Georgia Power

WALLACE DAM

Lake Oconee

Study Report

Fish and Aquatic Resources

Wallace Dam Hydroelectric Project
FERC Project Number 2413

Prepared with:

Geosyntec consultants

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ACRONYMS AND ABBREVIATIONS

CBD	Center for Biological Diversity
CFR	Code of Federal Regulations
Commission	Federal Energy Regulatory Commission
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FS	U.S. Forest Service
ft	feet
FWS	U.S. Fish and Wildlife Service
GBCF	Georgia Bass Chapter Federation
GDNR	Georgia Department of Natural Resource
GEPD	Georgia Environmental Protection Division
Georgia Power	Georgia Power Company
GPS	Global Positioning System
HUC	Hydrologic Unit Code
Hwy	Highway
I-20	Interstate 20
ILP	Integrated Licensing Process
In	inches
lbs	pounds
Kn	relative condition factor
m	meters
mg/L	milligrams per liter
mm	millimeters
National Register	National Register of Historic Places
NF	National Forest
NTU	Nephelometric turbidity units
PAD	Pre-Application Document
PD	plant datum
PLP	Preliminary Licensing Proposal
PSD	Proportional Stock Density
PSP	Proposed Study Plan
ROW	right-of-way
RSP	Revised Study Plan

RTE	rare, threatened, and endangered
SD1	Scoping Document 1
SWAP	State Wildlife Action Plan
UGA	University of Georgia
USACE	U.S. Army Corps of Engineers
WMA	Wildlife Management Area
WRD	Wildlife Resources Division

EXECUTIVE SUMMARY

A fish and aquatic resources study was conducted for Georgia Power Company's (Georgia Power's) Wallace Dam Hydroelectric Project (Federal Energy Regulatory Commission No. 2413) to characterize the existing fish and aquatic resources in the project waters and to develop aquatic resource information for evaluating the potential impacts of continued project operation on fish and aquatic resources. The study area included Lake Oconee, the lower free-flowing reaches of larger tributaries to Lake Oconee within the project boundary, and the Wallace Dam tailrace area within the project boundary downstream of the dam. Information was developed based on review of existing information and field surveys.

The Wallace Dam Project is located on the Oconee River at river mile 172.7 in the Piedmont physiographic province of the greater Altamaha River basin. Impounded waters dominate aquatic habitats in the project vicinity and, therefore, the principal fisheries inhabiting project waters are reservoir fisheries. Wallace Dam discharges directly into the upper end of Lake Sinclair, which serves as the lower reservoir for pumped storage operations.

<u>Shoreline Habitat Survey</u>

Georgia Power conducted a shoreline reconnaissance survey of Lake Oconee and the Wallace Dam tailrace area in June 2016 which qualitatively characterized shoreline aquatic habitat and available sources of littoral-zone cover for fish to 50 feet from the shoreline. A total of 140 representative sites on Lake Oconee and 6 sites in the tailrace were surveyed.

The most frequently observed sources of littoral-zone fish cover across the study area were overhanging vegetation, docks and piers, riprap, emergent vegetation, and large woody debris. Based on estimated proportional length of coverage of shoreline sites, riprap was the predominant source of fish cover, followed by overhanging vegetation and docks and piers. Riprap was most prevalent in the lower reservoir, middle reservoir, and Richland Creek sections of Lake Oconee, where residential and resort development are widespread and riprap is commonly used to stabilize shorelines. Overhanging vegetation was the predominant cover type in the less developed upper reservoir section.

<u>Rare, Threatened, and Endangered Aquatic Species</u>

The occurrence and distribution of four rare, threatened, and endangered aquatic species were assessed by reviewing existing sources of information and data. The findings included:

- Altamaha Shiner **–** this state threatened species has been reported from seven tributary watersheds upstream of Lake Oconee but has not been documented in Lake Oconee.

- Robust Redhorse **–** this state endangered sucker inhabits the Oconee River downstream of Sinclair Dam and a tributary of Lake Sinclair but recent electrofishing status surveys

did not collect the species in rivers upstream of Wallace Dam or in the Wallace Dam tailrace area.

- Inflated Floater – although not listed as federal or state protected, this freshwater mussel previously was petitioned for federal listing and has since been withdrawn. Mussel surveys in 2016 found this species in both Lake Oconee and the tailrace area.

- Altamaha Arcmussel – a state threatened species known primarily from the Coastal Plain, there are no known records from project waters and it was not found during mussel surveys of Lake Oconee and the tailrace area in 2016.

Freshwater Mussel Survey

Two freshwater mussel surveys were conducted in summer 2016 in Lake Oconee and the Wallace Dam tailrace area. The surveys used an occupancy-based survey design developed by the Georgia Department of Natural Resources (GDNR) and included the techniques of visual observations while wading, hand grubbing, snorkeling, self-contained underwater breathing apparatus, and surface-supplied air. The surveys documented the occurrence of four native freshwater mussel species within the project boundary, none of which are listed as federally or state protected, including: Altamaha Slabshell, Inflated Floater, Paper Pondshell, and Variable Spike. All four species were found in both Lake Oconee and the tailrace area.

Summer Habitat for Sport Fish Species

The availability of suitable summer habitat for sport fish species in Lake Oconee, including Largemouth Bass and Striped Bass, was assessed using reservoir water quality data collected by Georgia Power, standardized fisheries survey data collected by GDNR, and temperature and dissolved oxygen (DO) preference criteria reported in the scientific literature. The analysis focused on the spatial and temporal extent of mixing that occurs in Lake Oconee as a result of summer pumpback and generation operations.

Most sport fish species residing in Lake Oconee are capable of tolerating seasonally high water temperatures and occasionally lower DO levels in summer. The GDNR standardized fishery survey data for Lake Oconee indicate an overall healthy and balanced fish community typical of southeastern Piedmont reservoirs. Recent and historic water quality monitoring data show that although pumpback operations cause mixing of the entire water column of the lower mainstem reservoir by August, water temperature and DO conditions remain within acceptable ranges for most of the resident sport fish species.

Based on the documented temperature and DO tolerances of Largemouth Bass, the water quality monitoring data show that summer water quality conditions in Lake Oconee support the survival and growth of Largemouth Bass. The catch rates, relative condition, and length-frequency distribution of Largemouth Bass in Lake Oconee indicate the presence of an overall healthy population. In addition, the weight characteristics of tournament bass caught in Lake Oconee compare favorably to other Georgia reservoirs.

Summer temperature profiles for Lake Oconee sufficiently explain the limiting nature of habitat suitability for Striped Bass, as reflected in low catch rates and low relative condition of the population. Summer water temperatures exceeding 29°C throughout the reservoir in many summers is likely the principal factor limiting survival and growth of the population. Recent and historic water quality sampling do not show widespread summer low-DO conditions in Lake Oconee. Although suitable DO conditions were available throughout much of the reservoir, by late July and August, temperatures were often higher than temperature criteria defining suitable adult Striped Bass habitat. Thus, available evidence indicates that it is naturally high water temperatures, and not low DO concentrations that limit the availability of suitable summer habitat for Striped Bass in Lake Oconee.

A variety of warmwater sport fish species typical of southeastern reservoirs likely use Wallace Dam tailrace habitats during the summer, especially in response to changing flow conditions with pumpback and generation. Continuous tailrace monitoring data indicate that the tailrace is unlikely to provide suitable adult Striped Bass habitat for much of the summer due to water temperatures exceeding 29°C. However, resident fishes in in the tailrace, many of which are habitat-generalist species, are likely to use tailrace habitats in the summer despite daily DO depressions in parts of June, July, and early August. The tailrace mussel survey in August 2016 found four native species of mussels, with the greatest numbers occurring a short distance downstream of the powerhouse. Thus, the tailrace area supports self-sustaining populations of aquatic species representative of a balanced community.

