and IM data. The social benefits include both the impingement and entrainment benefits estimated for each compliance option. The methodology and results for estimating the entrainment benefits are presented in the Entrainment Reduction Benefits Study (Appendix 11-E). The methods and results for estimating the social costs are presented in the Social Costs of Purchasing and Installing Entrainment Reduction Technologies Study (Appendix 10-H).

Figure 11-12 presents the social costs and benefits of the entrainment compliance options for Oconee discounted at 3 percent and also includes the social costs and benefits of the impingement compliance option. Including the impingement technology provides context for determining the entrainment BTA under the Rule's site-specific entrainment evaluation. Specifically, the Rule has two separate regulatory components:

- a command and control component in which the facility must implement one of seven impingement compliance alternatives (§ 125.94(c)) or demonstrate that its rate of impingement is *de minimis* (§ 125.94(c)(11)) or has a low capacity utilization factor (§ 125.94(c)(12)), and
- a site-specific best technology available evaluation to determine the maximum entrainment reduction warranted based, in part, on the social costs and social benefits of each technology.

By comparing the entrainment reduction options to the impingement option, the evaluation provides context for what is warranted for entrainment versus what is required for impingement.

The vertical axis in the top portion of Figure 11-12 presents the total social costs and total social benefits of each compliance option, and the bottom portion presents the net benefits (total social benefits minus total social costs) of each compliance option. The total social benefits are illustrated by the green bar, and the total social costs are illustrated by the black bar. The horizontal axis presents each compliance option. As the top portion of the figure shows, the total social costs are greater than the social benefits for each of the entrainment compliance options. The social costs of designating Lake Keowee as a closed-cycle recirculating system (CCRS) are the forgone incremental impingement benefits of the next least-cost impingement compliance alternative which is modified traveling water screens with an organism return system (not illustrated separately in Figure 11-12).

The bottom portion of the figure illustrates the net benefits of each compliance option. As the figure shows, the CCRS impingement compliance option (as identified in Section 6), represents the current configuration and has net benefits of -$461. By comparison, the entrainment compliance options of fine-mesh screens (FMS) and mechanical draft cooling towers (MDCT) have net benefits of -$105.61 M, and -$1.24 B, respectively.

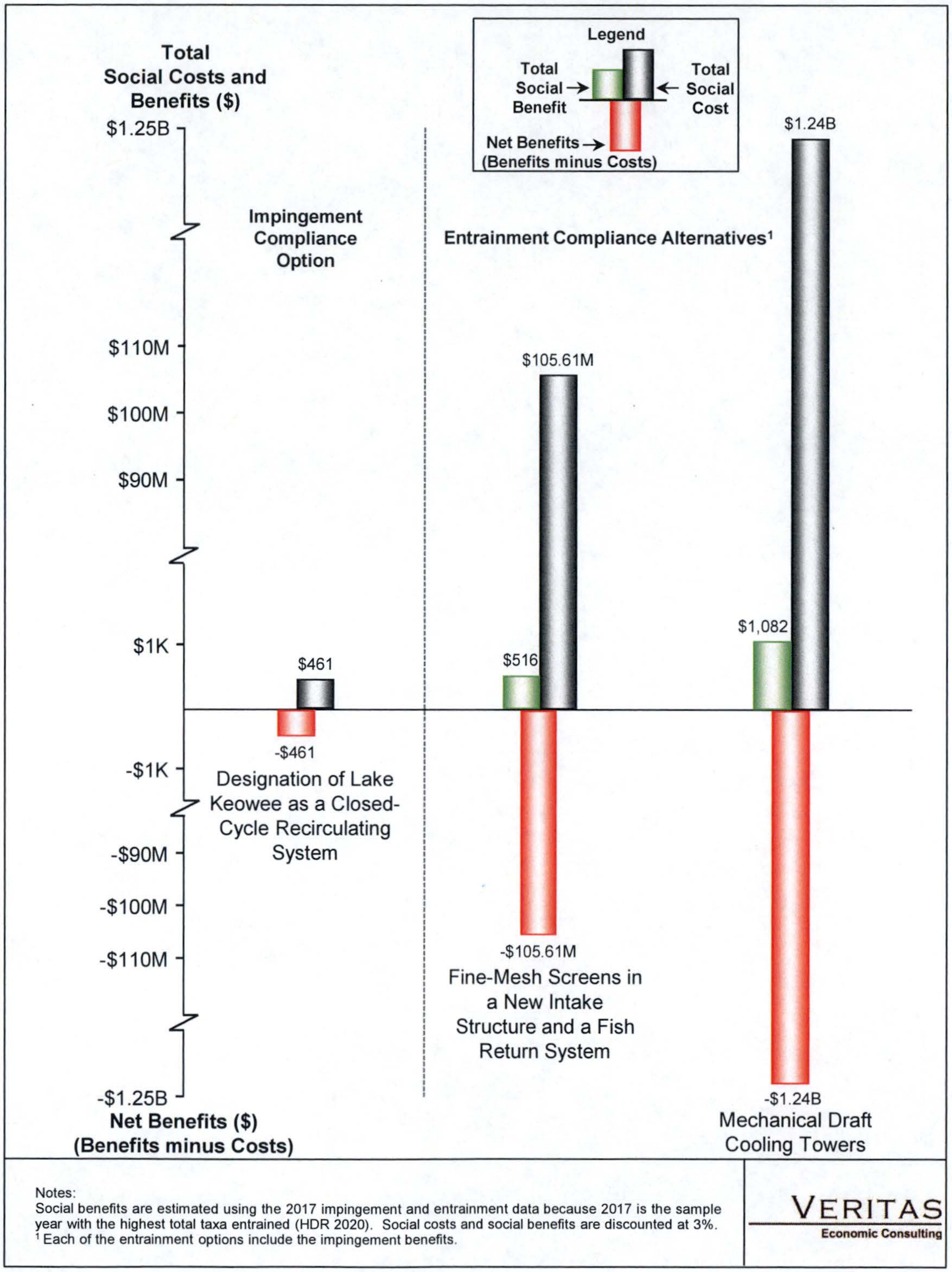


Figure 11-12. Comparison of Social Benefits and Costs at Oconee Nuclear Station (Assumes all units will be retired in 2034) (Source: Veritas 2020)

Entrainment BTA determinations require consideration of potential benefits and costs. Under the criterion that governs benefit-cost-based determinations, only technologies that have social benefits that exceed their social costs are justified (Boardman et al. 2018; Freeman et al. 2014). As noted in the Rule, "[i]f all technologies considered have social costs not justified by the social benefits...the Director may determine that no additional control requirements are necessary beyond what the facility is already doing. The Director may reject an otherwise available technology as a BTA standard for entrainment if the social costs are not justified by the social benefits (§ 125.98(f)(4))." Given that the net benefits are negative for each of the alternatives shown in Figure 11-12, the substantial social costs are wholly disproportionate to and not justified by the minimal social benefits. Therefore, none of the entrainment compliance options are justified as the BTA under the Rule's site-specific entrainment compliance requirements. Note that should the facility retire sooner than 2034, the results of the cost-benefit comparison would be even more disproportionate.

11.7 Uncertainty Analyses

Uncertainty is an inherent aspect of biological analyses such as equivalent adult and production foregone models due to the complexity, but necessary simplification, of biological systems. It is important to have an understanding of the potential influence that uncertainty may have on model-developed estimates presented in the benefits evaluation and the subsequent monetization of those benefits.

The equivalent adult (recreational species) and production foregone (forage or non-game species) estimates for Oconee were used to determine the benefits achievable under each candidate entrainment reduction technology scenario. Although unlikely to substantially change the results of the benefits analysis performed for Oconee, the BPJ decisions and assumptions made in the development of equivalent adult and production foregone models cumulatively have the potential to affect the monetization of benefits. Therefore, a qualitative evaluation was performed on the primary sources of uncertainty associated with this analysis (Appendix 11-F).

Estimates of recreational yield, derived from harvest foregone and production foregone, are used to determine the entrainment reduction benefits (ecological and economic) achievable at under each candidate entrainment reduction technology scenario; therefore, uncertainty surrounding underlying model parameters has the potential to significantly impact the monetization of benefits. In order to present the most conservative estimation of annual entrainment losses and associated benefits under existing and candidate entrainment reduction technology scenarios, the input parameters (including natural mortality rates) used in the Benefits Valuation Study were based on the most conservative data from the literature so as to present the largest estimates of potential technology benefits. Therefore, the estimated losses and entrainment reduction benefits presented in this section are conservative estimates and the actual annual entrainment reduction benefits, both biological (harvest foregone and total production foregone) and economic (monetized or dollar value), under each of the compliance scenarios would likely be much lower for any given year.

11.8 Discussion of Benefits Resulting from Thermal Discharge Reductions

Under certain BTA scenarios, the reduction or elimination of warm water discharges at Oconee could occur, and could potentially lead to certain social costs or benefits. Reducing warm water discharges may negatively affect angler catch rates during the winter season; this is viewed as a social cost and is discussed in Appendix 10-J. Other aspects of reducing warm water discharges can be seen as a benefit. For example, a reduction in the volume of warm water discharged to Lake Keowee may improve water quality (specifically, higher DO concentrations) in the localized area of the plume, particularly during the summer season when the lake water temperatures are already warm. However, the minimum surface DO value recorded at the discharge location typically is compliant with the instantaneous and daily average state water quality standard (Duke Energy 2015).

The fish species composition found in the vicinity of the discharge may also change in response to reduced warm water discharges. Depending on the species, this may be seen as either a cost or a benefit. Introduced species native to tropical regions may find refuge in the discharge areas of power plants, which allows these species to persist in their non-native range and the reduction or elimination of this refuge would be seen as a benefit (for example, Blue Tilapia in Lake Julian [Asheville Steam Electric Plant] or Hyco Reservoir [Roxboro Steam Station] (Mallin 1986; Duke Energy 2017). However, an example of a species which may use the thermal discharge as refuge in Lake Keowee is the Threadfin Shad, a species that provides an important forage base for recreational predator species (although an introduced species) (Duke Energy 2013, 2015).

Furthermore, the thermal discharge from Oconee has been permitted (SC0000515) since 1981 under the §316(a) NPDES provisions of the CWA, as authorized by SCDHEC. Thermal, water quality, plankton, and fishery monitoring has been regularly conducted in Lake Keowee over the past four decades in support of a §316(a) thermal variance for the Oconee CCW discharge. Long-term fish monitoring data indicate that Lake Keowee supports a balanced and indigenous fish population that is minimally impacted by operation of Oconee (Duke Energy 2007, 2013, 2018). As such, the elimination of Oconee's thermal discharge would provide no additional biological benefit to the fishery of Lake Keowee.

11.9 Discussion of Mitigation Efforts Made Prior to the Rule

There were three mitigation technologies installed at Oconee prior to the Rule. These technologies include:

- Intake canal curtain wall
- CWIS overhang
- Intake canal submerged weir

11.9.1 Intake Canal Curtain Wall

Oconee is equipped with a curtain wall located at the entrance of the intake canal leading to the CWIS. The primary purpose of the curtain wall is to facilitate selective withdrawal of cooler water from the hypolimnion to improve the thermal efficiency of the plant. As a supplemental benefit, the curtain wall reduces the number of ichthyoplankton susceptible to entrainment at the CWIS by withdrawing water from the bottom strata of the water column where fish eggs and larvae are less abundant. A 2017 Curtain Wall Entrainment Reduction Performance Study performed at Oconee demonstrated a substantial reduction in ichthyoplankton from the lake side to the intake side of the curtain wall (HDR 2018a), with commensurate reductions documented at the CWIS, as demonstrated in the entrainment Study (HDR 2018b) discussed in Sections 7 and 9.

A community analysis using multidimensional scaling techniques demonstrated similarities in the ichthyoplankton communities on both sides of the curtain wall (dominated by clupeids), indicating that the wall is effective at excluding ichthyoplankton of various species without bias (HDR 2018a). Over the study sampling period (March to October) sampling results showed a greater than 76 percent reduction in densities of entrainable-sized ichthyoplankton on the intake side of the curtain wall when compared to densities on the lake side, and an almost 90 percent reduction during the peak period of ichthyoplankton density, which is consistent with the peak spawning period for clupeids in Lake Keowee (April to May). The documented percent reduction during the peak spawning period is similar to what is expected with installation of wet cooling towers (95 percent; 79 FR 158, 48303).

Results of the curtain wall study (HDR 2018a) are consistent with those observed in prior and recent Duke Energy studies carried out at Oconee (Olmsted and Adair 1981) and at the Marshall Steam Station (Marshall) (Olmsted and Adair 1981; HDR 2017, 2018a) in North Carolina, which indicated that curtain walls can reduce densities of entrainable organisms to levels commensurate with what would be expected of closed-cycle cooling technology. The body of literature developed by Duke Energy at Marshall and Oconee, as well as studies performed by others, provides additional evidence that curtain walls can substantially reduce entrainment rates (EPRI 2017).

11.9.2 Intake Canal Submerged Weir

A submerged weir is located approximately 850 ft downstream of the curtain wall located at the mouth of the intake canal. The submerged weir was installed as a safety precaution to maintain sufficient water for the safe shutdown of the station in the event of an unexpected drawdown of Lake Keowee. The submerged weir extends from the bottom of the intake canal at 725 ft msl up to 770 ft msl (see Section 3.1 for more detail). Submerged weirs have been shown to reduce entrainment rates, especially for taxa and life stages associated with the deeper strata of the water column (Buchanan 1986). The curtain wall at the Tennessee Valley Authority Browns Ferry Nuclear Station extends from the surface 2.8 m down into the water column. The wall has a 7.3-m opening that begins at a depth of 2.8 m allowing the upper portion of the wall to function like a skimmer or curtain wall. The lower portion of the curtain wall extends from the bottom of the 7.3-m opening to the bottom of the water body and has a ledge. The lower portion of the wall, in conjunction with the ledge, extends upward from the waterbody floor, providing a physical barrier, which works to minimize entrainment susceptibility of demersal-oriented Freshwater Drum (*Aplodinotus grunniens*) eggs and larvae. Although not quantitatively assessed, based on the collected entrainment data, the submerged weir in the Oconee intake canal may have a positive benefit on entrainment of Herring Group eggs, which are initially demersal prior to water hardening (Pardue 1983).

11.9.3 CWIS Overhang

The Oconee CWIS is equipped with an overhang, located at the entrance of the intake, to facilitate debris management and protect infrastructure. The overhang extends to a depth of 19 ft at full pond elevation, resulting in in a 20-ft opening in the lower portion of each intake bay (see Sections 3.1 and 9.1 for more detail). While not quantitatively assessed, the Oconee CWIS overhang selectively withdraws cooling water from lower depths, potentially reducing entrainment by similar means as observed by curtain walls (i.e., physical exclusion of organisms behind the barrier or wall) (EPRI 2017). The mean ichthyoplankton density collected in entrainment samples collected at the CWIS during April, May, and June of both 2016 and 2017 was less than the mean ichthyoplankton density collected in those same months on the intake side of the curtain wall at the entrance to the intake canal. The presence of this pattern and its consistency suggests that the overhang at the CWIS may be responsible for the additional reductions in entrainment documented at the CWIS (HDR 2018a, 2018b). The trend of additional reduction in estimated densities at the CWIS did not extend into July due to a shift in the dominant taxa near the CWIS, when the density of clupeid eggs increased. The demersal nature of clupeid eggs results in their presence in the lower portion of the water column where they would still be susceptible to entrainment under the CWIS overhang.

11.10 Baseline Entrainment and Impingement Summary

The 2-year Study demonstrated that the species and life stage most susceptible to entrainment at the Oconee CWIS was Blueback herring eggs, which comprised 84.8 percent of the total estimated annual entrainment for both years, combined. A single sunfish larvae was the only recreational species collected throughout the Study. Greater than 99.0 percent of ichthyoplankton entrained in 2016 and 2017 were identified as or mapped to fragile forage species of the Clupeidae family, such as Blueback Herring and Threadfin Shad. Similarly, 95 percent of impingement at Oconee consisted of forage species, of which, almost 100 percent were fragile species. The estimated harvest foregone, which represents the potential entrainment impact to the fishery, was 3 lbs or less for 2016 and 2017, while harvest foregone estimates due to IM averaged 53 lbs across both years. Based on the estimated age and weight of these species at preferred length (Murphy and Willis 1996; EPRI 2012), this equates to approximately 1.0 Smallmouth Bass or 1.5 Bluegill per week; therefore, it is unlikely that impingement rates observed at Oconee have a substantial impact on the local fishery.

The low harvest foregone due to entrainment mortality was driven by the low species diversity and number entrained. As previously stated, a curtain wall study performed at Oconee in 2017 indicates that the existing curtain wall at the inlet of the intake canal reduces the abundance of ichthyoplankton from the lake side to the intake side of the curtain wall by 76 percent or more during the entrainment period, and up to 90 percent in April and May (period of greatest density of ichthyoplankton near the curtain wall) (HDR 2018b).