<u>Fish Entrainment</u>

Common trends and data from other studied hydroelectric sites, including several in South Carolina and Georgia and two pumped storage projects, indicate that small and/or young-of-year fish likely comprise the majority of fish entrained by the Wallace Dam Project. Entrainment is likely to be numerically dominated by species of sunfishes, shads, perch, suckers, catfishes, and minnows. Peak entrainment rates likely occur in the spring and summer for most species, when young fish are most abundant and tend to be dispersing between habitats, but entrainment rates for shad may peak in the fall and winter. More fish are likely to be entrained during pumpback operations than conventional generation because of the shallower depth and narrower width of the tailrace, closer proximity of shallow-water habitats, and the seasonal behavior of some fish, such as Striped Bass and Hybrid Bass, to congregate in the tailrace. In contrast, the open forebay and deep-water location of the Lake Oconee intake is relatively distant from shoreline and littoral-zone habitats.

The vast majority of entrained fish are small and likely to survive turbine passage. Trends in turbine passage survival studies at numerous hydroelectric sites predict average immediate survival rates at Wallace Dam in the range of 91 to 95 percent for small fish and 83 to 88 percent for moderate-sized and large fish, depending on the unit type. Overall, Lake Oconee supports a healthy fishery and evidence is lacking to suggest that current levels of fish entrainment and turbine mortality may be adversely affecting the fish community of the Oconee River. Continued operation of the Wallace Dam Project is likely to result in only minor impacts to fish populations and recreational fishing opportunities as a result of fish entrainment and turbine-induced mortality.

1.0 INTRODUCTION

This report presents findings of the Fish and Aquatic Resources Study conducted for Federal Energy Regulatory Commission (FERC) relicensing of Georgia Power Company's (Georgia Power's) Wallace Dam Hydroelectric Project (Wallace Dam Project, the Project) (FERC No. 2413). This study was conducted according to the approved Study Plan for the Wallace Dam Project. The approved Study Plan consists of Georgia Power's Revised Study Plan filed on November 24, 2015 (Georgia Power, 2015a), as approved by the Study Plan Determination issued by FERC on December 17, 2015 (FERC, 2015a). Georgia Power will use the information generated by the study to evaluate the environmental effects of its proposed action in the Preliminary Licensing Proposal, to be filed with FERC by November 21, 2017.

The Wallace Dam Project is an existing 321.3-megawatt pumped storage project consisting of Wallace Dam, a powerhouse, and Lake Oconee. The Project is located on the Oconee River in Hancock, Putnam, Greene, and Morgan Counties, Georgia (Figure 1). Georgia Power operates the Wallace Dam Project using Lake Oconee as the upper reservoir. Lake Sinclair, located immediately downstream, serves as the lower reservoir. Georgia Power operates Lake Sinclair as the separately licensed Sinclair Hydroelectric Project (Sinclair Project) (FERC No. 1951). Georgia Power is not proposing to add capacity or make any major modifications to the Wallace Dam Project under the new license. The Project occupies about 370 acres of U.S. Forest Service (FS) lands within the Oconee National Forest (NF), which abuts Lake Oconee's northernmost reaches. The current license expires May 31, 2020.

Georgia Power proposes to continue operating the Wallace Dam Project as it is currently operated. The Pre-application Document (PAD) describes the project facilities and current operations and summarizes information characterizing the affected environment (Georgia Power, 2015b). The PAD also includes the Wallace Dam Operations Primer as Appendix D. Scoping Document 1 (FERC, 2015b) summarizes the environmental issues identified during FERC's public scoping process pursuant to the National Environmental Policy Act.

1.1 Objectives

The specific objectives of the Fish and Aquatic Resources Study were to:

- Characterize representative shoreline and littoral-zone aquatic habitats occurring throughout the reservoir.

- Evaluate the occurrence of Altamaha shiner, a Georgia threatened fish species, and other rare, threatened, or endangered (RTE) aquatic species within the project boundary based on review of existing information and data.

- Conduct a freshwater mussel survey within the project boundary characterizing the occurrence, distribution, relative abundance, species richness, and population status of the native freshwater mussel community, especially RTE species of mussels.

- Evaluate the effects of continued project operations on summer reservoir water quality and habitat for sport fish species such as Largemouth Bass and Striped Bass.

- Evaluate the potential for fish entrainment and turbine-induced mortality by applying trends and data from entrainment studies completed at other hydroelectric projects to the physical, operational, and fisheries characteristics of the Wallace Dam Project.

1.2 Project Overview

The Wallace Dam Project is located on the Oconee River at river mile 172.7 in the upper Oconee River basin of the greater Altamaha River basin (Figure 2). The Altamaha River basin includes the Oconee, Ocmulgee, and Altamaha Rivers. The Middle Oconee and North Oconee Rivers originate in the Piedmont physiographic province (Edwards et al., 2013). These streams meet to form the Oconee River about 20 river miles upstream of Lake Oconee. The Oconee River flows south for 220 miles and joins the Ocmulgee River in the Coastal Plain physiographic province to form the Altamaha River. The Altamaha River then flows 137 miles southeast to the Atlantic Ocean. The Altamaha River basin drains an area of 14,000 square miles (sq mi) located entirely within Georgia.

The Oconee River basin drains a total watershed area of 5,330 sq mi in east-central Georgia (Georgia Environmental Protection Division [GEPD], 1998). The watershed upstream of Wallace Dam covers an area of 1,830 sq mi, comprising about 34 percent of the Oconee River basin (Figure 2). From Wallace Dam the river flows immediately into Lake Sinclair, a 15,330-acre reservoir formed by Sinclair Dam (Figure 1). From Sinclair Dam, the Oconee River flows another 143 miles to its confluence with the Ocmulgee River. About 5 miles downstream of Sinclair Dam, the Oconee River enters the Fall Line area, the hilly transition zone which descends from the Piedmont into the Coastal Plain (Edwards et al., 2013).

At full pool elevation of 435 feet (ft) project datum (PD)[1], Lake Oconee covers approximately 19,050 acres with 374 miles of shoreline (Figure 3). The pool elevation varies about 1.5 ft daily as part of the pumpback operation of Wallace Dam. The reservoir provides a total reservoir storage volume of 370,000 acre-feet. The average reservoir depth is 21 ft. The maximum depth is about 120 ft.

The Wallace Dam Project began commercial operation in December 1979. The powerhouse is located on the east side of the river (Figure 4) and contains six turbine-generator units, numbered 1 through 6 from west to east. There are two conventional units (Units 3 and 4) and

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[1] Plant datum = mean sea level (NAVD88) - 0.20 feet (+/- 0.01 feet).

four units that can also reverse direction and become pumps (Units 1, 2, 5, and 6). The powerhouse intake has an invert elevation of 343.0 ft PD. Steel trash racks in front of the intake consist of vertical bars with clear spacing between bars ranging from 1 ft, 2.5 inches to 1 ft, 3.5 inches. There are six penstocks with a maximum diameter of 25.5 ft.

Georgia Power operates the Wallace Dam Project in a pumped storage mode. Generation releases occur during peak demand hours to meet the electrical system demand. Lake Oconee typically begins the generation cycle near elevation 435 ft PD and ends near 433.5 ft PD. Water passed downstream during generation remains in Lake Sinclair for a few hours before being pumped back up and into Lake Oconee for reuse in the next day's generation cycle. Pumpback operations occur at night, when electrical system demand is low, and therefore, the cost of power is low. Lake Oconee typically refills up to elevation 435 ft PD.

Wallace Dam discharges directly into Lake Sinclair, with no intervening riverine reach or bypassed reach. Although there is no instantaneous discharge requirement, daily average discharges exceed 0 cfs about 85 percent of the time and 1,000 cfs about 64 percent of the time (Georgia Power, 2015b).

Wallace Dam and Sinclair Dam impound about 69 river miles of the mainstem Oconee River in the Piedmont physiographic province. There are no other major mainstem dams on the Oconee and Altamaha Rivers downstream of Sinclair Dam.

Barnett Shoals Dam is located on the mainstem Oconee River about 16 river miles upstream of Lake Oconee. It includes a low-head dam and powerhouse but does not currently produce electricity. The Tallassee Shoals Hydroelectric Project (FERC No. 6951), with a capacity of 2.3 MW, is located farther upstream on the Middle Oconee River.

1.3 Study Area

For the purposes of fish and aquatic resources, the proposed study area includes: the FERC project boundary extending around the reservoir upstream of the dam; the lower free-flowing reaches of larger tributaries to Lake Oconee within the project boundary; and the Wallace Dam tailrace area within the project boundary downstream of the dam (Figure 3).

2.0 STUDY METHODS

The study methods followed the approved Study Plan (Georgia Power, 2015a; FERC, 2015a) and consisted of the elements described below:

2.1 Shoreline Habitat Survey

Georgia Power conducted a shoreline reconnaissance survey of Lake Oconee and the Wallace Dam tailrace area in June 2016 to inventory and characterize existing sources of erosion and sedimentation within the project boundary. The survey sites were also qualitatively characterized with respect to shoreline aquatic habitat and available sources of littoral-zone cover for fish. The detailed methods are described in the Geology and Soils Study Report.

A total of 146 representative shoreline segments, or sites, were surveyed on June 7 and 8, 2016. The sites were each 500 feet (ft) long. Thirty-five sites were surveyed in each of four reservoir sections for a total of 140 sites on Lake Oconee. Six sites were also selected in the tailrace area. The four reservoir sections were (Figure 3; see also Geology and Soils Study Report for specific shoreline site locations):

- Upper reservoir (UR) – Lake Oconee north of I-20.
- Middle reservoir (MR) – Lake Oconee between Georgia Hwy 44 and I-20.
- Richland Creek (RC) – the Richland Creek embayment.
- Lower Reservoir (LR) – Lake Oconee from the dam upstream to Georgia Hwy 44.

Three survey teams (three investigators each) visually observed and assessed the sites from a boat. The teams inventoried and rated shoreline attributes, including: vegetative buffer zone condition (rated as either natural, landscaped-natural, or landscaped); adjacent land uses; bank stability and vegetative protection; shoreline structural stabilization practices (e.g., seawalls, riprap, etc.); potential causes of erosion; and sources of littoral-zone fish cover.

The shoreline habitat portion of the survey included identifying all sources of shoreline fish cover/habitat to 50 ft from the shoreline. Habitat categories included docks/piers/boatslips (docks and piers), riprap, bedrock and boulders, emergent and submersed vegetation, overhanging vegetation, large woody debris, standing timber, and any other types identified by the teams. The proportional length of each available fish cover/habitat type was visually estimated and recorded for each site. Other aquatic habitat observations were noted on the survey form where appropriate, and digital photographs were taken of each survey site.

2.2 Assessment of Rare, Threatened, and Endangered Aquatic Species

The occurrence and distribution of Altamaha Shiner (*Cyprinella xaenura*) and three other RTE aquatic species were assessed by reviewing existing sources of information and data and updating the distributional information summarized in the PAD (Georgia Power, 2015b). The Altamaha Shiner initially was of special interest during study plan development because it is a Georgia threatened species, historical and recent occurrences were known from streams upstream of Lake Oconee, and the species had been petitioned for federal listing under the Endangered Species Act; the species has since been withdrawn from the petition (Section 4.0). Three other aquatic RTE species also were assessed: Robust Redhorse (*Moxostoma robustum*), a Georgia endangered fish species; Inflated Floater (*Pyganodon gibbosa*), a freshwater mussel; and Altamaha Arcmussel (*Alasmidonta arcula*), a Georgia threatened freshwater mussel. These three species had also been petitioned for federal listing but Inflated Floater and Altamaha Arcmussel have since been withdrawn (Section 4.0).

Key sources of information and data used in the assessment included recent occurrence records mapped by the GDNR Nongame Conservation Section and Tennessee Aquarium Conservation Institute, the FWS Ecological Services Field Office in Athens, Georgia, the Fishes of Georgia website, technical reports, and scientific publications.

2.3 Freshwater Mussel Survey

A freshwater mussel survey was conducted within the Wallace Dam project boundary to characterize the occurrence, distribution, relative abundance, and species richness of the native freshwater mussel community. The survey effort was led by G. R. Dinkins of Dinkins Biological Consulting, LLC (DBC) as summarized below. The complete mussel survey reports (Dinkins, 2016a, 2016b) are provided in Appendix A.

2.3.1 Lake Oconee

A mussel survey of Lake Oconee was conducted on July 26-29, 2016. The study area included the main channel of Lake Oconee and the major tributary embayments of Richland Creek, Lick Creek, Sugar Creek, Apalachee River, and Greenbrier Creek (Figure 3). The survey used an occupancy-based sampling design developed by J. M. Wisniewski of the WRD Nongame Conservation Section. Thirty sites were surveyed, including 10 sites along the margins of the main channel and 20 sites in coves and tributary embayments.

One person-hour was spent underwater searching for native mussels at each site, for a total of 30 person-hours. The survey methods were tailored to site-specific conditions of depth, accessibility, and water clarity. They included visual observations while wading, hand grubbing while on hands and knees, snorkeling, self-contained underwater breathing apparatus (SCUBA), and surface-supplied air in deeper water. The survey team recorded observations of live mussels and shells of dead mussels. Most mussel specimens were measured (length in millimeters [mm]), or if a large number of live mussels was encountered, a representative subsample of shells was measured. The location of all survey areas was documented in the field using a hand-held Global Positioning System (GPS) unit. Representative live specimens of each species were digitally photographed. The field surveyors recorded field notes and general habitat information about the survey area.

2.3.2 Wallace Dam Tailrace Area

A mussel survey of the Wallace Dam tailrace area was conducted on August 23-25, 2016. The study area extended from Wallace Dam downstream approximately 1.5 miles to the end of the project boundary at the Georgia Hwy 16 bridge (Figure 3). The survey was conducted between sunrise and 11:30 am during a period of managed flow reduction to maximize the ability of the survey team to adequately search selected habitats. The survey used the occupancy-based sampling design recommended by WRD. Nine areas in the river channel and two backwater areas were searched for the presence of native mussels.

The nine areas in the river channel were arranged in groups of three each across the span of the channel. The two backwater areas occurred along the left descending (east) bank. One person-hour was spent searching for native mussels at each location. In the river channel, the field team used SCUBA. In the backwater areas, the field team snorkeled, waded, and grubbed the substrate while on hands and knees. A representative number of each species encountered was measured (mm length). Each survey location was documented using GPS, digital photographs were taken of representative live specimens, and field notes and general habitat information were recorded.