Lake Keowee supports a fishery typical of the southeastern U.S. Piedmont region, with a littoral zone community largely dominated by centrarchids and a pelagic community dominated by clupeids (ASA 2008; Duke Energy 2007, 2013). Changes in the fish community documented during periodic Duke Energy monitoring activities between 1993-2005 (Duke Energy 2007) and between 2005 -2011 (Duke Energy 2013) were attributed to the introduction of non-native species such as Flathead Catfish, Alabama Bass, or Blueback Herring. Continued lake monitoring studies indicate that Lake Keowee supports a balanced fish community.

Although entrainment and impingement estimates documented at Oconee were low, annual losses were estimated with a conservative approach for each candidate technology, resulting in an expected overestimation of losses. Even with conservative estimates of benefits developed through this environmental and economic analysis, the estimated value of potential social benefits are minimal at best. Regardless of the specific technology scenario or year of estimated loss, the present value (based on a 3 percent discount rate) of reductions in entrainment were estimated to range from $158 for the FMS with new CWIS and $353 for the MDCT scenario. Based on the technologies evaluated at Oconee, the potential benefit of reducing entrainment losses at Oconee had an estimated annual value (based on a 3 percent discount rate) between $20 and $44. The minimal potential entrainment reduction benefits (ecological and economic) that are estimated to accrue under the evaluated technologies illustrates how the system of technologies at Oconee (existing design, technologies, and station operations) already minimize impacts to the Lake Keowee fishery.

11.11 Section 11 References

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12 Non-water Quality Environmental and Other Impacts Study [§122.21(r)(12)]

The information required to be submitted per §122.21(r)(12), *Non-water Quality Environmental and Other Impacts Study*, is outlined as follows:

> *"The owner or operator of an existing facility that withdraws greater than 125 mgd AIF must develop for submission to the Director a detailed facility-specific discussion of the changes in non-water quality environmental and other impacts attributed to each technology and operational measures considered in paragraph (r)(10) of this section, including both impacts increased and impacts decreased."*

Pursuant to the Rule, a facility-specific report must be submitted that addresses the non-water quality environmental and other impacts for each technology or operational measure considered under §122.21(r)(10). The evaluation must address, if relevant to the alternative technology being assessed, the following items pursuant to the Rule at §122.21(r)(12):

- *(i)* *Estimates of changes to energy consumption, including but not limited to, auxiliary power consumption and turbine backpressure energy penalty;*
- *(ii)* *Estimates of air pollutant emissions and of the human health and environmental impacts associated with such emissions;*
- *(iii)* *Estimates of changes in noise;*
- *(iv)* *A discussion of impacts to safety, including documentation of the potential for plumes, icing, and availability of emergency cooling water;*
- *(v)* *A discussion of facility reliability, including but not limited to facility availability, production of steam, impacts to production based on process unit heating or cooling, and reliability due to cooling water availability;*
- *(vi)* *Significant changes in consumption of water, including a facility-specific comparison of the evaporative losses of both once-through cooling and closed-cycle recirculating systems, and documentation of impacts attributable to changes in water consumption; and*
- *(vii)* *A discussion of all reasonable attempts to mitigate each of these factors.*

Each of these requirements is addressed in the following subsections.

12.1 Background Information

12.1.1 Population Distribution near Oconee Nuclear Station

Understanding the population distribution in the area surrounding a facility is important when evaluating potential environmental impacts from the construction and operation of new equipment. Figure 12-1 provides population density information for a 1-mile radius surrounding Oconee.

The 1-mile area surrounding Oconee is largely comprised of Lake Keowee and property owned by Duke Energy. An undeveloped forest area exists to the south of the station, in addition to three small residential areas along the southwest, north, and northeast perimeters of the 1-mile area surrounding the station. The closest property to Oconee that is not owned by Duke Energy is a small rural heritage site[80] to the southeast of the station. Approximately 10 acres of land within the 1-mile area surrounding the station are owned by the United States government in association with the Hartwell Reservoir (Duke Energy 2015).

Within the general vicinity of Oconee, the population density is highest to the northwest, with a population density of greater than 1,000 people per square mile. The population density is lower in all other directions. There are three small areas with a population density of between 100 and 1,000 people per square mile to the southwest and northwest of the station. Aside from the aforementioned population centers, the population density in the general vicinity of the station ranges from 0 to 100 people per square mile (U.S. Census Bureau 2010). Because of the recreational opportunities provided by Lake Keowee, the transient recreational population of the area increases during the summer months (Duke Energy 2015).

[80] The heritage site is Old Pickens Presbyterian Church which is inactive, but open periodically to the public for historic purposes.

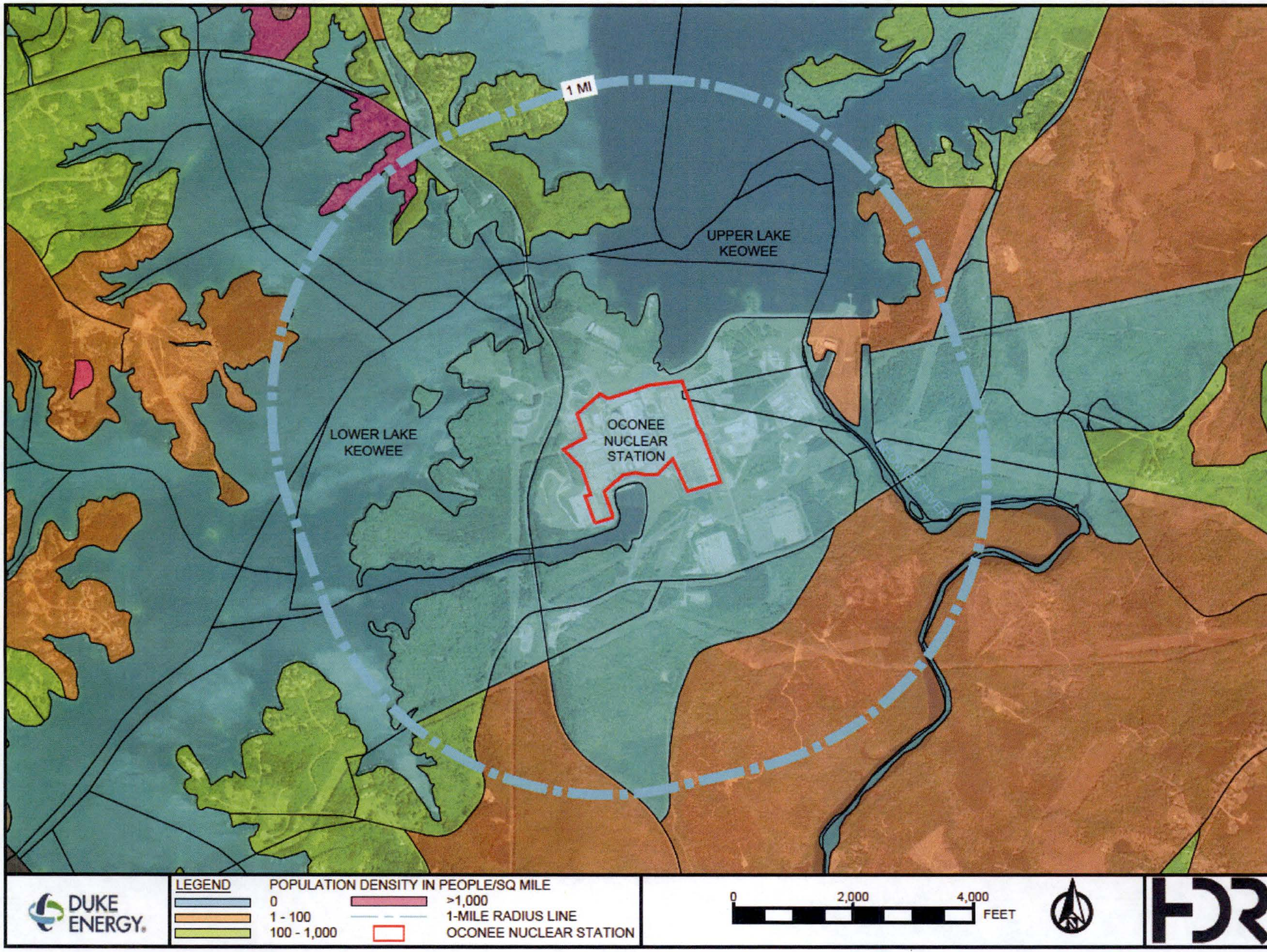

Figure 12-1. Population Density Surrounding Oconee Nuclear Station (U.S. Census Bureau 2010)

12.1.2 Evaluation Approach

The following sections discuss potential non-water quality and other environmental impacts of the entrainment reduction technology evaluated in Section 10 of this document, as required by the Rule. Section 10 of this document discusses the technical feasibility and costs of entrainment reduction technologies at Oconee. In Section 10, several potential entrainment reduction technologies were determined to be infeasible and were removed from further evaluation. The following potential entrainment reduction technologies were retained for benefits valuation and non-water quality and other environmental impacts studies because they were determined to be potentially feasible for implementation at Oconee, or because they are required to be evaluated by the Rule at §122.21(r)(10):

1. Closed-cycle MDCTs;
2. The retrofit of the existing coarse-mesh fixed-panel screens in the existing CWIS with 1.0-mm modified-Ristroph FMS units, and the installation of a new aquatic organism return system; and
3. The installation of 1.0-mm modified-Ristroph FMS units in a new CWIS and a new aquatic organism return system.

As specified in §122.21(r)(12), this non-water quality and other environmental impacts evaluation assesses the potential impacts to energy consumption, air pollutant emissions, noise, safety, station reliability, and consumptive water use due to the construction and operation of the previously listed entrainment reduction technologies. Potential impacts to the station and surroundings are described, and a quantification of impacts is provided where possible.

12.2 Closed-cycle Cooling Tower Retrofit

12.2.1 Energy Consumption Impacts (§122.21(r)(12)(i))

12.2.1.1 Description

There are two forms of additional energy consumption due to a closed-cycle cooling tower retrofit at an electric generating station like Oconee: the auxiliary energy requirement to operate new equipment, and the backpressure energy penalty.

In a closed-cycle cooling tower retrofit, the auxiliary energy requirement would be due to the operation of new cooling tower booster pumps and fans, and has been quantified using the approximate power rating of the equipment based on the conceptual designs discussed in Section 10, and the anticipated annual hours of operation[81].

The operation of closed-cycle cooling towers results in warmer condenser cooling water and reduces the efficiency of a turbine's capacity to produce electricity. This effect is referred to as the backpressure energy penalty, and it can be quantified as the energy that a power plant is unable to generate due to increased backpressure. A turbine's generating efficiency is related to cooling water

[81] Auxiliary energy required from additional lighting, signage, flow meters, and other small equipment is considered minor and is not quantified.

temperature, quality of exhaust steam, and other condenser losses. The temperature of once-through cooling water depends on the source waterbody temperature. The temperature of closed-cycle cooling water depends on the ambient wet-bulb temperature and the cooling tower design. During most of the year, the temperature of closed-cycle cooling water would be higher than once-through cooling water for the same facility, and turbine generating efficiency would be lower.

12.2.1.2 Quantification

Auxiliary Energy Requirements

The existing cooling system at Oconee utilizes 12 CCW pumps per unit to circulate cooling water and service water. Each CCW pump has a design capacity of 246,000 gpm (354.2 MGD), for a total intake design pumping capacity of 2,952,000 gpm (4,251 MGD). However, there is a piping restriction in the 8-ft-diameter header pipes on the downstream side of the CCW pumps at Oconee that limits the pumping capacity of each unit to 708,000 gpm (1,019.5 MGD) (Duke Energy 2002). For the hypothetical MDCT retrofit at Oconee, it is assumed these CCW pumps would remain in place and would continue to route cooling water from the CWIS to the condensers. The existing CCW pumps provide sufficient head to route cooling water through the condensers and the discharge network at Oconee; however, the hypothetical CCRS would require additional head and new cooling tower booster pumps would be required to route water from the condensers to the cooling tower water distribution system.

The hypothetical MDCT system would require 42 booster pumps (14 per unit), each with a capacity of 51,000 gpm. The auxiliary energy required for the cooling tower booster pumps was estimated based on the use of 3,500 ft of 4.5-ft diameter[82] reinforced concrete pipe[83] to route hot water from the condensers to the cooling towers, resulting in approximately 13.4 ft of friction head per unit. The hot water piping for each unit would require approximately ten 90-degree elbows and eight wye-fittings, resulting in approximately 4.8 ft of minor losses per unit. The static head would be approximately 59.1 ft per unit. In addition, a contingency factor of 1.2 was applied to the total dynamic pump head calculated, resulting in approximately 92.7 ft of total dynamic head per unit. The pumps are assumed to be 85 percent efficient, and the motors are assumed to be 90 percent efficient. As such, the auxiliary energy requirement for each new cooling tower booster pump would be approximately 1,550 horsepower (hp), or 1.2 MW.

The auxiliary energy required for each new cooling tower fan would be 300 hp (SPX 2019), which for 30 fans per unit, would be equal to 9,000 hp, or approximately 6.7 MW per unit (20.1 MW for the station in total).

The total auxiliary energy requirement for the hypothetical cooling tower booster pumps and fans would be approximately 22.9 MW per unit, or 68.7 MW for the station. See Appendix 12-A for engineering calculations of the estimated increase in energy consumption due to a hypothetical MDCT retrofit at Oconee.

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[82] This results in 7.1 fps in-pipe velocity.

[83] Hazen-Williams roughness coefficient of 100.

Backpressure Energy Penalty

Due to the dynamic nature of meteorological and operating conditions, the backpressure energy penalty is often estimated by aggregating energy losses over short periods of time, typically not larger than one-hour intervals. Veritas has estimated the energy penalty due to increased condenser backpressure at Oconee using hourly station heat rate data and hourly wet-bulb temperature data. Based on 2018 data, the average annual change in gross station efficiency for all hours due to backpressure impacts was estimated to be approximately 0.58 percent, which is equivalent to 5.2 MW for Unit 1, 5.3 MW for Unit 2, 5.3 MW for Unit 3, totaling 15.8 MW for the station (Veritas 2020a). These results are incorporated into the overall estimate of annual energy consumption due to a hypothetical MDCT retrofit provided in Table 12-1.

Replacement Energy Required due to Construction Outage

In addition to the recurring increase in energy consumption at Oconee due to new MDCT auxiliary energy requirements and the backpressure energy penalty, there would be a one-time loss in energy generated at Oconee in 2026 for Unit 1, 2027 for Unit 2, and 2028 for Unit 3 due to MDCT construction outages. The replacement energy required due to construction outage was calculated assuming each unit would have been fully utilized during the construction outage, other than the regularly-scheduled maintenance outage that has been incorporated into the construction outage for each unit. It is assumed the MDCT construction outage would be 6 months in total for each unit, and would include a regularly-scheduled unit maintenance outage (approximately 1 month) to help reduce replacement energy costs. Replacement energy required due to the anticipated MDCT construction outage is provided in Table 12-2.

Summary

The total annual increase in energy consumption due to a hypothetical MDCT retrofit at Oconee would be approximately 246,338 megawatt-hours (MWhr) for Unit 1, 246,592 MWhr for Unit 2, and 247,050 MWhr for Unit 3, totaling approximately 739,981 MWhr for the station, if each unit were to operate continuously. Considering Oconee's five-year CUR[84] of 92 percent for Unit 1 and 96 percent for Units 2 and 3, the total annual increase in energy consumption would be approximately 226,123 MWhr for Unit 1, 236,549 MWhr for Unit 2, and 236,190 MWhr for Unit 3, totaling approximately 698,862 MWhr for the station. The energy consumption calculations are summarized in Table 12-1.

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[84] Based on generation data for period July 1, 2014 through June 30, 2019.

Table 12-1. Increase in Energy Consumption due to a Hypothetical MDCT Retrofit at Oconee Nuclear Station

Increase in Energy Consumption	Unit 1	Unit 2	Unit 3	Total
Pumps (MW)	16.2	16.2	16.2	48.5
Fans (MW)	6.7	6.7	6.7	20.1
Backpressure Energy Penalty (MW)	5.2	5.3	5.3	15.8
Total Annual Increase in Energy Consumption (Continuous Operation) (MWhr / year)	246,338	246,592	247,050	739,981
Total Annual Increase in Energy Consumption (5-year CUR) (MWhr / year)	226,123	236,549	236,190	698,862

Table 12-2. Total Replacement Energy Required due to the Construction Outage for a Hypothetical MDCT Retrofit at Oconee Nuclear Station

Total Replacement Energy Required due to Construction Outage	Unit 1	Unit 2	Unit 3	Total
Total Replacement Energy Required (MWhr)	3,420,384	3,374,040	3,495,456	10,289,880

12.2.1.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

Energy consumed by the hypothetical closed-cycle cooling system at Oconee could be reduced or replaced in a variety of ways, including the following list. However, these measures were not incorporated into the conceptual design or costs.

1. Use of cooling tower fans with variable-speed motors. If fans were operated at reduced speed at night, when cooler temperatures would compensate for lack of air flow, they could provide a periodic reduction in energy consumption;
2. Construction of a new combined-cycle power plant elsewhere within the electricity grid to operate as needed, and especially during summer months when Oconee's backpressure energy penalty due to MDCT operation would be highest; and
3. Construction of larger cooling towers than those discussed in Section 10 to reduce the backpressure energy penalty. The hypothetical MDCTs at Oconee were designed for an approach temperature of 10°F and the 99th percentile wet-bulb temperature. Larger cooling towers with additional cooling capacity would reduce the backpressure energy penalty, but the auxiliary energy requirement would increase.

12.2.1.4 Uncertainty

The uncertainties associated with the evaluation of potential energy consumption impacts from a hypothetical closed-cycle cooling tower retrofit at Oconee include, but are not limited to the following:

1. The backpressure energy penalty due to a hypothetical MDCT retrofit was calculated based on historic hourly generation and wet-bulb temperature data at Oconee. The actual backpressure energy penalty could deviate from this estimate;
2. The MDCT construction outage was assumed to be 6 months in total for each unit and incorporated regularly-scheduled unit outages into the implementation schedule. The actual MDCT construction outage could deviate from this estimate; and
3. The auxiliary energy requirement was calculated using preliminary and approximate equipment sizes, lengths, and capacities. The actual equipment design and auxiliary energy requirement would be refined during detailed design and construction if closed-cycle cooling were to be selected as BTA for the station.

12.2.2 Air Pollutant Emissions, Environmental Impacts, and Human Health (§122.21(r)(12)(ii))

12.2.2.1 Description of Air Pollutant Emissions

A hypothetical MDCT retrofit at Oconee would increase air pollutant emissions in the following ways:

1. Recurring on-site particulate matter (PM) emissions from the cooling towers derived from the recirculated cooling water;
2. Recurring off-site combustion emissions produced to replace lost generation at Oconee during the MDCT operational period due to increased energy consumption from the auxiliary energy requirement and backpressure energy penalty; and
3. Off-site combustion emissions produced to replace lost generation at Oconee during the MDCT construction outage. The construction outage would occur in 2026 for Unit 1, 2027 for Unit 2, and 2028 for Unit 3, and would require other stations to generate power that would otherwise have been generated at Oconee.

On-site Cooling Tower PM Emissions

Cooling tower operation results in the emission of several trace elements, but the levels of emissions are highly variable depending upon the nature of the source water. PM emissions are formed by the concentration of total solids (TS) in the source waterbody and would be the most significant on-site air pollutant emissions due to a hypothetical MDCT retrofit at Oconee.

Drift droplets emitted from cooling towers contain dissolved minerals and organic matter that are captured in the cooling water. The water contained in the drift droplets that exits the cooling towers evaporates, leaving the remaining solid matter in the air column. The solids range in size based on the cooling water TDS and drift droplet size. Smaller PM can have a greater impact on human health.

Total PM, PM_{10} and $PM_{2.5}$ emissions due a hypothetical MDCT retrofit were evaluated at Oconee. PM_{10} refers to PM that is 10 microns or smaller, and $PM_{2.5}$ refers to PM that is 2.5 microns or smaller[85]. PM_{10} particles have a larger diameter and are heavier than $PM_{2.5}$ particles. Therefore,

[85] Note that because PM_{10} emissions are 10 microns or smaller, those results also include $PM_{2.5}$ emissions.

compared to $PM_{2.5}$, PM_{10} particle deposition velocity is faster, and the deposition distance is shorter. Based on the size and weight of PM, the highest rate of deposition can occur between approximately 2,500 ft and 3,600 ft from an MDCT (EPRI 2011). PM would be carried longer distances during periods of strong winds.

The TDS concentration in the drift particles is directly proportional to the TDS concentration in the source waterbody and is equal to the TDS concentration in the circulating water system, which is estimated as the source water TDS multiplied by the cooling tower COC[86].

Off-site Combustion Emissions

Combustion of fossil fuels produces a range of air pollutants of concern and includes carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_X). Off-site combustion emissions due to a hypothetical MDCT retrofit at Oconee could occur in two forms: recurring emissions from power generation to compensate for the MDCT auxiliary energy requirement and the backpressure energy penalty, and emissions from replacement power generated during the MDCT construction outage that would otherwise have been generated at Oconee.

12.2.2.2 Human Health

Human health-related impacts are a function of the change in air pollutant emissions, dispersion, deposition, human population density relative to the emissions, and the sensitivity of those populations. While increased air pollutant emissions could have environmental and human health impacts, air pollutant emissions are regulated by each power plant's emissions permit (such as Conditional Major Operating or Title V). Emissions standards and allowances are based on the cumulative impacts caused by most emissions sources; therefore, emissions that would be allowed by the facility's air permit are expected to be generally protective of surrounding populations. Sensitive populations that live downwind of power plants could be impacted differently than less sensitive populations.

12.2.2.3 Quantification of Air Pollutant Emissions

On-site Cooling Tower PM Emissions

The average TDS and TSS in Lake Keowee are approximately 15 mg/L and 2 mg/L, respectively (USACE 2014). As such, the TS concentration is approximately 16 mg/L. A COC of 5.0 was selected for the hypothetical MDCT retrofit at Oconee based on the freshwater source of make-up water. The amount of TS in the circulating water (TS_{CT}) is the product of the TS concentration in the source waterbody and the COC, equal to approximately 81 mg/L.

The cooling tower total PM emission rate is calculated as the product of the cooling water flow rate (Q_{CT}), the drift eliminator efficiency (DE), and TS_{CT}. Drift eliminators act to reduce the amount of drift lost from a cooling tower system by providing multiple airflow direction changes to enhance capture of larger water droplets.

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[86] COC is discussed in more detail in Section 10. COC is defined by the USEPA as "the ratio of dissolved solids in the recirculated water versus that in the make-up water" (USEPA 2014). If MDCTs were selected as BTA at Oconee, additional evaluations would be required to assess an appropriate COC value that addresses TDS and other water quality parameters.

At Oconee:

- Q_{CT} would be 708,000 gpm per unit;
- The cooling tower drift rate would be 0.0005% of Q_{CT};
- COC would be 5.0; and
- TS_{CT} would be 81 mg/L.

The size of PM emissions is influenced by the number and size of the drift droplets produced within a cooling tower. The relative magnitudes of PM_{10} and $PM_{2.5}$ emissions were estimated by incorporating a drift droplet size distribution per the Marley TU12 eliminator drift droplet distribution (SPX 2017). Since drift contains the same TS concentration as the circulating water, the amount of PM per water droplet is directly related to the size and volume of each drift droplet. Following the SPX (2017) drift droplet distribution, PM_{10} would represent approximately 97 percent of the on-site total PM emissions at Oconee, and $PM_{2.5}$ would represent approximately 64 percent of the on-site total PM emissions at Oconee.

Considering Oconee's five-year CUR of 92 percent for Unit 1 and 96 percent for Units 2 and 3, the estimated on-site cooling tower PM emissions are provided in Table 12-3 (Reisman and Frisbie 2002, USACE 2014, Duke Energy 2019a, Duke Energy 2019b, SPX 2019).

Table 12-3. On-site Cooling Tower Particulate Matter Emissions Due to a Hypothetical MDCT Retrofit at Oconee Nuclear Station

Parameter	Unit 1	Unit 2	Unit 3	Total
Annual Total On-site PM Emissions (tons/year)	0.58	0.60	0.60	1.8
Annual On-site PM_{10} Emissions (tons/year)	0.56	0.59	0.58	1.7
Annual On-site $PM_{2.5}$ Emissions (tons/year)	0.37	0.39	0.39	1.1

Calculations of on-site cooling tower PM emissions due to a hypothetical MDCT retrofit at Oconee are provided in Appendix 12-B.

Off-site Combustion Emissions

Differences in projections of existing off-site CO_2, NO_X, and SO_2 emissions (Base Case) and off-site CO_2, NO_X, and SO_2 emissions due to a hypothetical closed-cycle cooling tower retrofit at Oconee were simulated using the Duke Energy Power System Simulation Model (PROSYM). The MDCT construction outage was assumed to be six months in total for each unit, and would include a regularly-scheduled maintenance outage (approximately one month) to help reduce replacement energy costs. Off-site emissions due to the unit MDCT construction outages were included in the PROSYM simulation, and would be experienced in 2026 for Unit 1, 2027 for Unit 2, and 2028 for Unit 3 at Oconee. The cooling towers would be operational in 2026 for Unit 1, 2027 for Unit 2, and 2028 for Unit 3. The estimated annual net increases in off-site combustion emissions due to a hypothetical closed-cycle cooling tower retrofit at Oconee is provided in Table 12-4.

Table 12-4. Estimated Net Increases in Off-site Combustion Emissions due to a Hypothetical MDCT Retrofit at Oconee Nuclear Station

Year	NO_X (Tons)	Increase from Base Case	SO_2 (Tons)	Increase from Base Case	CO_2 (Tons)	Increase from Base Case
2026	20,220	1,350	16,640	1,030	38,703,510	1,772,880
2027	19,510	1,710	14,440	1,200	38,203,590	2,235,400
2028	20,200	1,570	16,620	740	39,360,950	2,394,890
2029	18,620	400	14,100	200	37,016,690	648,560
2030	19,860	400	8,260	250	39,057,770	653,740
2031	21,400	310	11,170	210	41,341,200	596,810
2032	22,450	490	13,340	360	42,926,880	710,860
2033[a]	27,370	150	19,330	130	52,352,280	211,620
2034	28,580	30	23,500	10	56,257,310	<10,000

[a] Oconee's USNRC operating licenses expire at midnight on the following dates for each unit: Unit 1 – 2/6/2033, Unit 2 – 10/6/2033, and Unit 3 – 7/19/2034. This, in combination with increased use of replacement zero carbon generation, results in a sharp decrease in net off-site emissions in 2033 – 2034.

12.2.2.4 Impact Mitigation Methods (§122.21(r)(12)(vii))

Air pollutant emissions due to a hypothetical MDCT retrofit at Oconee could be reduced in a variety of ways, including the following list. However, these measures were not incorporated into the conceptual design or costs.

1. Use of cooling tower fans with variable-speed motors. If fans were operated at reduced speed at night, when cooler temperatures would compensate for lack of air flow, they could provide a periodic reduction in energy consumption, which would also cause reduced emissions;
2. Treatment of the recirculating water to reduce solids concentrations would reduce the amount of cooling tower drift. However, the solids concentrations in Oconee's intake canal are already low; and
3. Use of renewable or low-carbon energy sources to provide the additional energy requirements or replacement energy at Oconee could potentially reduce the off-site combustion emissions, but were not evaluated due to the complexity of determining potential reductions over time.

12.2.2.5 Uncertainty

Key sources of uncertainty associated with the air pollutant emissions evaluation include the following:

1. The particle size distribution used in the on-site cooling tower PM emissions estimates is based on the Marley TU12 eliminator drift droplet distribution, which may not be representative of water quality and PM distribution of the circulating water at Oconee;
2. PM emissions and drift rates are affected by water quality and there is uncertainty in TDS and TSS concentrations;

3. The actual MDCT construction outage at Oconee could differ from the assumptions made in this evaluation;
4. Air pollutant emissions factors today may not be representative of future emissions factors due to changes in fuel mix and emissions controls; and
5. Regulations governing air pollutant emissions may change in the future.

12.2.3 Noise Impacts (§122.21(r)(12)(iii))

12.2.3.1 Description

Hypothetical MDCTs would increase noise levels at Oconee due to cascading water in the cooling towers, and the operation of new booster pumps, fans, and other equipment. Heavy construction and vehicular traffic would increase noise levels at Oconee during the MDCT construction period. This evaluation considers a noise source to be any new equipment that would generate noise at Oconee, and considers a noise receptor to be any point of reception where extraneous noise and/or vibration would be perceived.

Because there are no federal regulations limiting environmental noise levels[87], the USEPA released a document in March 1974 titled "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety" that provided a basis for state and local governments' judgment in setting standards for noise levels (USEPA 1974). Noise exposure goals for various locations depend on the noise sensitivities of the surroundings. Areas zoned for residential use usually have more stringent noise exposure limits than commercial, industrial, or agricultural areas. Similarly, specific institutions, such as places of worship, schools, hotels, hospitals, and libraries, may also have more stringent noise exposure limits.

Noise pollution can generally fall into two groups: acute sound levels that can lead to hearing impairment, and nuisance sound levels that impact the wellbeing of surrounding communities. Acute sound levels are often controlled, but nuisance noise is not. The USEPA states that a sound level of 55 decibels (dB) is satisfactory in protecting the public health and welfare and does not create an annoyance in most cases (USEPA 2014)[88].

In Oconee County, per Chapter 12, Article II of the Code of Ordinances, there are no specific decibel thresholds for noise. The Code of Ordinances in Section 12-32 provides the following declaration regarding nuisance noise that is generally prohibited (Municode Library 2019):

> *Any noise of such character, intensity, or duration which substantially interferes with the comfortable enjoyment of persons of ordinary sensibilities occupying, owning, or controlling*

[87] "Under the Clean Air Act, the USEPA administrator established the Office of Noise Abatement and Control (ONAC) to carry out investigations and studies on noise and its effect on the public health and welfare. Through ONAC, the USEPA coordinated all Federal noise control activities, but in 1981 the Administration concluded that noise issues were best handled at the State and local level. As a result, ONAC was closed and primary responsibility of addressing noise issues was transferred to State and local governments. However, USEPA retains authority to investigate and study noise and its effect, disseminate information to the public regarding noise pollution and its adverse health effects, respond to inquiries on matters related to noise, and evaluate the effectiveness of existing regulations for protecting the public health and welfare, pursuant to the Noise Control Act of 1972 and the Quiet Communities Act of 1978." (USEPA 2018).

[88] A dB is a logarithmic unit expressing the ratio of two physical quantities, such as noise.

> *nearby properties or of persons making use of public properties for their intended purposes, is hereby declared to be unlawful and to be a nuisance, and is prohibited.*

However, the Oconee County Code of Ordinances provides the following exemption in Section 12-35 (Municode Library 2019):

> *This article does not apply to noise emanating from industrial, warehouse, distribution, and manufacturing activities and facilities and operations related thereto, governmental activities, emergency signal devices, firearms discharges as a result of lawful game hunting or lawfully operating shooting ranges, agricultural activities (including livestock), parades, carnivals, school band practice or performances, and school or government sponsored athletic events.*

The operation of cooling towers at Oconee would likely be considered an industrial activity, and noise produced in association with this activity is listed as an exception in the Oconee County Code of Ordinances. Cooling tower construction could still be governed by the ordinance[89]. Should an MDCT retrofit project be implemented, it would be required to meet local zoning requirements, including noise control. Therefore, this evaluation assumes that noise would be mitigated in order to meet the most stringent of the federal, state, or local requirements if the project were implemented.

12.2.3.2 Quantification

The quantification of noise within and outside the station's property boundaries would require noise propagation modeling, which would include consideration of topography, sound levels of each point source, noise barriers (such as buildings), and atmospheric conditions. This noise modeling would be performed to support project permitting and design if MDCTs were selected as BTA. Table 12-5 provides noise levels from common noise sources.

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[89] Per Section 12-34(a)(8) of the Oconee County Code of Ordinances (Municode Library 2019):

> *Operation of certain instruments, devices and equipment.* Nuisance noises shall include, but not be limited to, the use or operation of the following instruments, devices, or pieces of equipment when operated in the manner prohibited by Section 12-32: When operated between the hours of 10:00 p.m. and 6:59 a.m., construction machinery, heavy duty equipment, used in street repair and maintenance, domestic and commercial power tools, and the like, unless a permit is obtained.

Table 12-5. Common Noise Levels (Cowan 1994)

Sound Source	(dBA)
Military jet, air raid siren	130
Amplified rock music	110
Jet takeoff at 500 meters	100
Freight train at 30 meters	
Train horn at 30 meters	90
Heavy truck at 15 meters	
Busy city street, loud shout	80
Busy traffic intersection	
Highway traffic at 15 meters, train	70
Predominantly industrial area	60
Light car traffic at 15 meters, city or commercial areas or residential areas close to industry	
Background noise in an office	50
Suburban areas with medium density transportation	
Public library	40
Soft whisper at 5 meters	30
Threshold of hearing	0

The USEPA states that a cooling tower in operation would have a typical noise level of approximately 70 dB within 50 ft of the tower (2014). Sound levels diminish approximately 5 dB as the distance from the source doubles, and 55 dB represents a common noise level that is not considered noise pollution (Table 12-5). As such, a buffer of 400 ft would be sufficient for natural abatement of noise generated by cooling towers at most sites (Table 12-6) (USEPA 2014).