2.4 <u>Summer Habitat for Sport Fish Species</u>

2.4.1 Lake Oconee

The availability of suitable summer water quality for sport fish species in Lake Oconee was assessed using reservoir water quality data collected by Georgia Power, standardized fisheries survey data for primary sport fishes collected by WRD, and Largemouth Bass and Striped Bass temperature and dissolved oxygen (DO) preference criteria reported in the scientific literature. Existing water quality data collected since 2003 and new water quality data collected from June 2015 through August 2016 for the Water Resources Study were used to assess summer habitat for sport fish species in the reservoir, including the popular sport fisheries Largemouth Bass and Striped Bass.

Vertical profile data collected during the warmest months of the year were analyzed to characterize the spatial and temporal extent of mixing that occurs in Lake Oconee as a result of the pumpback and generation cycles. The monitoring data reviewed from the Water Resources Study included:

- Seasonal vertical temperature and DO profiles collected annually from 2003 to 2016.
- Monthly vertical temperature and DO profiles from June 2015 through August 2016, including monthly isopleths showing variation over the length of the reservoir.
- Hourly vertical temperature and DO profiles collected over two 24-hour sampling events in July and August 2016 during normal pumpback and generation operations.

Plots of these datasets are reproduced from the Water Resources Study Report and provided in Appendix B. Based on patterns in the extent of summer mixing revealed by these data and discussed in detail in the Water Resources Study Report, the reservoir was segregated into the following areas for analysis of the fisheries survey data (Figure 5):

- Mainstem reservoir – the lower and middle reach of Lake Oconee extending from the dam upstream to near I-20 (Parks Mill area), excluding tributary embayments. This area exhibits the greatest degree of summertime mixing due to pumpback operations.
- Tributary embayments – tributaries to the mainstem reach, including Richland Creek, Lick Creek, and Sugar Creek. These larger embayments tend to retain summer vertical stratification in DO concentrations.
- Upstream reservoir – the area near and upstream of I-20. This area is farthest from the dam and tends to exhibit some vertical stratification due to it shallower depths and greater influence of diurnal ambient air temperature variation.

WRD standardized fisheries survey data available for Lake Oconee were then analyzed to compare population characteristics of representative sport fish species between the different areas of the reservoir delineated above based on the extent of summer vertical mixing that results from project operations.

WRD annually conducts fisheries surveys targeted toward sport fish via electrofishing and gillnetting at 26 stations throughout Lake Oconee. Twelve to 14 stations are surveyed by boat electrofishing in the spring, and 12 stations are surveyed using gillnets in the fall. Spring electrofishing was not conducted in 2006 or 2007, so these years exhibit only gillnetting data. Gillnetting was not conducted in 2010, so data that year are for electrofishing only. The 2016 data did not yet include the fall gillnet sampling, so all 2016 data presented are electrofishing data. Data collected by WRD consists of sampling effort, species richness, length, weight, relative condition factor (Kn), and other survey station details.

Fish sampling stations were categorized by their location in Lake Oconee with respect to the areas delineated based on their mixing tendencies (Figure 5). The location categories were: “mainstem” (ten stations), “tributary” (eight stations), and “upper reservoir” (eight stations).

Descriptive statistics were completed for several selected sportfish species, including Largemouth Bass, Black Crappie, Bluegill, Striped Bass, and Hybrid Bass (White Bass X Striped Bass). These statistics include: average station catch rate by location across years (2008-2016); average station relative condition by location across years (2008-2016); and length-frequency distributions by location across years (2011-2015). Length-frequency distributions were also evaluated by length categories described by Gabelhouse (1984) to assess the number of quality-sized individuals. Relative condition factor and length-frequencies included data collected by both electrofishing and gillnetting in order to better represent all size classes. Catch rates were calculated from data collected by whichever method was more effective at sampling the species. Data were pooled from reservoir locations for length-frequency distributions for Striped Bass and Hybrid Bass due to limited sample sizes. An assessment of the proportion of each bass species (Largemouth Bass, Striped Bass, and Hybrid Bass) caught by location per year was also conducted.

A two-way analysis of variance (ANOVA) model was developed to evaluate how relative condition varied by location (three locations: mainstem, tributary, and upper reservoir), species (five species), or year. The factors of location and species were designed as an interaction effect because it is likely that certain species occurrence is not independent of location due to habitat preferences.

In addition, summer habitat suitability for Largemouth Bass and Striped Bass in Lake Oconee was evaluated on the basis of temperature, DO concentration, and time of year with consideration for ranges defined by scientific literature sources as appropriate for each species. For Largemouth Bass, which is a habitat-generalist species, different areas of the reservoir were compared as to the ranges and stability of summer water quality conditions. Documented temperature and DO habitat suitability criteria for adult Striped Bass were compared to the summer vertical profiles and isopleths to identify areas of the reservoir providing suitable habitat under representative summer conditions.

2.4.2 Wallace Dam Tailrace

The suitability of summer water temperatures and DO concentrations for fish and other aquatic organisms in the Wallace Dam tailrace were evaluated using newly collected water quality monitoring data and literature review. The following tailrace water quality monitoring data were reviewed from the Water Resources Study:

- Continuous DO and temperature monitoring data collected at Station OCTR from July 2015 to September 2016.
- Hourly measurements of DO and water temperature in the tailrace area over the course of a summer day during two events in August 2016 to characterize variation in tailrace water quality during a normal cycle of pumpback and generation operations.

The continuous DO and temperature monitoring data presented in the Water Resources Study Report are summarized in the tailrace analysis. Plots of the hourly transect monitoring events are reproduced from the Water Resources Study Report and provided as Appendix C.

2.5 Fish Entrainment Evaluation

The potential for fish entrainment and turbine-induced mortality at the Wallace Dam Project was evaluated using a literature-based approach that draws upon entrainment field studies completed at numerous other hydroelectric projects east of the Mississippi River, including several in the southeastern U.S. and other pumped storage facilities. Common trends and data from these other studies were applied with consideration of the site-specific physical, operational, and fisheries characteristics of the Wallace Dam Project.

The primary source of turbine entrainment field study information was the database prepared by the Electric Power Research Institute (EPRI, 1997a). The EPRI database includes test data from 43 hydroelectric sites and provides detailed information on the species and size classes of fish collected in monthly entrainment samples. All of these sites are located east of the Mississippi River, and seven are located in the southeastern U.S. (South Carolina, Georgia, and Virginia).

Other sources of turbine entrainment information and data included comprehensive reviews prepared by EPRI (1992) and FERC (1995a). The FERC (1995a) review provides information for two additional sites in South Carolina and Georgia. Entrainment sampling data for the Stevens Creek Project (Dames and Moore, 1993; FERC, 1995b) and the Richard B. Russell Pumped Storage Project (U.S. Army Corps of Engineers [USACE], 1998; Nestler et al., 1999) on the Savannah River also were examined for species composition, relative abundance, and size distribution trends.

The primary source of turbine mortality field study information was the turbine passage survival database prepared by EPRI (1997a). The database includes test data from studies conducted at 51 different turbines (41 hydroelectric sites), including Francis turbines and propeller-type turbines.

Common trends and data from field studies completed at other hydroelectric sites were applied to the Wallace Dam Project to:

- Characterize potential turbine entrainment that could be occurring at the Project, including fish size distribution, species composition, and seasonal variation in entrainment rates.

- Evaluate potential mortality rates of fish passing through the turbines based on turbine survival tests conducted at other projects with head and turbine design characteristics similar to those in use at Wallace Dam.

- Characterize relative differences in entrainment and mortality potential between the generation and pumpback cycles based on the design differences between the reversible pump turbines (Francis type) and conventional turbines (modified propeller type), the times of day they operate, and other relevant factors.

The potential impacts of losses of fish due to entrainment mortality were assessed based upon fishery survey data for the project reservoir, intake location and related factors in the reservoir forebay and in the tailrace, natural mortality rates of young fish, and other relevant factors.

3.0 SHORELINE HABITAT SURVEY

The detailed results of the shoreline reconnaissance survey, including the locations of individual numbered survey sites, tables and graphics, and copies of the completed survey forms are presented in the separate Geology and Soils Study Report. This section further evaluates the results of the shoreline habitat survey component.

The 140 shoreline sites surveyed on Lake Oconee represented 70,000 ft of shoreline. The six tailrace sites represented 3,000 ft of shoreline in the upper end of Lake Sinclair. Visual observations of shoreline habitat and estimation of the proportional length of each type of fish cover/habitat present were made to a distance of 50 ft from the shoreline. The habitat survey area included the littoral zone, the peripheral shallows where light usually penetrates to the bottom allowing rooted vegetation to grow, and which are subject to fluctuating temperatures and water levels, erosion of shore materials through wave action, and provide important habitat for many fish and other aquatic organisms. Fishes using littoral-zone habitats in southeastern reservoirs for spawning and rearing of young include Largemouth Bass, Bluegill, Black Crappie, Redear Sunfish, and a variety of other species and life stages.

3.1 Habitat by Reservoir and Tailrace Sections

A variety of natural and man-made habitat features were inventoried as potential sources of littoral-zone fish cover along the Lake Oconee and tailrace shorelines (Table 1). The most frequently observed sources of littoral-zone fish cover across the study area, in descending order, were overhanging vegetation, docks and piers, riprap, emergent vegetation, and large woody debris. Based on visually estimated proportional length, riprap was the predominant source of fish cover, totaling 30 percent of the 73,000 ft of shoreline surveyed, followed by overhanging vegetation (23 percent) and docks and piers (11 percent). Riprap was the predominant fish cover type by length available in the lower reservoir, middle reservoir, and Richland Creek sections of Lake Oconee, where residential and resort development are widespread and riprap is commonly used to stabilize shorelines. In contrast, overhanging vegetation was the predominant fish cover type in the less developed upper reservoir, where it covered 42 percent of the shoreline. Overhanging vegetation and riprap were the predominant sources of shoreline fish cover in the tailrace.

3.2 Habitat by Shoreline Vegetative Buffer Zone Condition

Of the 146 shoreline sites surveyed, 65 (44 percent) were characterized as having a “natural” shoreline vegetative buffer zone condition. Their buffer zones were heavily vegetated with less than about 20 percent of the natural vegetation removed. Forty-two sites (29 percent) had “landscaped” buffer zones. They were cleared of more than 50 percent of the natural vegetation or had the undergrowth completely removed. Thirty-nine sites (27 percent) had “landscaped-natural” buffer zones. They were disturbed and cleared up to 50 percent with some trees and understory remaining. Natural vegetative buffer zone conditions were most prevalent in the upper reservoir and in the tailrace area, where 59 percent of surveyed sites had riparian zones that were heavily vegetated, typically forested. Sites with landscaped riparian zones occurred throughout the reservoir but were most prevalent throughout the Richland Creek and lower reservoir sections. The landscaped-natural sites were more numerous in the lower reservoir and middle reservoir than in the upper reservoir.

Table 2 summarizes the availability of littoral-zone fish cover types at the Lake Oconee and tailrace area survey sites by observed shoreline vegetative buffer zone condition. The most frequently observed sources of fish cover at landscaped and landscaped-natural shoreline sites were, in descending order, docks and piers, riprap, overhanging vegetation, and emergent vegetation. Riprap, by far, covered the greatest length of the shoreline length at these sites, representing nearly half of the total surveyed length. Docks and piers were next in relative length, covering 17 and 19 percent of the shoreline length at landscaped and landscaped-natural sites, respectively. In contrast, the most frequently observed fish cover types at natural sites were, in descending order, overhanging vegetation, large woody debris, emergent vegetation, riprap, and standing timber (including fish plots, which are stands topped out below the surface). Overhanging vegetation occurred along 44 percent of the survey length of natural sites, while docks and piers totaled only 2 percent. Large woody debris, riprap, standing timber/fish plots, and emergent vegetation each covered 6 to 8 percent of the total surveyed length.

3.3 Habitat by Sport Fish Assessment Areas of Lake Oconee

The shoreline habitat survey findings were also summarized with respect to different areas of Lake Oconee identified for the analysis of summer habitat for sport fish species (Section 6.0). The sport fish analysis segregates the reservoir into three different types of areas based on patterns of summertime mixing that occur in Lake Oconee as a result of the pumpback and generation cycles (documented in the separate Water Resources Study) and the locations of WRD standardized fishery survey sites. The areas include mainstem reservoir, tributary embayments, and upstream reservoir (Section 2.4) (Figure 6).

Of the 140 shoreline sites on Lake Oconee, 43 sites (21,500 ft) were along the mainstem reservoir, 53 sites (26,500 ft) were in tributary embayments, and 44 sites (22,000 ft) were in the upper reservoir. Figure 7 depicts the fish cover types observed in each area as the proportion of shoreline length surveyed. The predominant fish cover type at mainstem sites was riprap (41 percent), followed by docks and piers (14 percent), overhanging vegetation (9 percent), and emergent vegetation (7 percent). Riprap also covered the greatest length of the tributary sites (35 percent), followed by overhanging vegetation (16 percent), docks and piers (13 percent), and emergent vegetation (5 percent). Residential and resort land uses are common in both the mainstem and tributary areas. In contrast, overhanging vegetation occurred along 41 percent of the survey length of upper reservoir sites, while riprap totaled 13 percent, and docks and piers and large woody debris each totaled 7 percent. The upper reservoir also contained a higher proportion of standing timber/fish plots than the other areas.

3.4 Shoreline Structural Stabilization Practices and Littoral Zone Fish Habitat

The shoreline reconnaissance survey documented the use of structural practices in Lake Oconee for stabilizing shoreline modified by residential or other development or otherwise subject to erosion (see Geology and Soils Study Report). The most common types of structural stabilization practices in place were seawalls with riprap at the base, seawalls, and riprap. The Geology and Soils Study Report provides a literature review on the relationship between shoreline structural stabilization practices and littoral-zone fish habitat. The literature review included field studies at other southeastern hydropower reservoirs in North and South Carolina (Barwick, 2004) and Alabama (Purcell et al., 2013) and other relevant literature. The literature review is not repeated in this report but a brief summary follows:

- The relevant scientific literature dealing with the effects of shoreline structural practices on littoral fish habitat indicates an overall positive relationship between greater habitat complexity of riprapped shoreline habitats and higher species richness, diversity, and abundance of littoral zone fish assemblages, including sport fishes.

- When erosion control is necessary at a developed shoreline site, available evidence supports the use of riprap, either alone or in front of seawalls, as providing more beneficial fish habitat than the use of seawalls alone without accompanying structural or non-structural practices.