Table 12-6. Noise Level Compared to Distance

Distance from Noise Source (ft)	Noise Level at Receptor (dB)
50	70
100	65
200	60
400	55

The hypothetical locations for an MDCT retrofit, as described in Section 10 of this document, have been compared to property boundaries at Oconee in Figure 12-2. At Location A, the hypothetical cooling towers are located at a distance greater than 400 ft from the closest property boundary, excluding public roadways. As such, it is likely that additional noise from the hypothetical MDCTs would be attenuated naturally, and no impacts would be expected.

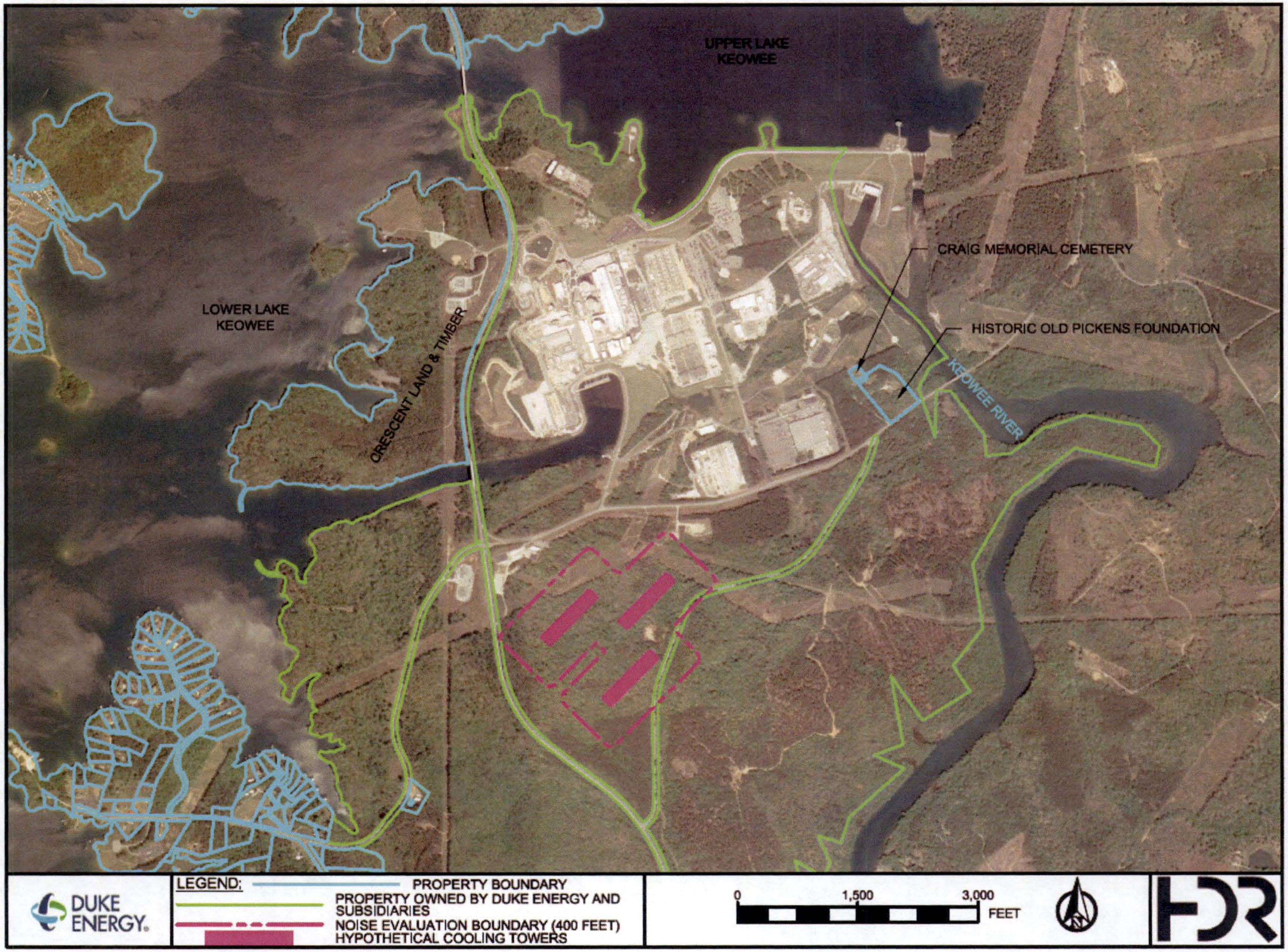

Figure 12-2. Hypothetical Cooling Tower Location Compared to Property Boundaries at Oconee Nuclear Station

12.2.3.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

If noise sources due to a hypothetical MDCT retrofit were to be located within close proximity of sensitive receptors, or if existing noise levels at the station property boundaries are known to approach ordinance thresholds, then an evaluation of noise mitigation methods could be required at Oconee. As previously discussed, the distance between hypothetical cooling tower Location A and the closest sensitive noise receptor or property boundary would likely be sufficient to provide natural attenuation.

12.2.3.4 Uncertainty

Key sources of uncertainty associated with the noise evaluation include the following:

1. Many factors can influence the noise perceived by receptors including site topography, line-of-sight, and type and location of equipment installed;
2. Existing noise sources and actual sound levels generated and received at off-site receptors are unknown; and
3. The quantification of noise levels are based on the USEPA's assumption that typical noise levels within 50 ft of a cooling tower are expected to be approximately 70 dB. The rate of noise attenuation presented in Table 12-6 is an approximation that can vary depending on site conditions, including presence and height of buildings and structures. While this evaluation conservatively assumes a flat, open terrain between the noise sources and receptors, the surrounding trees and vegetation around the proposed MDCT Location A should provide for some attenuation.

12.2.4 Safety Impacts (§122.21(r)(12)(iv))

12.2.4.1 Description

This section provides a discussion of potential safety impacts due to a hypothetical retrofit at Oconee, including an evaluation of the potential for cooling tower plume formation, ice formation, and availability of emergency cooling water. In addition, §125.94(f) provides the following description for nuclear power stations and compliance impacts on safety requirements:

> *If the owner or operator of a nuclear facility demonstrates to the Director, upon the Director's consultation with the Nuclear Regulatory Commission, the Department of Energy, or the Naval Nuclear Propulsion Program, that compliance with this subpart would result in a conflict with a safety requirement established by the Commission, the Department, or the Program, the Director must make a site-specific determination of best technology available for minimizing adverse environmental impact that would not result in a conflict with the Commission's, the Department's, or the Program's safety requirement.*

As such, potential nuclear safety impacts due to a hypothetical MDCT retrofit at Oconee will also be discussed.

Cooling Tower Plume and Fog Formation

Wet cooling towers produce a plume by way of evaporation. Depending on the atmospheric conditions, the plume can condense and become visible as fog. Cooling tower plume is more visible in the wintertime, when the difference between the cool, ambient atmosphere and the warm exhaust air is the greatest. During adverse wind conditions, the plume can remain at low elevations until dissipating, resulting in ground-level fogging (SPX 2012). Cooling tower plumes and fogging can have safety impacts due to loss of visibility. Per §125.94(f)(iv), fogging can adversely impact safety of the station and surrounding community.

As described in Section 10 of this document, wind at Oconee can originate from any direction. During the winter, the predominant wind directions are from the northeast and southwest directions (WMO 1999). Fogging due to cooling tower plume formation could affect local roadways in these areas and present a hazard to drivers. Fogging due to cooling tower plume formation could be hazardous in areas close to airports. The closest public airport is the Oconee County Regional Airport located 8 miles south of the station. There are several small private airports located closer to the station. Roadways and airports located in the vicinity of Oconee are provided on Figure 12-3 and Figure 12-4, respectively.

In addition to potential hazards to local roadways and airports, the loss of visibility near the property boundaries and perimeter of Oconee's protected area[90] could cause adverse impacts to station safety and security. Line-of-sight and monitoring of the station perimeter is critical to the safety and security of the station and surrounding areas. Per the USNRC Regulations at 10 CFR Part 73.55(e)(8)(ii):

> *Penetrations through the protected area barrier must be secured and monitored in a manner that prevents or delays, and detects the exploitation of any penetration.*

Station security and monitoring is further explained in the USNRC's Regulatory Guide 5.44, *Perimeter Intrusion Alarm Systems*, which describes the functions of a perimeter intrusion alarm system, as well as the security methods acceptable for meeting the USNRC requirements (USNRC 1997). Through the use of watchtowers and a perimeter intrusion alarm system, security personnel monitor the property boundaries and perimeter of protected areas for potential unauthorized penetration or activity. Environmental factors, such as fog formation, can reduce the effectiveness of the monitoring systems and reduce station security.

The World of Energy is adjacent to Oconee. This education center contains self-guided exhibits that provide information on electrical generation, a nature trail, a butterfly garden, and a picnic area. Since its opening in July 1969, more than 3 million people have visited the World of Energy. If MDCTs were erected at Oconee, guests for this attraction would encounter the plume effects either through aesthetic impacts or when fog impacts the state highway access.

Ice Formation

Ice formation due to cooling tower operation occurs in freezing weather when moisture from the cooling tower plume causes frost or ice crystals to form on nearby surfaces or structures. Ice formation within the station's property boundaries and on adjacent roads, transmission lines, and switchyard could potentially impact public safety, station generation reliability, and station security.

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[90] The protected area is defined at 10 CFR Part 73.2 as "an area encompassed by physical barriers and to which access is controlled".

Impacts due to ice formation would likely be found in areas downwind of the winter prevailing wind directions, which are from the northeast and southwest.

Availability of Emergency Cooling Water

"Safety-related" is defined by the USNRC as applying to "systems, structures, components, procedures, and controls (of a facility or process) that are relied upon to remain functional during and following design-basis events. Their functionality ensures that key regulatory criteria, such as levels of radioactivity released, are met" (USNRC 2016b). Design-basis accidents (DBA) are defined as "postulated accidents that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to ensure public health and safety" (USNRC 2016a).

Safe shutdown and maintenance of a nuclear reactor is an example of a safety-related function (USNRC 2016b). With respect to the USNRC Regulatory Guide 1.27, *Ultimate Heat Sink for Nuclear Power Plants*, and regulations at 10 CFR Parts 50 and 52, nuclear power stations establish a safety-related ultimate heat sink (UHS) to aid in performing principal safety functions, including dissipation of residual heat after reactor shutdown or after an accident, and dissipation of the maximum expected decay heat from the spent fuel pool. Generally, the UHS should be capable of delivering sufficient cooling water to accomplish these safety functions for a single unit or multiple units simultaneously for a period of 30 days[91].

The UHS is the primary emergency water source that would be utilized during a DBA, such as a loss of coolant accident (LOCA). The UHS is designed such that it would still function despite the LOCA.

As described in USNRC Regulatory Guide 1.27 (USNRC 2015):

> *The UHS is the system of structures and components and associated assured water supply and atmospheric condition(s) credited for functioning as a heat sink to absorb reactor residual heat and essential station heat loads after a normal reactor shutdown or a shutdown following an accident or transient including a loss-of-coolant accident (LOCA). This includes those necessary water-retaining structures (e.g., a pond, a reservoir with its dam) and the canals, aqueducts, or piping systems connecting those cooling water sources with the essential or safety-related cooling water intake structure of the nuclear power units. Non-safety systems (e.g., circulating water supply) may share this safety-related water supply. If cooling towers or portions of cooling towers are required to accomplish the UHS safety functions, they should satisfy the same requirements as the UHS.*

Oconee's UHS is comprised of two sources of water in the event Lake Keowee were to be lost. The first is the water in the intake canal between the submerged weir and the CWIS. The second is the cooling water piping system between the CCW pumps and the discharge structure[92].

The hypothetical MDCT retrofit discussed in Section 10 of this document includes the enclosure of Oconee's intake canal by sealing off the existing curtain wall. If a hypothetical MDCT retrofit were to

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[91] The USNRC's Regulatory Guide 1.27 provides more discussion on the specific design of the UHS.

[92] In addition to these, Oconee can utilize Lake Keowee via the intake canal using the CCW pumps or gravity flow through the circulating water system (Duke Energy 2015).

be implemented at Oconee, the intake canal would need to be protected during the MDCT construction to allow uninterrupted flow to the CWIS to preserve the UHS. Extensive review of the intake piping and UHS would be required prior to the selection of closed-cycle cooling towers as a compliance option to avoid any impacts to Oconee's UHS and nuclear safety requirements.