4.0 RARE, THREATENED, AND ENDANGERED AQUATIC SPECIES

This section assesses the occurrence and distribution of Altamaha Shiner, Robust Redhorse, Inflated Floater, and Altamaha Arcmussel, including their known habitat use, recent occurrence records in rivers and tributaries that enter Lake Oconee, and their potential to occur within the project boundary. Table 3 summarizes the conservation status, habitat, and counties of occurrence of these four species and two other aquatic species tracked by GDNR. The other two species were not evaluated further. Goldstripe Darter occurs below the Fall Line in small streams and is not expected to occur in Lake Oconee. Brassy Jumprock does not have federal or state protected status and has not been petitioned for federal listing.

4.1 Altamaha Shiner

The Altamaha Shiner, a Georgia threatened species, is endemic to the Piedmont of the upper Altamaha River basin in north-central Georgia, where it occurs in both the upper Oconee and upper Ocmulgee River basins. CBD petitioned Altamaha Shiner for federal listing in April 2010 but withdrew the species from the petition in December 2015 based on new (unspecified) information (CBD, 2015). The U.S. Forest Service (2004) lists the Altamaha Shiner as a sensitive species on Oconee National Forest. The Altamaha Shiner inhabits rocky and sandy pools in creeks and small rivers and appears to prefer pools behind obstacles along and under banks (Page and Burr, 1991; Gilbert, 1980). There are no known occurrence records of Altamaha Shiner from Lake Oconee within the project boundary.

GDNR and the Tennessee Aquarium Conservation Institute recently assessed the conservation status of Altamaha Shiner based on occurrence records from major fish collections, state and federal sampling programs, and species-specific surveys and monitoring efforts (Albanese et al., 2015a). Historical collections of the species have been documented from 10 different HUC-10 watersheds upstream of Wallace Dam. Since 2010, Altamaha Shiner has been reported to occur in 7 of these watersheds from sites located upstream of Lake Oconee and outside of the project boundary. The nearest collections documented since 2010 were from the lower Apalachee River upstream of Lake Oconee. The most recent occurrence records from Richland Creek, Oconee River, and Hard Labor Creek just upstream of Lake Oconee are over 11 years old.

4.2 Robust Redhorse

The Robust Redhorse, a Georgia endangered species, is a migratory riverine sucker that occurs in large rivers of the Atlantic slope in Georgia, South Carolina, and North Carolina (Freeman et al., 2016; Rhode et al., 2009). It inhabits the Oconee and Ocmulgee Rivers in the Altamaha River basin. CBD petitioned the Robust Redhorse for federal listing in 2010. The species is currently undergoing a status review by FWS to determine if listing as a threatened or endangered species is warranted (FWS, 2011). A population currently exists in the Oconee River downstream of Sinclair Dam but the species is not known to occur upstream of Wallace

Dam (Albanese et al., 2015b). Georgia Power (2016) recently provided an update on the status of the Oconee River population, ongoing conservation efforts in Georgia, and the current status of the species across its range. The report is the latest in a series of biannual reports documenting the status of the species, as required by the Sinclair Project license.

The Robust Redhorse typically inhabits main-channel, free-flowing rivers in riffles, runs, and pools (Freeman et al., 2016; Rohde et al., 2009). Adults reside in deep waters in moderate to swift current, often on the outside of river bends in association with woody debris. Spawning occurs in rivers over coarse gravel.

Recent occurrences of Robust Redhorse in Little River, a tributary to Lake Sinclair, and Lake Sinclair appear to have resulted from escaped hatchery fish (Zelko, 2012). The electrofishing capture of a single large female Robust Redhorse from Little River in April 2012 suggests that a small spawning population may presently exist in Little River and the upper end of Lake Sinclair (Zelko, 2012). As part of focused survey efforts for the species, Georgia Power surveyed the Wallace Dam tailrace in 2014 and 2015 but did not detect any Robust Redhorse (Robust Redhorse Conservation Committee's Oconee Technical Working Group, 2014 and 2015).

Electrofishing status surveys for Robust Redhorse conducted in spring 2012 and spring 2013 upstream of Lake Oconee, including a 10.7-mile segment of the Oconee River (8.7 hours effort) and a 1.5-mile segment of the Apalachee River (2.3 hours effort), did not collect or observe any Robust Redhorse upstream of Wallace Dam (Zelko, 2012, 2013).

4.3 Inflated Floater

The Inflated Floater is endemic to the Altamaha River basin in south-central Georgia. It is primarily known from Coastal Plain reaches of the lower Ocmulgee, lower Oconee, Ohoopee, and Altamaha Rivers (Wisniewski et al., 2005; NatureServe, 2015). During study plan development, the U.S. Fish and Wildlife Service (FWS) and GDNR identified a recently documented occurrence of Inflated Floater from Lake Oconee, extending the species presently known range above the Fall Line. The species is not listed as federally protected or protected in Georgia. CBD petitioned the Inflated Floater for federal listing in April 2010 and it had been under review by FWS for possible listing under the Endangered Species Act. However, CBD (2015) withdrew the species from the petition in December 2015 based on new (unspecified) information.

The Inflated Floater is usually found in rivers in soft substrates such as mud, silts, or fine sands (NatureServe, 2015). These habitat preferences suggested to Wisniewski et al. (2005) that future mussel surveys might find the species in backwaters and oxbows. The July 2016 freshwater mussel survey of Lake Oconee led by G. R. Dinkins with the participation of J. M. Wisniewski of GDNR (Dinkins, 2016a) documented the occurrence of Inflated Floater (66 specimens) in the main channel of Lake Oconee and tributary embayments (Section 5.0).

Inflated Floaters (10 specimens) were also collected in the August 2016 mussel survey of the Wallace Dam tailrace area (Dinkins, 2016b).

4.4 Altamaha Arcmussel

The Altamaha Arcmussel, a Georgia threatened species, is endemic to the lower Altamaha River basin, where it is primarily known from the Ocmulgee, Little Ocmulgee, Ohoopee, and Altamaha Rivers in the Coastal Plain (Wisniewski, 2008; NatureServe, 2015). CBD petitioned the Altamaha Arcmussel for federal listing in 2010 but withdrew it from the petition in December 2015 in light of new information. The species typically occurs in sloughs, oxbows, or depositional areas in large creeks to large rivers with silt, mud, and/or sand substrates (Wisniewski, 2008). There are no known records of the species occurring within the project area. The species was not detected during mussel surveys conducted in Lake Oconee and the Wallace Dam tailrace area in July and August 2016 (Dinkins, 2016a, 2016b) (Section 5.0).

5.0 FRESHWATER MUSSEL SURVEY

Two freshwater mussel surveys were conducted in summer 2016 in Lake Oconee and the Wallace Dam tailrace area (Dinkins, 2016a, 2016b). Appendix A provides the complete survey reports. The surveys documented the occurrence of four native freshwater mussel species within the project boundary, none of which are listed as federally or state protected. The species include:

- Altamaha Slabshell (*Elliptio hopetonensis*) –widespread and locally abundant; the most common Altamaha River basin native mussel (Cummings and Cordeiro, 2011).
- Inflated Floater – endemic to the Altamaha River basin; usually found in rivers in stable but soft mud, silts, or fine sand (NatureServe, 2015); recently found by GDNR in coves and backwaters of main-stem reservoirs (Dinkins, 2016a).
- Paper Pondshell (*Utterbackia imbecillis*) – widely distributed from the Great Lakes and Mississippi River to Gulf Coast and Atlantic Coast drainages; inhabits slackwater areas of creeks, rivers, and reservoirs, usually in mud or sand (Williams et al., 2008).
- Variable Spike (*Elliptio* sp. cf. *icterina*) – ranges along Atlantic Coast from North Carolina to northeast Florida; occurs in lakes, ponds, reservoirs, and streams with slight to moderate current (NatureServe, 2015).

5.1 <u>Lake Oconee</u>

Dinkins (2016a) surveyed 30 sites in Lake Oconee on July 26-29, 2016, including 10 sites along the margins of the historic main channel of the Oconee River and 20 sites in coves and tributary embayments. The predominant bottom substrates were silt and/or sand. Site depth ranged from 0.9 to 10.5 meters (m) in the main channel (mean = 3.8 m) and from 0.3 to 6.7 m in the tributary embayments (mean = 2.3 m).

The Lake Oconee survey yielded 355 live specimens of native mussels representing four species (Table 4). All four species occurred in the main channel and tributary embayments. The most common species was Altamaha Slabshell, which comprised 71.0 percent of the live native mussels found in Lake Oconee. It was followed in relative abundance by Inflated Floater (18.6 percent), Paper Pondshell (9.6 percent), and Variable Spike (0.8 percent).

In the main channel, Altamaha Slabshell was found at 60 percent of the sites and comprised 86 percent of the specimens (Table 4). The greatest number of live mussels (168) was found in the main channel (Site M-1) about 2 kilometers upstream of Wallace Dam (Dinkins, 2016a). This was the only site where boulders were present and the only site where all four species were found together in Lake Oconee. In general, the number of mussels at main-channel sites decreased with increasing distance upstream from the dam. The vast majority (98.3 percent) of mussels were found downstream of I-20 (Dinkins, 2016a).

In the tributary embayments, Inflated Floater and Altamaha Slabshell were found in approximately equal relative abundance, although Inflated Floater occurred at more of the tributary embayment sites than Altamaha Slabshell (Table 4). Overall, live native mussels were found at 19 of the 20 tributary embayment sites surveyed, and there was no discernible pattern in abundance related to distance from the dam (Dinkins, 2016a).

Length-frequency distributions for Altamaha Slabshell, Inflated Floater, and Paper Pondshell indicate that their populations in Lake Oconee are successfully reproducing and recruiting young mussels (Dinkins, 2016a; Appendix A). Similar inferences could not be drawn about Variable Spike because of the small sample size.

5.2 Wallace Dam Tailrace

Dinkins (2016b) surveyed 11 sites in the Wallace Dam tailrace area on August 23-25, 2016, including 9 non-wadeable sites in the main river channel and 2 wadeable sites in backwater coves next to the main channel. Most sites in the main channel had substrates of sand, gravel, and/or cobble. Boulders or bedrock were also present at most sites. Depths in the main channel ranged from 1.5 to 9.1 m, averaging about 7 m. The two cove sites were dominated by silt substrate and ranged in depth from 0.3 to 1.2 m.

The Wallace Dam tailrace survey yielded 1,479 live specimens of native freshwater mussels representing the same four species found in Lake Oconee (Table 4). The most abundant species overall was Altamaha Slabshell, which comprised 97.5 percent of all live native mussels found. It was followed in relative abundance by Variable Spike (1.1 percent), and Inflated Floater and Paper Pondshell (0.7 percent each). The vast majority of the mussels found in the tailrace area occurred in the main channel (1,453 mussels, or 98.2 percent).

All four species were found in the main channel. Altamaha Slabshell numerically dominated the main-channel sample, comprising 98.1 percent of the specimens (Table 4). The greatest number of live mussels (501) was found in the main channel (Site 3) about 300 m downstream of the dam near the left descending (east) bank. Mussels were more common along the sides of the main channel than in the center of the channel, and over twice as many mussels were found along the left (east) side than on the right (west) side (Dinkins, 2016b).

The length-frequency distribution for Altamaha Slabshell in the tailrace main channel and the sizes observed of the other three species indicate that all four species are successfully reproducing and recruiting young mussels into their populations (Dinkins, 2016b).

6.0 SUMMER HABITAT FOR SPORT FISH SPECIES

6.1 Lake Oconee Fishery

As described in the PAD (Georgia Power, 2015b), Lake Oconee supports a popular fishery for Largemouth Bass, Black Crappie, Striped Bass, Hybrid Bass, Channel Catfish, Blue Catfish, and a variety of other warmwater species (GDNR, 2016b). Lake Oconee has numerous public access areas which provide for a wide range of boat- and bank-fishing opportunities and tournament fishing. A variety of fish habitat structure, including standing timber, fish plots (stands topped out below the surface), riprap, docks and piers, overhanging vegetation, fish attractors, artificial reefs, aquatic vegetation, and other features provide cover and nursery habitat for sport and forage fishes (Georgia Power, 2015b, and included references).

GDNR annually stocks both Striped Bass and Hybrid Bass into Lake Oconee (Table 5). Stocking numbers have been transitioning from a predominance of Striped Bass to that of Hybrid Bass based on angler preferences for Hybrid Bass (GDNR, 2016b). Stocking rates from 2013 to the present have been about 15 Hybrid Bass and 5 Striped Bass per acre. GDNR began stocking American Shad (*Alosa sapidissima*), a migratory species, into Lake Oconee in 2015. Historical evidence suggests that American Shad formerly occurred as far upstream in the Oconee River as near Athens-Clarke County (GDNR, 2014).

Tournament fishing is popular on Lake Oconee and primarily targets Largemouth Bass. The Georgia Bass Chapter Federation (GBCF), which has gathered and compiled angler catch data from bass tournaments annually for Lake Oconee, Lake Sinclair, and numerous other Georgia reservoirs, has established a long-term dataset of catch statistics for detecting changes in the Largemouth Bass fishery over time. Table 6 summarizes 19 years of Lake Oconee tournament creel data for the years 1996 through 2014. The average tournament bass weight, which ranged from 1.76 to 2.08 pounds (lbs), ranked among the top five reservoirs in Georgia in 17 of the 19 years (GBCF, 1996-2014). The average largest bass reported in Lake Oconee tournaments ranged in weight from 3.51 to 4.64 lbs.

A popular year-round catfish fishery has developed in Lake Oconee and continues to expand. Both Blue Catfish and Flathead Catfish were introduced into the reservoir in the mid-1990's (Homer and Jennings, 2011). Catch data indicate that the Blue Catfish population expanded rapidly after 1997. The Flathead Catfish population also has been increasing but not as rapidly. Anglers now have the opportunity to catch trophy-size catfish in Lake Oconee, with some Blue Catfish and Flathead Catfish exceeding 40 lbs (GDNR, 2016b).

6.2 Analysis of Lake Oconee Standardized Fishery Survey Data

WRD has conducted standardized fisheries surveys in Lake Oconee biannually since 2002 with the objectives of evaluating the overall health of the fishery and making informed management decisions. These unpublished data were used to evaluate the potential effects of Wallace Dam generation and pumpback operations on summer habitat for sport fishes in Lake Oconee, including Largemouth Bass (LMB) and Striped Bass (STB) as the primary species of interest, as well as Black Crappie (BCR), Bluegill (BLG), and Hybrid Bass (WXS). The 26 WRD fish sampling stations were categorized by their location in the reservoir as either mainstem, tributary, or upper reservoir stations (Figure 5), as described in Section 2.4.

Table 7 lists the fish taxa collected by WRD in 2015 from the mainstem, tributary, and upper reservoir locations. Species composition and richness of the targeted species was similar among the three areas, with the tributary embayments yielding the most taxa. Nine species were common to all three areas. They included four of the species selected for this analysis (Largemouth Bass, Striped Bass, Bluegill, and Black Crappie). Hybrid Bass was collected in the mainstem and tributaries in 2015 but not the upper reservoir.