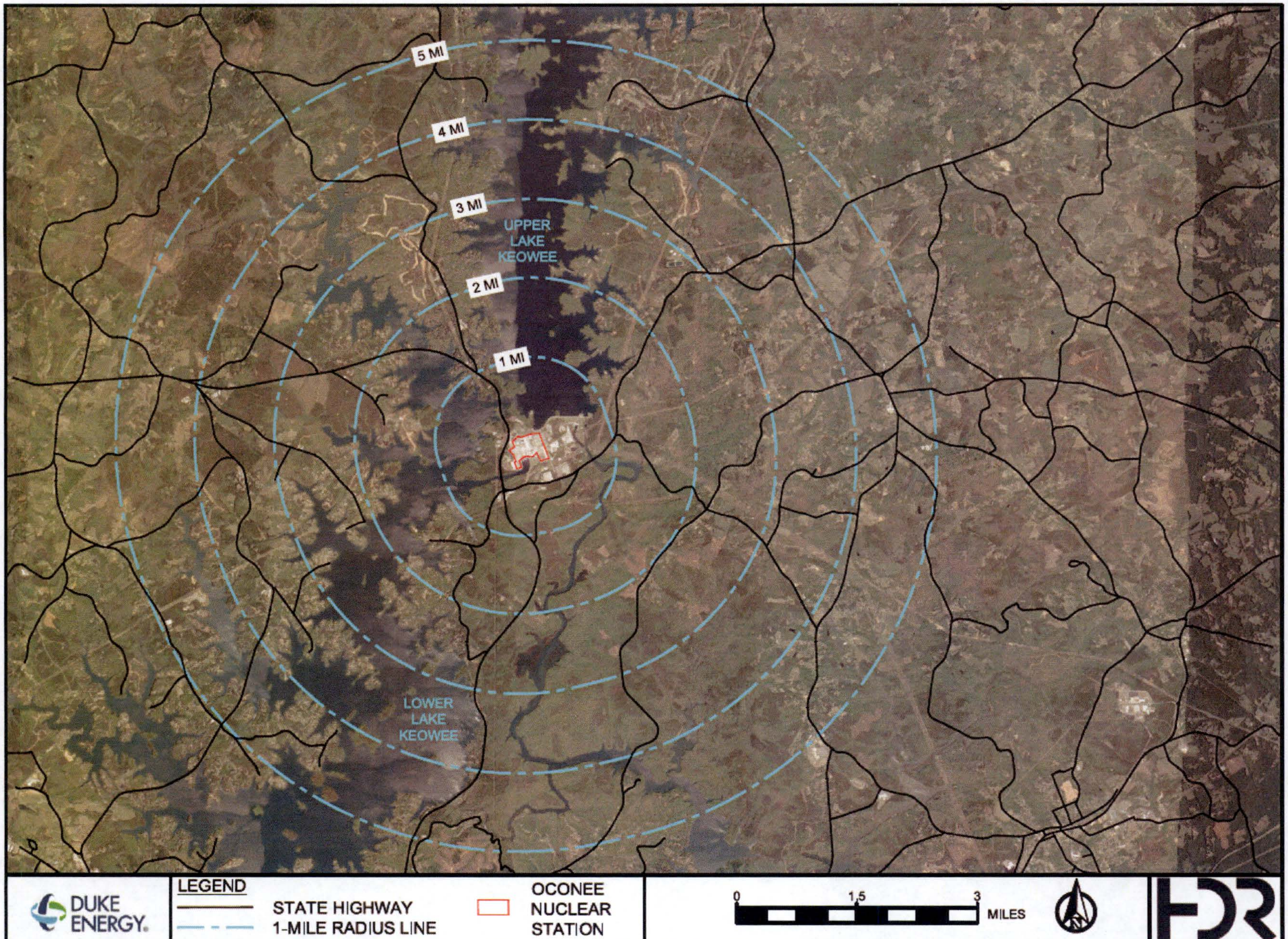

Figure 12-3. Highway Network Surrounding Oconee Nuclear Station

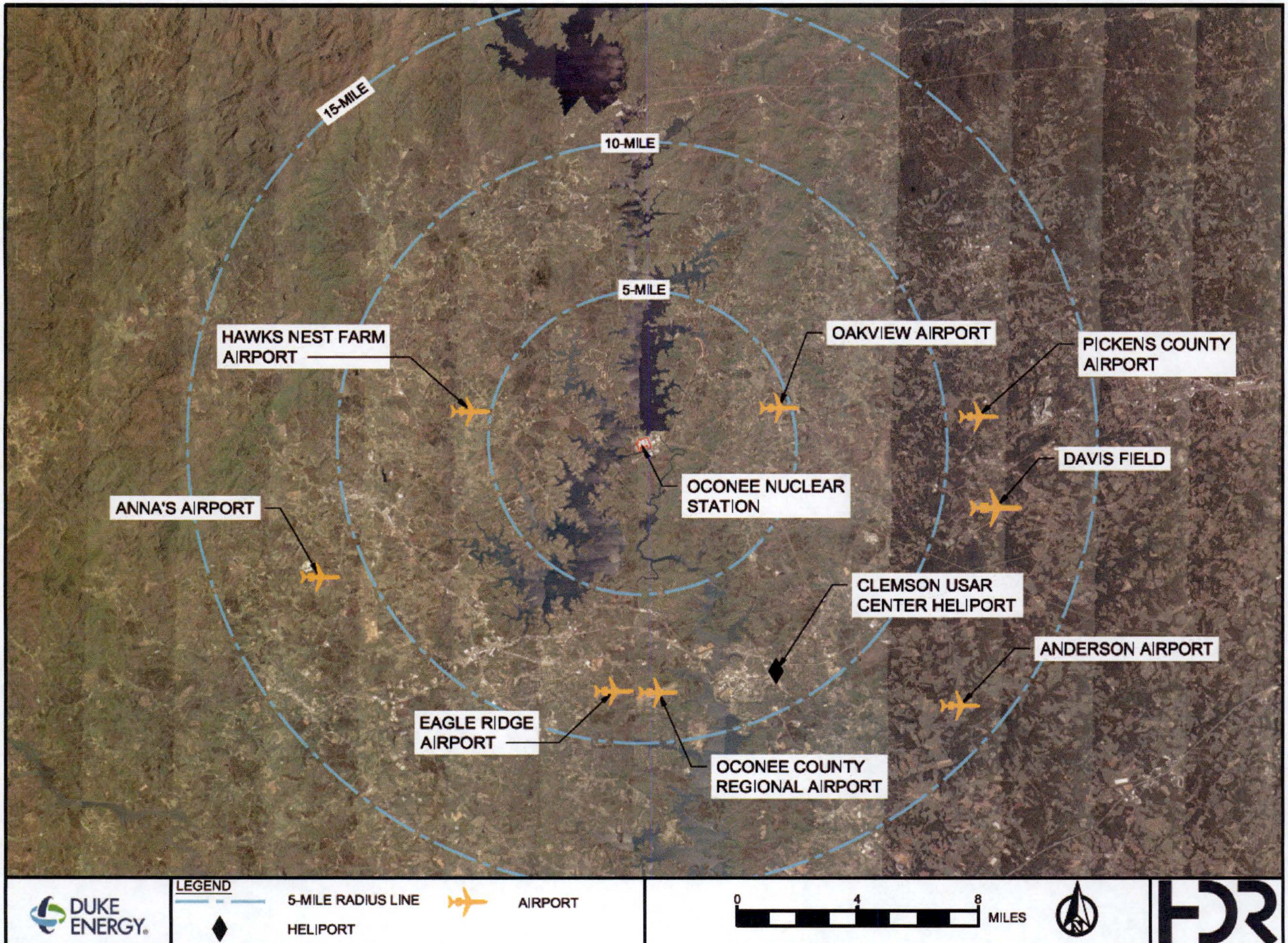

Figure 12-4. Airports and Heliports in the Vicinity of Oconee Nuclear Station

12.2.4.2 Quantification

Cooling Tower Plume and Fog Formation

Cooling tower plume and fog formation can occur throughout the year, but the possibility is increased in the colder months. While plume and fog formation is difficult to forecast, fog and other meteorological events are recorded at the National Oceanic and Atmospheric Administration (NOAA) Station WBAN 53850, Clemson Oconee County Airport, SC (Table 12-7), which is located approximately 8 miles south of Oconee.

The data indicate that fogging conditions[93] occur near Oconee most frequently in the months of November, December, and January, with nearly 46 percent of all recorded days with fogging conditions occurring in these months. During the period of record from July 1, 2014 through June 30, 2019, NOAA Station WBAN 53850 recorded fogging conditions on approximately 31 percent of days in November, 30 percent of days in December, and 23 percent of days in January. In total, fogging conditions were recorded on 16 percent of days within the period of record. MDCT operation would likely increase the duration of fogging conditions experienced on these days (EPRI 2011).[94]

Table 12-7. Days with Fogging Conditions Reported at NOAA Station WBAN 53850 from July 1, 2014 through June 30, 2019

Month	Number of Days in Record with Fogging Conditions	Average Number of Days in a Typical Month with Fogging Conditions	Percent of Total Days with Fogging Conditions	Percent of Total Days in a Typical Month with Fogging Conditions
January	36	7	13	23
February	25	5	9	18
March	17	3	6	11
April	25	5	9	17
May	14	3	5	9
June	16	3	6	11
July	6	1	2	4
August	14	3	5	9
September	9	2	3	6
October	27	5	10	17
November	47	9	17	31
December	47	9	17	30

[93] For the purposes of this evaluation, fogging conditions are defined as any period of time during a calendar day where the presence of fog was recorded. This does not include haze, smoke, dust, mist, ash, spray, or any other obscuration type.

[94] Especially considering that Oconee is adjacent to a cooling lake where fogging could be greater than the location of the weather station.

Month	Number of Days in Record with Fogging Conditions	Average Number of Days in a Typical Month with Fogging Conditions	Percent of Total Days with Fogging Conditions	Percent of Total Days in a Typical Month with Fogging Conditions
Total	**283**	**5**	**100**	**16**

Notes:
Total number of data points July 1, 2014 through June 30, 2019 is 1,825.
Source: NOAA 2019

Ice Formation

While similar to fog formation in that localized conditions can vary, the possibility for ice formation can be more easily predicted with forecasted regional freezing temperatures. Air temperature data at NOAA Station WBAN 53850, Clemson Oconee County Airport, SC (located approximately 8 miles south of Oconee) has been evaluated for days with a recorded minimum temperature of less than or equal to 32°F (Table 12-8).

The data indicate that freezing conditions[95] occur near Oconee most frequently in the winter months of December, January, and February, with approximately 83 percent of all recorded freezing days occurring within these months. There is recorded freezing in the late fall and early spring months, and none in the summer months. During the period of record from July 1, 2014 through June 30, 2019 NOAA Station WBAN 53850 recorded freezing conditions on approximately 23 percent of days in December, 45 percent of days in January, and 27 percent of days in February. MDCT operation would likely increase the duration of ice formation on typical freezing days (EPRI 2011).

Table 12-8. Days with a Recorded Freezing Temperature at NOAA Station WBAN 53850 from July 1, 2014 through June 30, 2019

Month	Number of Days in Record with a Freezing Temperature	Average Number of Days with Freezing Temperature per Month	Percent of Total Days with Freezing Temperature in Record	Percent of Total Days in Month with Freezing Temperatures
January	69	14	40	45
February	38	8	22	27
March	13	3	8	8
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0

[95] For the purposes of this report, freezing conditions are defined as any period of time during a calendar day when the recorded temperature was at or below the freezing temperature of 32°F.

Month	Number of Days in Record with a Freezing Temperature	Average Number of Days with Freezing Temperature per Month	Percent of Total Days with Freezing Temperature in Record	Percent of Total Days in Month with Freezing Temperatures
October	0	0	0	0
November	17	3	10	11
December	35	7	20	23
Total	**172**	**3**	**100**	**9**

Note:
Total number of data points July 1, 2014 through June 30, 2019 is 1,825.
Source: NOAA 2019

12.2.4.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

A potential mitigation method for safety impacts due to hypothetical MDCT plume formation would be the installation of plume-abated cooling towers. Plume abatement is accomplished through the use of an additional technology component installed in the cooling tower prior to the exhaust point. Plume-abated cooling towers require additional footprint, capital cost, and O&M cost when compared to standard MDCTs. Due the lack of critical infrastructure or airports in the immediate vicinity of Oconee, as discussed in Section 10, plume-abated cooling towers were not selected for further evaluation.

12.2.4.4 Uncertainty

Key sources of uncertainty associated with the evaluation of potential safety impacts due to a hypothetical MDCT retrofit at Oconee include the following:

1. While wind roses provide data on long-term average wind speeds and directions, specific wind speeds have not been compared to the number of recorded days with freezing temperatures or fogging conditions. Fog and ice formation due to cooling tower plume could occur in any direction at the station and would follow the instantaneous prevailing wind direction;
2. Fog and ice formation depend on a number of atmospheric and ground conditions that can vary over a large region, and conditions reported at NOAA Station WBAN 53850 may not be representative of the conditions at Oconee; and
3. Actual unsafe conditions can develop rapidly within shorter time spans than those evaluated in this study. Additional safety evaluations would be performed if MDCTs were selected as BTA at Oconee.

12.2.5 Station Reliability Impacts (§122.21(r)(12)(v))

12.2.5.1 Description

Station reliability refers to a power station's ability to produce power when the station is required to do so. Oconee's reliability could be impacted by both the operation of MDCTs in summer months and icing due to plume formation in winter months. The hypothetical cooling towers in this evaluation have been designed to the 99th percentile wet-bulb temperature obtained from WMO Station Number 723120 (Greenville/Spartanburg, SC), which means that the cooling towers would not be able to fully cool their design heat load for 1 percent of the time, on average (WMO 1999). As such, for approximately 88 hours each year, when the ambient wet-bulb temperature is at its annual peak, the station would be required to operate at reduced power. In addition, the potential for icing of Oconee's transmission lines due to cooling tower plume formation could impact station reliability during periods of peak electricity demand in the winter.

12.2.5.2 Quantification

Based on the hypothetical MDCT design parameters, Oconee would need to operate at reduced power for approximately 88 hours per year during the warmest and most humid periods. The actual magnitude of the percent reduction in power would depend on specific meteorological conditions. Given the uncertainty associated with icing conditions, the risks to the transmission system were not quantified.

12.2.5.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

The construction and installation of larger MDCTs than those discussed in Section 10 would decrease the likelihood of the need to operate at reduced power; however they would be significantly more costly and would require a larger footprint.

12.2.5.4 Uncertainty

Key uncertainties associated with the evaluation of station reliability impacts due to a hypothetical MDCT retrofit at Oconee include the following:

1. The preliminary cooling tower design discussed in Section 10 used the 99th percentile wet-bulb temperature, which is a long-term indicator. There may be some years when the actual wet-bulb temperature would not exceed the design value, and other years when it is exceeded more frequently than 1 percent of the time;
2. If electricity demand and/or operating conditions at Oconee and other stations were to deviate from the present forecast, the actual impacts could vary; and
3. This evaluation does not account for potential equipment failures and performance degradations. If hypothetical cooling towers were to be constructed and operated at Oconee, a robust maintenance schedule would be required to minimize unplanned outages.

12.2.6 Consumptive Water Use Impacts (§122.21(r)(12)(vi))

12.2.6.1 Description

Evaporation occurs naturally in surface water bodies and is affected by the stored energy in water. A number of variables factor into surface water evaporation, including incoming solar radiation, ambient water temperatures, and psychrometric[96] and atmospheric conditions. When heated water is discharged to a surface waterbody, the evaporation rate in the waterbody is increased due to the

[96] Psychrometrics is the field of study relating to physical and thermodynamic properties of gas-vapor mixtures. Typical psychrometric parameters include dry-bulb, wet-bulb, and dew point temperatures.

additional heat. The increase in evaporation due to thermal discharge is referred to as forced evaporation and is directly related to the amount of additional heat discharged to the receiving waterbody. The additional heat can be estimated using the stations' temperature differential across the condensers and the condenser water flow rate.

In wet cooling towers, water is consumed through evaporation to cool the water circulating through the towers. The cooling tower flow rate and range are the primary parameters the affect cooling tower evaporation. Forced evaporation in the waterbody due to the discharge of cooling tower blowdown would be minor compared to the cooling tower evaporation and is not quantified.

Increases in consumptive water use at Oconee due to a hypothetical closed-cycle cooling tower retrofit would have physical impacts on lake area and water level in Lake Keowee.

12.2.6.2 Quantification

Forced Evaporation due to Once-through Thermal Discharge

The forced evaporation due to the existing once-through thermal discharge at Oconee has been estimated using the Edinger-Geyer Method[97]. A series of papers by Edinger and Geyer presented a consumptive water loss estimation method based on a basic heat budget (Maulbetsch and DiFilippo 2008; Davis 1979). In this method, the heat removal rate of condenser circulating water is a function of the quantity and temperature of the condensed steam and the condenser efficiency (USDOE 2002). A heat rejection rate can be quantified using the circulating water heat removal rate.

Heat exchange between a waterbody and the atmosphere is governed by atmospheric radiation, conduction, convection, and evaporation (Solley et al. 1998). The majority of heat loss from a waterbody is through evaporation, which is dependent upon the latent heat of evaporation. The forced evaporation rate (Eq. 12-1) due to thermal discharge is calculated by multiplying the station's heat rejection rate (Eq. 12-2*)* by an evaporative loss coefficient. Edinger and Geyer (1965) developed the method to calculate the evaporative loss coefficient (Eq. 12-3). The formulae and variables used in this evaluation of forced evaporation due to once-through thermal discharge include the following:

$$EE = H_r \times C \qquad \textbf{Eq. 12-1}$$

Where,

EE = Forced Evaporation (cfs)

H_r = Heat Rejection Rate (Btu / hr)

C = Evaporative Loss Coefficient due to Thermal Discharge (cfs / 10^9 Btu / hr)

$$H_r = \rho \times Q \times c \times \Delta T \qquad \textbf{Eq. 12-2}$$

Where,

[97] The Edinger-Geyer Method terms forced evaporation as "in-stream evaporative water loss". The term forced evaporation is being used in lieu of the Edinger-Geyer terminology to be consistent within this document.

ρ = Density of Water (lb_m / ft^3) (Approximate value of 62.37 lb_m / ft^3 was used)

Q = Circulating Water Flow Rate (cfs)

c = Specific Heat of Water (Btu / lb_m / °F) (Approximately 1.0 Btu / lb_m / °F)

ΔT = Condenser Temperature Differential (°F)

$$C = \left(\frac{4450}{L}\right)\frac{B(K - 15.7)}{(0.26 + B)K}$$ **Eq. 12-3**

Where,

L = Latent Heat of Vaporization

$$L = 1093 - 0.56T_s$$

B = Slope of Saturated Water Vapor Pressure (mmHg / °F)

$$B = 0.255 - 0.0088T + 0.000204T^2$$

K = Surface Heat Exchange Coefficient (Btu / ft^2 / °F)

$$K = 15.7 + (B + 0.26)f(u)$$

T = Temperature Function

$$T = {}^1/_2(T_s + T_d)$$

T_d = Dew Point Temperature (°F)

T_s = Background Temperature of Receiving Waterbody (°F)

f(u) = Function of Wind

$$f(u) = 70 + 0.7u^2$$

u = Wind Speed, MPH

The Edinger-Geyer method was developed for power stations in Pennsylvania that used fresh water for once-through cooling, and was later tested for estuarine environments. The results have been compared to benchmarks in the power industry (EPRI 2011). Using input data specific to Oconee, forced evaporation due to once-through thermal discharge has been estimated for both design and actual conditions at the station. The design forced evaporation was calculated using the design condenser cooling water flow and design temperature differential across the condensers, while actual forced evaporation was calculated using the actual condenser cooling water flow[98] and actual temperature differential across the condensers, for the period of record from July 1, 2014 through June 30, 2019.

The maximum and average forced evaporation due to once-through thermal discharge is provided in Table 12-9 on a monthly basis for the period of record for both design and actual conditions at Oconee. See Appendix 12-C for engineering calculations of forced evaporation.

[98] The design service water flow was subtracted from the actual intake flow for the period of record from July 1, 2014 through June 30, 2019 to obtain the actual condenser cooling water flow for the same time period (Duke Energy 2019a; Duke Power Company 1970).

Table 12-9. Forced Evaporation due to Once-through Thermal Discharge from July 1, 2014 through June 30, 2019 at Oconee Nuclear Station

Month	Design Conditions		Actual Conditions	
	Maximum (MGD)	Average (MGD)	Maximum (MGD)	Average (MGD)
January	19.0	17.3	16.4	14.4
February	19.4	17.9	16.5	14.8
March	19.3	18.6	17.6	14.4
April	22.7	21.3	20.7	17.3
May	25.1	24.4	22.6	19.7
June	27.6	27.1	25.9	22.1
July	29.6	28.9	26.5	22.6
August	30.3	29.6	28.6	23.5
September	29.9	29.2	27.6	23.6
October	27.0	25.5	23.8	18.2
November	22.8	21.7	14.5	12.9
December	21.9	19.7	20.3	16.0

Design Cooling Tower Evaporation

MDCTs are evaporative cooling towers, which utilize evaporation as the primary means of cooling. The cooling tower evaporative water loss as a result of the cooling effect is governed by latent heat transfer and the direct contact of water and air in the tower. The rate of cooling tower evaporation can be calculated using Eq. 12-4[99].

$$E = 0.0008 \times R \times Q_{CT}$$ **Eq. 12-4**

Where,

E = Rate of Evaporation (gpm)

R = Cooling Tower Range (°F)

Q_{CT} = Cooling Tower Water Flow Rate (gpm)

Drift is an additional water loss in cooling towers and occurs as circulating water droplets are captured in the exhaust air stream (SPX 2009) (Eq. 12-5).

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[99] The formulae and variables presented in this section are detailed in SPX (2009).

$$D = DE \times Q_{CT}$$ **Eq. 12-5**

Where,

D = Drift Flow Rate (gpm)

DE = Drift Eliminator Efficiency (%)

Q_{CT} = Cooling Tower Water Flow Rate (gpm)

Design cooling tower evaporation and drift rates due to a hypothetical MDCT retrofit at Oconee are provided in Table 12-10. Cooling tower evaporation at Oconee would consume approximately 5,106 MGY per unit (15,317 MGY total) on a design basis. Cooling tower drift would consume approximately 1.9 MGY per unit (5.6 MGY total) on a design basis. The total annual design consumptive water use at Oconee due to a hypothetical MDCT retrofit would be approximately 5,107 MGY per unit (15,322 MGY total). See Appendix 10-A for engineering calculations of cooling tower evaporation and drift.

Table 12-10. Hypothetical MDCT Design Evaporation and Drift Rates at Oconee Nuclear Station

Estimated Cooling Tower Flow Rates		Units	Unit 1	Unit 2	Unit 3	Total
Design Evaporation Rate	E	gpm	9,714	9,714	9,714	29,141
Design Drift Rate	D	gpm	3.5	3.5	3.5	10.6

Design consumptive water use at Oconee due to a hypothetical closed-cycle cooling tower retrofit would have physical impacts on lake area and water level in Lake Keowee, as discussed in the Social Costs of Water Consumption Impacts from a Closed-Cycle Cooling Conversion report prepared by Veritas (provided in Appendix 10-J). According to this report, the Lake Keowee reservoir level would decrease by approximately 8 inches at full pond water elevation, and approximately 9 inches at maximum drawdown elevation due to operation of closed-cycle cooling towers at Oconee (Veritas 2020b).

During the past two decades, there have been several severe droughts that have impacted Lake Keowee reservoir levels (i.e., 1998 – 2002, 2007 – 2009, and 2011 – 2012). During these drought periods, downstream flow releases from the Keowee Development were often reduced to only the leakage through the hydroelectric turbines (estimated at approximately 50 cfs) for extended periods. To help alleviate reservoir level impacts to Oconee's operations during drought conditions, Duke Energy, the USACE, and Southeastern Power Administration collaborated on a reservoir level operating agreement between the Duke Energy and USACE reservoirs in the Savannah River drainage basin (including Lake Keowee) (USACE 2014). This agreement would likely need to be revisited/revised if closed-cycle cooling towers were installed at Oconee due to the additional consumptive water use and associated impacts on Lake Keowee reservoir levels and Oconee operations.

Increase in Consumptive Water Use

The design consumptive water use in evaporative cooling towers is typically higher than design forced evaporation due to once-through thermal discharge. The increase in design evaporation due to a hypothetical MDCT retrofit at Oconee was estimated using Eq. 12-6 and is provided in Table 12-11. The estimated design cooling tower evaporation at Oconee would be higher than the estimated design forced evaporation due to once-through thermal discharge for all months of the year, with the increase ranging from 41.7 percent in the summer to 143.2 percent in the winter. The overall average increase in evaporation due to a hypothetical MDCT retrofit at Oconee would be approximately 85.7 percent.

$$Percent\ Increase\ in\ Evaporation = \frac{Cooling\ Tower\ Evap.\ -\ Forced\ Evap.}{Forced\ Evap.} \times 100 \qquad \textbf{Eq. 12-6}$$

Table 12-11. Comparison of Design Forced Evaporation due to Once-through Thermal Discharge and Hypothetical Design Cooling Tower Evaporation from July 1, 2014 through June 30, 2019 at Oconee Nuclear Station

Month	Average Forced Evaporation (Existing) at Design Conditions (MGD)	Design Cooling Tower Evaporation (MGD)	Percent Increase (%)
January	17.3	42.0	143.2
February	17.9	42.0	134.4
March	18.6	42.0	125.4
April	21.3	42.0	96.7
May	24.4	42.0	71.8
June	27.1	42.0	55.0
July	28.9	42.0	45.1
August	29.6	42.0	41.7
September	29.2	42.0	43.6
October	25.5	42.0	64.5
November	21.7	42.0	93.5
December	19.7	42.0	113.4

Note: Design cooling tower evaporation is calculated using the design cooling tower range and design intake flow for the station.

12.2.6.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

If hybrid or plume-abated cooling towers were installed, it is possible that a portion of the water vapor in the cooling tower exhaust could be condensed, collected, and potentially reused in the system to reduce the total water consumption. However, the volume of water collected using this technology would be a minor portion of the overall evaporation rate (SPX 2016). Evaporation is critical to the cooling process, and mitigation measures that would reduce evaporative losses would not be incorporated into a potential design.

12.2.6.4 Uncertainty

Key uncertainties associated with the evaluation of potential consumptive water use impacts due to a hypothetical MDCT retrofit at Oconee include the following:

1. Actual evaporation rates are dependent on psychrometrics and ambient conditions at any given time, and could vary from those evaluated; and
2. The evaluation of forced evaporation assumes a well-mixed thermal discharge. The station's existing once-through thermal discharge could differ from the characteristics assumed in the calculation.

12.3 Retrofit of Existing Coarse-mesh Screens with 1.0-mm FMS in the Existing CWIS

12.3.1 Energy Consumption Impacts (§122.21(r)(12)(i))

12.3.1.1 Description

A hypothetical retrofit of the existing coarse-mesh fixed-panel screens with 1.0-mm FMS units and an aquatic organism return system at Oconee would require continuous operation to optimize the IM benefits of the technology (USEPA 2014). This would include continuous screen rotation, continuous operation of low-pressure screen wash pumps to remove aquatic organisms, and continuous operation of high-pressure screen wash pumps to remove debris. The continuous screen rotation and additional pumping requirements would increase energy consumption of the hypothetical 1.0-mm FMS retrofit system when compared to the existing screens at Oconee.

The operation of 1.0-mm FMS would increase headloss across the screens by approximately 12.1 inches on average when compared to the existing screens at Oconee (see Section 10.4.3 of this document for additional information). This increase in headloss would cause a decrease in water elevation at the existing CCW pump suction locations within the CWIS, which in turn would cause the pumps to require more power to route cooling water to the condensers. The increase in energy consumption of the existing CCW pumps is included in this evaluation.

12.3.1.2 Quantification

Auxiliary Energy Requirements

The increase in energy consumption due to hypothetical 1.0-mm FMS retrofit at Oconee would be caused by the auxiliary energy requirements of new equipment, and the impacts of increased screen headloss on the performance of the existing CCW pumps. The auxiliary energy requirements would be from the new screen motors, the low-pressure screen wash system, the high-pressure screen wash system, and the aquatic organism return system make-up water system. It is assumed the FMS system would operate continuously when the CCW pumps are operating to optimize IM reduction benefits, and to reduce maintenance requirements (USEPA 2014).

The 1.0-mm FMS motor and pumping requirements were provided by Evoqua Water Technologies (2019) for the hypothetical 1.0-mm FMS retrofit at Oconee. The annual hours of FMS operation were estimated by incorporating an intake flow capacity factor for each unit, equal to the ratio of the unit AIF for the period of record to the unit DIF. The quantification of the increase in energy consumption due to a hypothetical 1.0-mm FMS retrofit in the existing CWIS at Oconee is summarized in Table 12-13 and calculation inputs are provided in Table 12-12. Engineering calculations are provided in Appendix 12-D.

Replacement Energy Required due to Construction Outage

In addition to the recurring increase in energy consumption due to the 1.0-mm FMS auxiliary energy requirements and impacts on existing CCW pump performance, there would be a one-time loss in energy generated at Oconee in 2024 for Unit 1, 2025 for Unit 2, and 2026 for Unit 3 due to the 1.0-mm FMS construction outage. The replacement energy required due to the 1.0-mm FMS retrofit construction outage was calculated assuming each unit would have been fully utilized during the construction outage, other than the regularly-scheduled maintenance outage that has been incorporated into the construction outage for each unit. It is assumed the 1.0-mm FMS retrofit construction outage would be 2 months in total for each unit and would include a regularly-scheduled unit maintenance outage (approximately 1 month) to help reduce replacement energy costs. The total replacement energy required due to the construction outage for a hypothetical 1.0-mm FMS retrofit within the existing CWIS at Oconee is provided in Table 12-14.

Table 12-12. Operational Parameters for the Existing Coarse-mesh Screen System and Hypothetical 1.0-mm FMS Retrofit in the Existing CWIS at Oconee Nuclear Station

Existing Coarse-mesh Screens	Value	Units
Existing Screen Motor Rating*	0	hp/screen
Screen Wash Pump System*	0	hp
Total Annual Hours of Operation*	0	hours/year
Number of Screens	24	-
Total Annual Energy Consumption*	0	MWhr/year
Hypothetical 1.0-mm FMS Retrofit[100]	**Value**	**Units**
Screen Motor Rating (Input)	2.0	hp/screen
Low-pressure Screen Wash System	2.0	hp/screen
High-pressure Screen Wash System	13.5	hp/screen
Auxiliary Low-pressure Screen Wash System	0.4	hp/screen
Aquatic Organism System Make-up Water	0.7	hp
Increase in Headloss due to FMS	10.3	inch
Number of Screens	24	-

Note: *The existing screens at Oconee are coarse-mesh fixed-panel screens without motors or an automated screen wash system.
Source: Evoqua Water Technologies 2019

[100] The 1.0-mm FMS retrofit energy requirements (in hp) were calculated based on vendor information, and include pump and motor inefficiencies. These values were not based on actual motor selection for the FMS system. If 1.0-mm FMS were selected as BTA at Oconee, motors and pumps would be selected based on detailed design information.

Table 12-13. Increase in Energy Consumption due to a Hypothetical 1.0-mm FMS Retrofit in the Existing CWIS at Oconee Nuclear Station

Hypothetical 1.0-mm FMS Retrofit[101]	Unit 1	Unit 2	Unit 3	Total
Total Weekly Increase in Energy Consumption (MWhr / week)	40.3	41.0	40.9	122.2
Total Annual Increase in Energy Consumption (MWhr / year)	2,094	2,133	2,129	6,356

Table 12-14. Total Replacement Energy Required due to the Construction Outage for a Hypothetical 1.0-mm FMS Retrofit in the Existing CWIS at Oconee Nuclear Station

Total Replacement Energy Required due to Construction Outage	Unit 1	Unit 2	Unit 3	Total
Total Replacement Energy Required (MWhr)	714,384	783,648	725,472	2,223,504

12.3.1.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

Regular inspection and maintenance of the 1.0-mm FMS system, including screens, motors, pumps, and aquatic organism return system would help to minimize operational inefficiencies, which would reduce extraneous energy consumption to the extent practicable. This mitigation method is incorporated into the preliminary 1.0-mm FMS retrofit design discussed in Section 10 of this document, and no additional mitigation methods are included.

12.3.1.4 Uncertainty

Key uncertainties associated with the evaluation of potential energy consumption impacts due to a hypothetical 1.0-mm FMS retrofit in the existing CWIS at Oconee include the following:

1. The auxiliary energy requirements were calculated using preliminary and approximate equipment sizes, lengths, and capacities. The actual auxiliary energy requirements would be refined during detailed design and construction if a 1.0-mm FMS retrofit in the existing CWIS were to be selected as BTA for the station;
2. The 1.0-mm FMS retrofit construction outage was assumed to be 2 months in total for each unit and incorporated regularly-scheduled unit outages into the implementation schedule. The actual construction outage could deviate from this estimate; and
3. Actual debris and organism loading at Oconee could impact screen headloss and existing CCW pump performance differently than the estimate provided in this evaluation.

[101] This calculation incorporates unit intake flow capacity factors of 85 percent, 86 percent, and 86 percent for Units 1, 2, and 3, respectively.

12.3.2 Air Pollutant Emissions, Environmental Impacts, and Human Health (§122.21(r)(12)(ii))

12.3.2.1 Description of Air Pollutant Emissions and Human Health

While there would be no on-site PM emissions generated by a hypothetical 1.0-mm FMS retrofit in the existing CWIS at Oconee, the operation of 1.0-mm FMS would contribute to increased off-site combustion emissions in two forms: recurring emissions due to the FMS auxiliary energy requirements and impacts to the performance of the existing CCW pumps, and emissions produced during the construction outage. A description of off-site combustion emissions is provided in Section 12.2.2.1 of this document. A description of potential concerns to human health due to air pollutant emissions is provided in Section 12.2.2.2 of this document.

12.3.2.2 Quantification of Air Pollutant Emissions

Differences in projections of existing off-site CO_2, NO_X, and SO_2 emissions (Base Case) and off-site CO_2, NO_X, and SO_2 emissions due to the hypothetical 1.0-mm FMS retrofit at Oconee were simulated using PROSYM. The construction outage was assumed to be two months in total for each unit, and would include a regularly-scheduled maintenance outage (approximately one month) to help reduce replacement energy costs. Off-site emissions due to the unit construction outages were included in the PROSYM simulation, and would be experienced in 2024 for Unit 1, 2025 for Unit 2, and 2026 for Unit 3 at Oconee. The new 1.0-mm FMS units would be operational in 2024 for Unit 1, 2025 for Unit 2, and 2026 for Unit 3. The estimated annual net increases in off-site air pollutant emissions due to the hypothetical 1.0-mm FMS retrofit at Oconee is provided in Table 12-15.

Table 12-15. Estimated Net Increases in Off-site Air Pollutant Emissions due to a Hypothetical 1.0-mm FMS Retrofit at Oconee Nuclear Station[1]

Year	NO_X (Tons)	Increase from Base Case	SO_2 (Tons)	Increase from Base Case	CO_2 (Tons)	Increase from Base Case
2024	20,350	330	16,850	200	39,562,200	447,180
2025	18,680	250	15,190	200	37,125,180	394,230
2026	19,140	270	15,720	110	37,289,080	358,450
2027	17,850	50	13,260	20	35,981,900	13,710
2028	18,660	30	15,880	0	36,970,340	4,280
2029	18,210	<10	13,890	<10	36,372,620	4,490
2030	19,450	<10	8,030	20	38,414,950	10,920
2031	21,130	40	10,940	<10	40,760,480	16,090
2032	21,980	20	12,990	10	42,216,740	720
2033	27,230	10	19,200	0	52,142,580	1,920
2034	28,550	0	23,490	0	56,257,560	0

[1]Less than values (i.e., <10 tons) reflect the increased use of zero carbon replacement generation and also fall within the acceptable range of modeling uncertainty.

12.3.2.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

Regular inspection and maintenance of the 1.0-mm FMS system, including screens, motors, pumps, and aquatic organism return system would help to minimize operational inefficiencies, which would reduce extraneous energy consumption and the associated air pollutant emissions to the extent practicable. This mitigation method is incorporated into the preliminary 1.0-mm FMS retrofit design discussed in Section 10 of this document, and no additional mitigation methods are included.

12.3.2.4 Uncertainty

Key uncertainties associated with the evaluation of potential air pollutant emissions impacts due to a hypothetical 1.0-mm FMS retrofit in the existing CWIS at Oconee include the following:

1. The actual FMS construction outage at Oconee could differ from the assumptions made in this evaluation;
2. Air pollutant emissions factors today may not be representative of future emissions factors due to changes in fuel mix and emissions controls; and
3. Regulations governing air pollutant emissions may change in the future.

12.3.3 Noise Impacts (§122.21(r)(12)(iii))

The existing screens at Oconee are coarse-mesh fixed-panel screens that do not travel or rotate. In a hypothetical 1.0-mm FMS retrofit, the screens would be rotated continuously, which would result in a minor noise increase at the CWIS. However, it is not expected that the minor increase in noise would have any off-site impacts since the new equipment at the CWIS would be shielded by other structures and would be located more than 3,000 ft from the nearest station property boundary. This distance would be sufficient to provide natural noise attenuation.

12.3.4 Safety Impacts (§122.21(r)(12)(iv))

TSV and headloss in the existing CWIS due to a hypothetical 1.0-mm FMS retrofit would increase considerably, which could impact the existing CCW pumps and cause impacts to station reliability, availability of cooling flow, and nuclear safety. Hydraulic evaluations would be performed if this option were considered for further BTA evaluation.

12.3.5 Station Reliability Impacts (§122.21(r)(12)(v))

12.3.5.1 Description

Station reliability refers to a power plant's ability to produce power when the station is required to do so. Oconee's reliability could be impacted by a hypothetical 1.0-mm FMS retrofit in the existing CWIS if the increased headloss across the screens were to affect performance of the existing CCW pumps, including potential pump damage or cavitation. Significant debris loading scenarios could cause severe headloss and would increase the likelihood of impacts to the existing CCW pumps. The hypothetical 1.0-mm FMS would be rotated and cleaned continuously to reduce reliability impacts.

12.3.5.2 Impact Mitigation Methods (§122.21(r)(12)(vii))

The FMS would be required to be rotated and cleaned continuously, and the screen units would be maintained and inspected regularly to optimize operations. No additional mitigation methods are included in the evaluation.

12.3.5.3 Uncertainty

The magnitude and variability of actual debris loading at Oconee would impact reliable FMS operation.

12.3.6 Consumptive Water Use Impacts (§122.21(r)(12)(vi))

A hypothetical 1.0-mm FMS retrofit in the existing CWIS at Oconee would not be expected to impact consumptive water use at the station.

12.4 Installation of 1.0-mm FMS in a New CWIS at Oconee

12.4.1 Energy Consumption Impacts (§122.21(r)(12)(i))

12.4.1.1 Description

The hypothetical installation of 30 new 1.0-mm FMS units in a new CWIS with an aquatic organism return system at Oconee would require continuous operation to optimize the IM benefits of the technology (USEPA 2014). This would include continuous screen rotation, continuous operation of low-pressure screen wash pumps to remove aquatic organisms, and continuous operation of high-pressure screen wash pumps to remove debris. The continuous screen rotation and additional pumping requirements would increase energy consumption of the hypothetical 1.0-mm FMS system when compared to the existing screens at Oconee.

The operation of 1.0-mm FMS units within the new CWIS would increase headloss across the screens by approximately 8.8 inches on average when compared to the existing screens at Oconee (see Section 10.4.3 of this document for additional information). This increase in headloss would cause a decrease in water elevation at the existing CCW pump suction locations in the existing CWIS, which in turn would cause the pumps to require more power to route cooling water to the condensers. The increase in energy consumption of the existing CCW pumps is included in this evaluation.

12.4.1.2 Quantification

The increase in energy consumption due to hypothetical 1.0-mm FMS installation in a new CWIS at Oconee would be caused by the auxiliary energy requirements of new equipment, and the impacts of increased screen headloss on the performance of the existing CCW pumps. It is assumed there would be no construction outage necessary for the hypothetical 1.0-mm FMS installation in a new CWIS at Oconee. The auxiliary energy requirements would be from the new screen motors, the low-pressure screen wash system, the high-pressure screen wash system, and the aquatic organism return system make-up water system. It is assumed the FMS system would operate continuously when the CCW pumps are operating to optimize IM reduction benefits, and to reduce maintenance requirements (USEPA 2014).

The 1.0-mm FMS motor and pumping requirements were provided by Evoqua Water Technologies (2019) for the hypothetical 1.0-mm FMS installation at Oconee. The annual hours of FMS operation were estimated by incorporating an intake flow capacity factor for each unit, equal to the ratio of the unit AIF for the period of record to the unit DIF. The quantification of the increase in energy consumption due to a hypothetical 1.0-mm FMS installation in a new CWIS at Oconee is summarized in Table 12-17 and calculation inputs are provided in Table 12-16. Engineering calculations are provided in Appendix 12-E.

Table 12-16. Operational Parameters for the Existing Coarse-mesh Screen System and Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Existing Coarse-mesh Screens	Value	Units
Existing Screen Motor Rating*	0	hp/screen
Screen Wash System*	0	hp
Total Annual Hours of Operation*	0	hours/year
Number of Screens	24	-
Total Annual Energy Consumption*	0	MWhr/year
Hypothetical 1.0-mm FMS in a New CWIS[102]	**Value**	**Units**
Screen Motor Rating (Input)	2.0	hp/screen
Low-pressure Screen Wash System	2.0	hp/screen
High-pressure Screen Wash System	13.5	hp/screen
Auxiliary Low-pressure Screen Wash System	0.4	hp/screen
Aquatic Organism System Make-up Water	0.7	hp
Increase in Headloss due to FMS	8.8	inch
Number of Screens	30	-

Notes: *The existing screens at Oconee are coarse-mesh fixed-panel screens without motors or an automated screen wash system.
Source: Evoqua Water Technologies 2019

[102] FMS energy requirements (in hp) were calculated based on vendor information, and include pump and motor inefficiencies. These values were not based on actual motor selection for the FMS system. If 1.0-mm FMS were to be selected as BTA at Oconee, actual motor ratings would be chosen based on detailed design information.

Table 12-17. Increase in Energy Consumption due to a Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Hypothetical 1.0-mm FMS in a New CWIS[103]	Unit 1	Unit 2	Unit 3	Total
Total Weekly Increase in Energy Consumption (MWhr / week)	37.4	38.1	38.0	113.5
Total Annual Increase in Energy Consumption (MWhr / year)	1,945	1,981	1,978	5,904

12.4.1.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

Regular inspection and maintenance of the 1.0-mm FMS system, including screens, motors, pumps, and aquatic organism return system would help to minimize operational inefficiencies, which would reduce extraneous energy consumption to the extent practicable. This mitigation method is incorporated into the preliminary 1.0-mm FMS installation design discussed in Section 10 of this document, and no additional mitigation methods are included.

12.4.1.4 Uncertainty

Key uncertainties associated with the evaluation of potential energy consumption impacts due to a hypothetical 1.0-mm FMS installation in a new CWIS at Oconee include the following:

1. The auxiliary energy requirements were calculated using preliminary and approximate equipment sizes, lengths, and capacities. The actual auxiliary energy requirements would be refined during detailed design and construction if the installation of 1.0-mm FMS in a new CWIS were to be selected as BTA for the station;
2. It is assumed that a construction outage would not be required for the hypothetical 1.0-mm FMS installation in a new CWIS. Energy consumption would increase if a construction outage were to be necessary; and
3. Actual debris and organism loading at Oconee could impact screen headloss and existing CCW pump performance differently than the estimate provided in this evaluation.

12.4.2 Air Pollutant Emissions, Environmental Impacts, and Human Health (§122.21(r)(12)(ii))

12.4.2.1 Description of Air Pollutant Emissions and Human Health

While there would be no on-site PM emissions generated by a hypothetical 1.0-mm FMS installation in a new CWIS at Oconee, the operation of 1.0-mm FMS would contribute to increased recurring off-site combustion emissions due to the FMS auxiliary energy requirements and impacts to the performance of the existing CCW pumps. A description of off-site combustion emissions is provided in Section 12.2.2.1 of this document. A description of potential concerns to human health due to air pollutant emissions is provided in Section 12.2.2.2 of this document.

[103] This calculation incorporates unit intake flow capacity factors of 85 percent, 86 percent, and 86 percent for Units 1, 2, and 3, respectively.

12.4.2.2 Quantification of Air Pollutant Emissions

Differences in projections of existing off-site CO_2, NO_X, and SO_2 emissions (Base Case) and off-site CO_2, NO_X, and SO_2 emissions due to the hypothetical installation of 1.0-mm FMS in a new CWIS at Oconee were simulated using PROSYM. There is no construction outage assumed for this technology, and the new FMS units would be operational in 2026 for all three units. The estimated annual net increases in off-site air pollutant emissions due to the hypothetical installation of 1.0-mm FMS in a new CWIS at Oconee is provided in Table 12-18.

Table 12-18. Estimated Net Increases in Off-site Air Pollutant Emissions due to a Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Year	NO_X (Tons)	Increase from Base Case	SO_2 (Tons)	Increase from Base Case	CO_2 (Tons)	Increase from Base Case
2026	18,840	<10	15,610	0	36,948,420	17,790
2027	17,840	40	13,260	20	35,980,910	12,720
2028	18,660	30	15,880	0	36,973,600	7,540
2029	18,210	<10	13,890	<10	36,373,090	4,960
2030	19,450	<10	8,030	20	38,414,850	10,820
2031	21,100	10	10,940	<10	40,752,250	7,860
2032	21,980	20	12,990	10	42,216,860	840
2033	27,230	10	19,200	0	52,142,680	2,020
2034	28,550	0	23,490	0	56,257,560	0

[1]Less than values (i.e., <10 tons) reflect the increased use of zero carbon replacement generation and also fall within the acceptable range of modeling uncertainty.

12.4.2.3 Impact Mitigation Methods (§122.21(r)(12)(vii))

Regular inspection and maintenance of the 1.0-mm FMS system, including screens, motors, pumps, and aquatic organism return system would help to minimize operational inefficiencies, which would reduce extraneous energy consumption and the associated air pollutant emissions to the extent practicable. This mitigation method is incorporated into the preliminary 1.0-mm FMS installation design discussed in Section 10 of this document, and no additional mitigation methods are included.

12.4.2.4 Uncertainty

Key uncertainties associated with the evaluation of potential air pollutant emissions impacts due to a hypothetical 1.0-mm FMS installation in a new CWIS at Oconee include the following:

1. It is assumed that a construction outage would not be required for the hypothetical 1.0-mm FMS installation in a new CWIS. Energy consumption and associated air pollutant emissions would increase if a construction outage were to be necessary;
2. Air pollutant emissions factors today may not be representative of future emissions factors due to changes in fuel mix and emissions controls; and
3. Regulations governing air pollutant emissions may change in the future.

12.4.3 Noise Impacts (§122.21(r)(12)(iii))

The existing screens at Oconee are coarse-mesh fixed-panel screens that do not travel or rotate. In a hypothetical 1.0-mm FMS installation in the new CWIS, the screens would be rotated continuously, which would result in a minor noise increase at the CWIS. However, it is not expected that the minor increase in noise would have any off-site impacts since the new CWIS would be located more than 3,000 ft from the nearest station property boundary. This distance would be sufficient to provide natural noise attenuation.

12.4.4 Safety Impacts (§122.21(r)(12)(iv))

Headloss due to a hypothetical 1.0-mm FMS installation in a new CWIS at Oconee could cause a minor increase in headloss at the screens in the existing CWIS, which could impact the existing CCW pumps and cause impacts to station reliability, availability of cooling flow, and nuclear safety. These potential impacts to safety would be expected to be minor, and no potential mitigation methods have been considered. Hydraulic evaluations would be performed if this option were considered for further BTA evaluation.

12.4.5 Station Reliability Impacts (§122.21(r)(12)(v))

12.4.5.1 Description

Station reliability refers to a power plant's ability to produce power when the station is required to do so. Oconee's reliability could be impacted by a hypothetical 1.0-mm FMS installation in a new CWIS if the increased headloss across the screens were to affect performance of the existing CCW pumps, including potential pump damage or cavitation. Significant debris loading scenarios could cause severe headloss and would increase the likelihood of impacts to the existing CCW pumps. The hypothetical 1.0-mm FMS units would be rotated and cleaned continuously to reduce reliability impacts.

12.4.5.2 Impact Mitigation Methods (§122.21(r)(12)(vii))

The FMS units would be required to be rotated and cleaned continuously, and the screen units would be maintained and inspected regularly to optimize operations. No additional mitigation methods are included in the evaluation.

12.4.5.3 Uncertainty

The magnitude and variability of actual debris loading at Oconee would impact reliable FMS operation.

12.4.6 Consumptive Water Use Impacts (§122.21(r)(12)(vi))

A hypothetical 1.0-mm FMS installation in a new CWIS at Oconee would not be expected to impact consumptive water use at the station.

12.5 Summary of Findings

A summary of findings for the technologies evaluated at Oconee for compliance with §122.21(r)(10) and §122.21(r)(12) is provided in Table 12-19.

Table 12-19. Summary of Findings

Parameter	MDCT Retrofit[104]	1.0-mm FMS Retrofit in the Existing CWIS[105]	1.0-mm FMS Installation in a New CWIS[98]
Anticipated Year of Commission	Unit 1 – 2026 Unit 2 – 2027 Unit 3 – 2028	Unit 1 – 2024 Unit 2 – 2025 Unit 3 - 2026	2026
Anticipated Construction Outage (Per Unit)	6 months	2 months	None[106]
Capital Costs (2019 $M)	1,109.3	65.6	122.2
O&M Costs (2019 $M)	15.0	1.9	2.3
Annual Increase in Energy Consumption (MWhr / year)	698,862	6,356	5,904
Energy Consumption Due to Construction Outage (MWhr)	10,289,880	2,223,504	0
Annual Increase in On-site Air Pollutant Emissions (tons / year)	$PM_{2.5}$ – 1.1 PM_{10} – 1.7	0	0
Annual Net Increase in Off-site Air Pollutant Emissions (tons / year)[107]	CO_2 – 470,223 SO_2 – 110 NO_X – 297	CO_2 – 6,516 SO_2 – 2.5 NO_X – 16	CO_2 – 7,172 SO_2 – 2.2 NO_X – 6.7
Noise Impacts	Moderate increase in on-site noise	Minor increase in on-site noise	Minor increase in on-site noise

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104 MDCT annual increase in energy consumption and annual increase in air pollutant emissions presented here are based on the five-year CUR for Units 1, 2, and 3 at Oconee.

105 FMS annual energy consumption and emissions impacts presented here are based on the assumption that FMS would operate based on the five-year intake flow capacity factors for each unit, which is equal to the ratio of unit AIF for the period of record to the unit DIF.

106 It is assumed the new CWIS would be constructed while the station is operating and would not require a construction outage.

107 The annual net increases in off-site air pollutant emissions provided here are overall average values per parameter for each technology's operational period, and do not include emissions due to construction outages.

Parameter	MDCT Retrofit[104]	1.0-mm FMS Retrofit in the Existing CWIS[105]	1.0-mm FMS Installation in a New CWIS[98]
Station Reliability Impacts	Annual design wet-bulb temperature exceedances (average 88 hours) would require the station to operate at reduced power.	Increased FMS headloss could impact existing CCW pumps, station reliability, availability of cooling flow, and nuclear safety.	Increased FMS headloss could impact existing CCW pumps, station reliability, availability of cooling flow, and nuclear safety.
Consumptive Water Use Impacts	Consumptive water use would increase by an average of 85.7% and a maximum of 143.2% at design conditions.	None	None

Key impacts from the evaluation are summarized in Table 12-20 for the hypothetical closed-cycle cooling tower retrofit, Table 12-21 for the hypothetical 1.0-mm FMS retrofit within the existing CWIS, and Table 12-22 for the hypothetical installation of 1.0-mm FMS in a new CWIS at Oconee.

Table 12-20. Summary of Impacts for a Hypothetical MDCT Retrofit at Oconee Nuclear Station

Parameter	Nature of Impact	Notes
Energy Consumption	Significant increase	Additional electricity is assumed to be generated within the grid. While an increase in electricity consumption at Oconee would occur, that increase would likely not impact the grid's operations.
Air Pollutant Emissions	Increase in PM emissions on-site Increase in CO_2, SO_2, and NO_X emissions off-site	The increase in on-site PM emissions from the hypothetical MDCTs would require a modification to the station's Conditional Major Operating Air Permit. The increases in CO_2, SO_2, and NO_X emissions off-site would be considerable, but their impacts would be distributed over the grid and would not be localized. No appreciable health impacts would be expected.
Noise	Increased on-site noise	The continuous operation of MDCT fans and pumps, and cascading water in the MDCTs would increase on-site noise. The distance from the hypothetical MDCT locations to the nearest property boundaries would likely be large enough to facilitate natural noise attenuation. If MDCTs were to be selected as BTA, noise modeling would be required to determine if mitigation methods would be necessary.

Parameter	Nature of Impact	Notes
Safety	Minor reduction in safety	Increased incidence of cooling tower plume, fog, and ice formation could reduce safety on on-site and off-site roadways. A state highway is adjacent to the preferred hypothetical MDCT site. Fogging could periodically impact the nuclear station security monitoring. In addition, since it's opening in July 1969, more than 3 million people have visited the World of Energy located adjacent to Oconee. If MDCTs were erected at Oconee, visitors would encounter the plume effects either through aesthetic impacts or when fog impacts the state highway access.
Station Reliability	Reduction in reliability	The station would be required to operate at reduced power for 88 hours per year on average due to cooling tower design wet-bulb temperature exceedances, which would typically coincide with periods of peak electricity demand in the summer months. During colder months, icing of nearby transmission lines (resulting from the cooling tower plume) could impact station reliability and would, therefore, likely have to be relocated.
Consumptive Water Use	Increase in evaporation	Operation of MDCTs would increase the evaporative loss of water at Oconee, potentially exacerbate Keowee Lake drought conditions and have commensurate water quality impacts.

Table 12-21. Summary of Impacts for a Hypothetical 1.0-mm FMS Retrofit in the Existing CWIS at Oconee Nuclear Station

Parameter	Nature of Impact	Notes
Energy Consumption	Moderate increase	Additional electricity is assumed to be generated within the grid. While an increase in electricity consumption at Oconee would occur, that increase would be moderate and would not impact the grid's operations.
Air Pollutant Emissions	Minor increase in CO2, SO2, and NO_X emissions off-site	The increases in CO_2, SO_2, and NO_X emissions would be minor, and their impacts would be distributed over the grid and would not be localized. No appreciable health impacts would be anticipated.
Noise	Minor increase	The continuous operation of the screens, pumps, and motors would increase the noise levels at the CWIS. However, the increase would be minor and the existing structures at the site and distance to nearest property boundaries would likely provide natural noise attenuation.
Safety	Potential impacts	Headloss due to FMS would increase considerably, which could impact the existing CCW pumps and cause impacts to station reliability, availability of cooling flow, and nuclear safety. Hydraulic evaluations would be performed if this option were considered for further BTA evaluation.
Station Reliability	Potential impacts	Headloss due to FMS would increase considerably, which could impact the existing CCW pumps and cause impacts to station reliability, availability of cooling flow, and nuclear safety. Hydraulic evaluations would be performed if this option were considered for further BTA evaluation. The resultant calculated TSV for this option is higher than the screen vendor recommendation which could result in unpredictable screen collapse events.
Consumptive Water Use	No impacts	The installation and operation of FMS would not be expected to impact Oconee's consumptive use of water.

Table 12-22. Summary of Impacts for a Hypothetical 1.0-mm FMS Installation in a New CWIS at Oconee Nuclear Station

Parameter	Nature of Impact	Notes
Energy Consumption	Moderate increase	Additional electricity is assumed to be generated within the grid. While an increase in electricity consumption at Oconee would occur, that increase would likely be small and not impact the grid's operations.
Air Pollutant Emissions	Minor increase in CO2, SO2, and NO_X emissions off-site	The increases in CO_2, SO_2, and NO_X emissions would be minor, and their impacts would be distributed over the grid and would not be localized. No appreciable health impacts would be anticipated.
Noise	Minor increase	The continuous operation of the screens, pumps, and motors would increase the noise levels at the new CWIS. However, the increase would be minor and the existing structures at the site and distance to nearest property boundaries would likely provide natural noise attenuation.
Safety	Potential impacts	Headloss due to FMS in a new CWIS would cause a moderate increase in headloss in the existing CWIS, which could impact the existing CCW pumps and cause impacts to station reliability, availability of cooling flow, and nuclear safety. Hydraulic evaluations would be performed if this option were considered for further BTA evaluation.
Station Reliability	Potential impacts	Headloss due to FMS in a new CWIS would cause a moderate increase in headloss in the existing CWIS, which could impact the existing CCW pumps and cause impacts to station reliability, availability of cooling flow, and nuclear safety. Hydraulic evaluations would be performed if this option were considered for further BTA evaluation.
Consumptive Water Use	No impacts	The installation and operation of FMS in a new CWIS would not impact Oconee's consumptive use of water.

12.6 Section 12 References

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13 Peer Review [§122.21(r)(13)]

The information required to be submitted per §122.21(r)(3), *Peer Review*, is outlined as follows:

> *If the application is required to submit studies under paragraphs (r)(10) through (12) of this section, the application must conduct an external peer review of each report to be submitted with the permit application.*

Oconee has a DIF of greater than 125 MGD; therefore submittal documents under §122.21(r)(10)–(12) are required as well as external peer review of each report.

The regulation goes on to state:

> *The applicant must select peer reviewers and notify the Director in advance of the peer review. The Director may disapprove of a peer reviewer or require additional peer reviewers. The Director may confer with EPA, Federal, State and Tribal fish and wildlife management agencies with responsibility for fish and wildlife potentially affected by the cooling water intake structure, independent system operators, and state public utility regulatory agencies, to determine which peer review comments must be addressed. The applicant must provide an explanation for any significant reviewer comments not accepted. Peer reviewers must have appropriate qualifications and their names and credential must be included in the peer review report. This section introduces the peer reviewers, a summary of the peer review process, and the results of peer review.*

Each of these requirements is addressed in the following subsections.

13.1 Peer Reviewers

Peer Reviewers were selected in accordance with their expertise in the disciplines necessary to adequately and thoroughly evaluate approaches to entrainment BTA under the §316(b) Rule; these disciplines include economics, engineering, and aquatic ecology. Peer reviewers were also chosen due to their level of familiarity with the §316b process.

Information regarding peer reviewers selected to review Sections 10-12 of this document is presented in the subsections that follow and their resumes are included in Appendix 13-A. Expert level assessments were obtained from the following five peer reviewers:

- **Paul Jakus, PhD** – Dr. Jakus is professor and Head of the Department of Applied Economics at Utah State University and was selected to review the economics portions of the §122.21(r)(10) Comprehensive Technical Feasibility and Social Cost Evaluation as well as the §122.21(r)(11) Monetized Benefits Evaluation.
- **John Maulbetsch, PhD, PE –** Dr. Maulbetsch is owner and principal of Maulbetsch Consulting in Menlo Park, California, and was selected to review the Closed-cycle Recirculating Systems Retrofit Approach and Technologies engineering portions of the §122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study.

- **Joe Raulli, PE** – Mr. Raulli is the Technical Director at O'Brien and Gere and was selected to review Fine-Mesh and Fine-Slot Screen Retrofit and Alternate Cooling Water Sources engineering portions of the §122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study as well as the §122.21(r)(12) Non-water Quality Environmental and Other Impacts Assessment.
- **James Rice, PhD** – Dr. Rice is a Professor Emeritus in the Department of Applied Ecology at North Carolina State University and was selected to review the biological portion of the §122.21(r)(11) Benefits Valuation Study.
- **Charles Coutant, PhD** – Dr. Coutant is a private consultant for Coutant Aquatics and was selected to review the biological portion of the §122.21(r)(11) Benefits Valuation Study.

13.2 Peer Review Process

In 2015 (i.e., prior to the beginning the entrainment BTA process), Duke Energy identified and selected a pool of potential peer reviewers to provide (1) input on the approach for formally addressing the Rule requirements in §122.21(r)(10) – (12); (2) an informal review of proposed economic, engineering, and biology study methodologies; and (3) an informal review of proposed entrainment and impingement study plans. While an informal review on approaches and methodology is not mandatory under the Rule, Duke Energy considered this an important step to gain information on the peer reviewers' professional perspectives and expectations.

On December 1, 2015 Duke Energy submitted to SCDHEC the names and resumes of proposed peer reviewers to review §122.21(r)(10)-(12) sections of compliance submittal for South Carolina facilities, including Oconee. Response was received on January 5, 2016 stating that SCDHEC had no objections to the proposed peer review panel (submitted at that time), but preferred Dr. Coutant as the biology peer reviewer.

A Peer Review Kick-off Meeting was held in Charlotte, North Carolina on January 28-29, 2016. Participants included Duke Energy, HDR (including representatives from individual sub-consultants directly involved with the project), and selected peer reviewers (at the time). The objectives of the kick-off meeting were to:

1. Introduce peer reviewers to the Duke Energy §316(b) program and provide a high level overview of the facilities subject to requirements under §122.21(r)(10)-(12).
2. Introduce peer reviewers to the technical approaches and proposed methodologies anticipated for the required biology, engineering, and economic studies.
3. Discuss the overall formal peer review process, timelines, and responsibilities, including introduction to the Peer Review Facilitator.

The peer review process depicted in Figure 13-1 is administered by the Peer Review Facilitator. This process was presented to peer reviewers during the kick-off meeting.

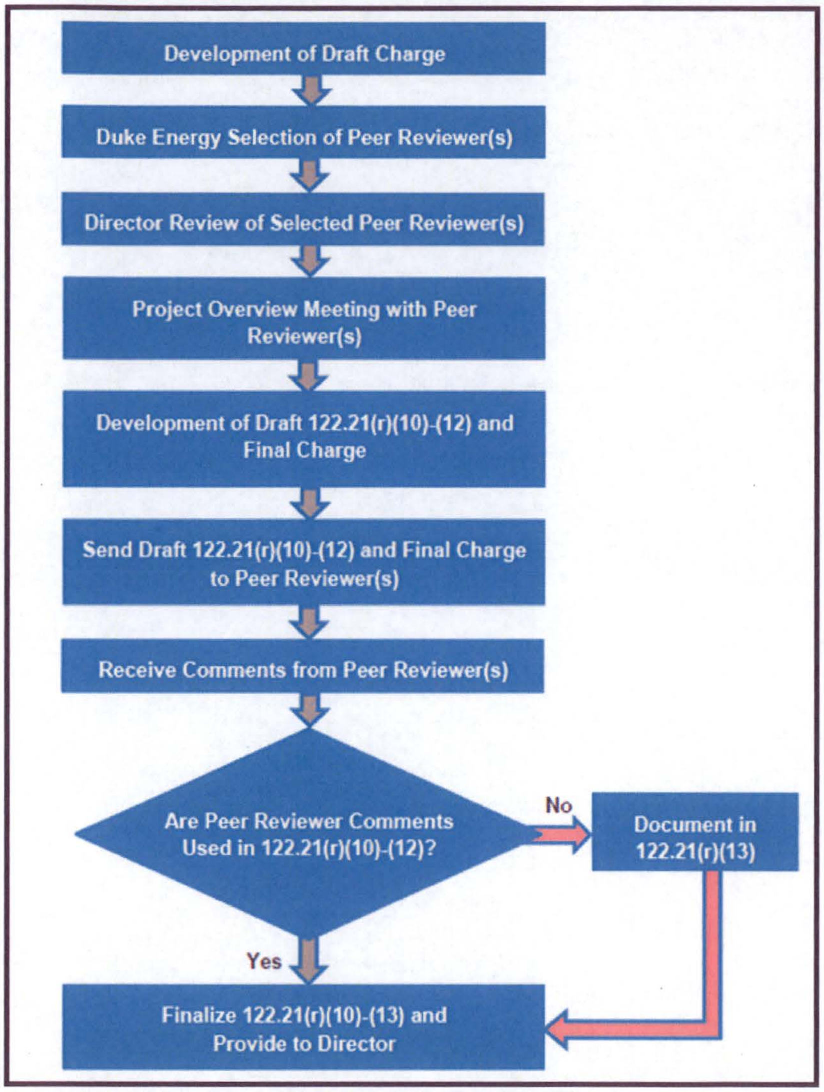

Figure 13-1. Peer Review Process Flow Chart

Following the kick-off meeting, the peer reviewers were asked to review and provide comments in response to the technical approaches and methodologies presented during the kick-off meeting. Comments were received and incorporated into the study project protocol. All contact with peer reviewers related to technical content and/or project schedule was either made by, or facilitated by, the Peer Review Facilitator.

Although not specifically required by the Rule, Duke Energy elected to ask Dr. Jakus and Dr. Lupi to perform an informal review of the proposed study plan for Power System Capacity Loss (PSCL) on November 13, 2017. Comments were received on December 1, 2017 by Dr. Jakus and December 14, 2017 by Dr. Lupi. Additionally, Dr. Jakus performed an informal review of the Economic Study Plan document for all tier 1 facilities, which was sent to him on September 30, 2016 and completed on October 8, 2016. In addition, Dr. Rice and Dr. Coutant performed an informal review of the Entrainment Characterization Study Plan, which was completed on January 15, 2016 and February

16, 2016, respectively. SCDHEC also reviewed and approved the Entrainment Characterization Study Plan.

Between 2016 – 2018, additional searches, similar to that which resulted in the identification of potential peer reviewers in 2015, were conducted to compile a list of qualified engineering peer reviewers and at the end of that process (in 2018), Mr. Raulli and Dr. Maulbetsch were selected as the engineering peer reviewers. SCDHEC approved Mr. Raulli and Dr. Maulbetsch as engineering peer reviewers on October 30, 2020.

The formal peer review process officially commenced on July 5, 2020 with submittal of the draft Oconee compliance submittal package §122.21(r)(10)-(12) to the first four peer reviewers listed in Section 13.1 (Dr. Jakus, Dr. Rice, Dr. Maulbetsch, and Mr. Raulli). The package included a set of instructions, charge document (or list of specific questions the peer reviewers were asked to respond to), and the draft §122.21(r)(2)-(9) reports as reference material. The instructions and charge document were specific to each peer reviewer as each was asked to review different portions of the §122.21(r)(10)-(12) documents. Return of the completed charge documents, along with any other comments, questions, and/or recommendations was requested by August 7, 2020 (approximately five weeks).

On October 7, 2020, Duke Energy met with SCDHEC regarding submittal to the state and the Peer Review process. Because SCDHEC had originally preferred Dr. Coutant to provide an external peer review for the biological components of §316(b) compliance documents for all South Carolina facilities; a subsequent biological review was carried out by Dr. Coutant. The Oconee §316(b) compliance package was sent to Dr. Coutant on October 9, 2020 and comments were received on October 14, 2020.

All correspondence between the peer reviewers and the Peer Review Facilitator was tracked and communication logs are included in Appendix 13-B.

Upon receipt of peer reviewer comments, the Peer Review Facilitator transmitted the completed charge documents along with additional comments received to both the HDR and Duke Energy project teams for review and evaluation (see Appendix 13-C). A comment response table was developed and responses to peer reviewer comments are provided in Appendix 13-D. All correspondence and documents exchanged are stored within HDR's project files as well as a SharePoint site administered by HDR.

13.3 Comment Response Criteria

This section documents the external Peer Review process by categorizing and developing responses to peer reviewers' comments on Oconee §122.21(10)-(12) report sections using the following criteria:

- **Category 1**: Comments that are clearly applicable (i.e., relevant under the charge and improve the quality of the work product). These comments will be incorporated into the Reports.
- **Category 2**: Comments that represent a misunderstanding by peer reviewers and should not be incorporated into the Report. These comments will not be incorporated into the Reports.

- **Category 3:** Comments that are minor and do not materially change or lend additional value to the Reports (e.g., comments provided for informational purposes, or meant as preferential suggestions, or are beyond the scope of the charge). These comments may or may not be incorporated into the Reports at the discretion of the Report Originator.
- **Category 4**: Major peer reviewer comments that the Report Originators do not agree with and choose not to incorporate into the Reports. These comments will be provided along with an explanation as to why they were not incorporated into the Reports in §122.21(13).

13.4 Peer Review Results

Peer reviewer comments in response to the Directed Charge Questions are included in Appendix 13-C.

HDR developed comprehensive comment response tables in which all peer reviewer comments were addressed; the tables are presented in Appendix 13-D. Revisions to the compliance document were made based on reviewer comments and suggestions; however, if a peer reviewer comment was not addressed in the revised submittal document, an explanation is provided in the comment response table. Responses from all four peer reviewers were assigned as Category 1 (i.e., clearly applicable) or Category 3 (i.e., minor) comments and were either addressed in the compliance document, or an explanation as to why the comment was not addressed is included in Appendix 13-D (Responses to Peer Reviewer Comments). There were no Category 2 (i.e., misunderstanding) or Category 4 (i.e., major comments not incorporated) comments in response to the Directed Charge Questions.

On August 26, 2020 HDR conducted a separate follow-up call with Dr. Maulbetsch to discuss the best approach in resolving two of his comments received on the §122.21(10) section of the compliance package. The first comment discussed during this call was related to the assessment of hypothetical MDCTs as "technically feasible, but challenging" or "infeasible". Dr. Maulbetsch shared his opinion that it would be within reason for HDR to downgrade the assessment of MDCTs to "infeasible". HDR discussed their recommended approach to continue to assess MDCTs as "technically feasible, but challenging", and Dr. Maulbetsch was in agreement with this approach. The second comment discussed during the call was related to the design heat load and temperature differential of the existing condensers at Oconee, and how these design parameters would affect the design range of hypothetical MDCTs. HDR discussed their approach to address Dr. Maulbetsch's comment by revising the hypothetical MDCT design range to a lower value, which would then require revision to the design MDCT evaporation rate and sizing. Dr. Maulbetsch was in agreement with this approach.

The comment response table, along with revised §122.21(10)-(12) report sections, were subsequently provided to the peer reviewers to confirm that all questions and/or comments were adequately addressed. Confirmation was provided (via email) by:

- Dr. Rice on September 30, 2020
- Dr. Jakus on October 1, 2020
- Dr. Maulbetsch on October 5, 2020
- Mr. Raulli on October 9, 2020
- Dr. Coutant on October 16, 2020

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