Comparison of the total catch via electrofishing and gillnetting for 2011-2015 shows the differential selectivity of the sampling gear for the sport fish species of interest (Table 8). The five species of interest comprised the vast majority of electrofishing samples but made up less than a third of the gillnetting samples. Gillnet samples tended to be dominated by Blue Catfish, Channel Catfish, Black Crappie, and Threadfin Shad.

The statistical analysis showed that factors of sampling location (mainstem, tributary, or upper) and fish species, as well as year, significantly influence the relative condition of fish captured in Lake Oconee (ANOVA, $p<0.01$) (Table 9). The analysis also indicated that reservoir location and fish species, in combination, is a significant interaction influencing the relative condition of sampled fish, suggesting that the reservoir location of fish sampled is dependent upon fish species. This is to be expected since particular fish species may prefer certain areas of the reservoir. Tukey's Honestly Significant Difference test was used for post-hoc analysis to evaluate the effect of reservoir location within fish species.

6.2.1 Largemouth Bass

Lake Oconee supports a quality Largemouth Bass fishery that is popular with recreational and tournament anglers alike (GDNR, 2016b). Largemouth Bass prefer habitats with structure such as bridge pilings, boat docks, submersed vegetation, brush piles, and standing timber; however, they will also school in open water (North Carolina Water Resources Commission [NCWRC], 2016; Forida Fish and Wildlife Conservation Commission [FWC], 2016; Table 10). Juvenile bass feed upon insects and fish fry, gradually transitioning to sunfish, shad, and crayfish (NCWRC, 2016; FWC, 2016; Huskey and Turingan, 2001). Largemouth Bass spawn from April to June in nests constructed on gravel or other firm substrates. Males guard the nest until fry depart. Largemouth Bass are tolerant of high temperatures (up to 40°C [104°F]) and low DO concentrations (avoiding areas with DO concentrations less than 2.0 mg/L). However, hypoxia (DO <2.0 mg/L) is not an absolute barrier and Largemouth Bass will occasionally make excursions to hypoxic zones for opportunistic feeding (Burleson et al. 2001).

Electrofishing catch-per-hour of Largemouth Bass was high across all years and locations (Figure 8). Catch rates were highest in tributaries (M=77.24, SE=8.36), followed by mainstem (M=58.18, SE=12.37) and the upper reservoir (M=49.06, SE=11.61). Catch rates were higher in the mainstem reservoir compared to the upper reservoir in all years except 2013 and 2016. Catch rates exhibit a slight decline in recent years, with lowest catch rates seen in spring 2016.

The average relative condition factor (Kn) standard is 1.00 across all lengths and species (Murphy and Willis, 1996). Largemouth Bass average relative condition in Lake Oconee from 2008-2016 (Figure 8) is slightly below the average standard and ranges from 0.89 to 0.95 (mean [M]=0.93, standard error [SE]=0.01, n=1,325) for mainstem fish, 0.89 to 0.96 (M=0.92, SE=0.01, n=1,756) for tributary fish, and 0.91 to 0.99 (M=0.95, SE=0.01, n=890) for upper reservoir fish. Relative condition of fish caught in the upper reservoir is significantly higher than both mainstem (ANOVA, p=0.008) and tributary fish (ANOVA, p<0.01). The relative condition of Largemouth Bass caught in the mainstem reservoir is somewhat higher than tributary fish but the difference is not significant (ANOVA, p=0.15). Overall, the Largemouth Bass population appears to be healthy.

The length-frequency distributions using the years 2011-2015 indicate a healthy Largemouth Bass population with a diversity of size classes in all locations (Figure 9). Length-frequencies ranged 68–582 mm (2.7–22.9 inches [in]) in mainstem locations (n=1,328), 77–575 mm (3.0–22.6 in) in tributary locations (n=1,761), and 85–564 mm (3.3–22.2 in) in the upper reservoir (n=895) over the last five years. The largest Largemouth Bass caught was 582 mm (22.9 in) and weighed 3,055 grams (6.7 lbs) in the mainstem reservoir in 2015.

Proportional Stock Density (PSD) is a quantification method of the length-frequency data (Willis et al. 1993). PSD summarizes length-frequency data by categorizing catch by specific length classes. Gabelhouse (1984) defined length classes for 70 species of fish, defined as stock (S), quality (Q), preferred (P), memorable (M), and trophy (T) lengths. Stock-length fish are roughly defined as the approximate length at recruitment (maturity) or vulnerability to gear (Willis et al. 1993). Quality length is the minimum fish size that most anglers like to catch (Murphy and Willis, 1996). The PSD is a proportion of the number of fish greater than or equal to quality length, to the total number of fish greater than or equal to stock length (Murphy and Willis, 1996).

A large proportion of collected Largemouth Bass are greater than or equal to quality length fish (305 mm [12 in]). The objective PSD range for Largemouth Bass in a balanced fish community is 40-70, or 50-80 for a “big bass” community (Murphy and Willis, 1996). The PSD for this population ranged 66–74 over the last five years, slightly higher than the objective range for a balanced fish community and well within the objective range for the big bass management strategy. Largemouth Bass in Lake Oconee exhibit relative condition values slightly less than average and high PSD consistent over the previous five years, indicating a stable and healthy predator population.

6.2.2 Black Crappie

Black Crappie prefer clear, off-shore habitats and slow-moving rivers, although they are often associated with moderate vegetation and structure such as fallen trees and stumps (NCWRC, 2016; FWC, 2016) (Table 10). Black Crappie feed upon plankton, insects and larval fishes, while adults feed mainly on small fishes and crustaceans (NCWRC, 2016; FWC, 2016). Black Crappie spawn from late February to early May in nests constructed in shallow to moderately-deep pools on sand or fine gravel, usually near vegetation. Black Crappie prefer moderate-to-warm temperatures around 23-32°C (73-90°F), and can tolerate DO to 2.5 mg/L, or otherwise comparable to other freshwater fishes.

Electrofishing catch rates were variable across years, particularly in tributary and upper reservoir locations (Figure 10). Catch rates were high in tributary and upper reservoir locations in 2010-2011, then declined to low rates in all locations in 2012; however, catch rates have stabilized roughly around 20 fish per hour over the last several years.

Black Crappie average relative condition is largely above the average standard (Kn=1.00) (Figure 10). Relative condition ranges from 1.01.to 1.12 (M=1.06, SE=0.01, n=1,023) for mainstem fish, 0.96 to 1.08 (M=1.01, SE=0.01, n=736) for tributary fish, and 0.95 to 1.10 (M=1.03, SE=0.02, n=629) for upper reservoir fish. Black Crappie relative condition is significantly lower in tributary and upper reservoir locations compared to the mainstem reservoir (ANOVA, $p<0.01$). Black Crappie may have higher condition factors in the mainstem reservoir since this fish tends to use deeper waters than other sunfish species and commonly prefers open water habitats. However, Black Crappie average condition is above average in all locations, suggesting this species is doing very well throughout Lake Oconee.

Black Crappie length-frequency distributions indicate a relatively healthy population with a diversity of size classes in most years (Figure 11). Length-frequencies ranged 128 – 385 mm (5.0–15.1 in.) in mainstem locations (n=701), 130–356 mm (5.1–14.0 in.) in tributary locations (n=457), and 120–388 mm (4.7–15.3 in.) in the upper reservoir (n=439) over the last five years. A higher number of smaller fish (less than 250 mm) were caught in 2012, with catch rates very low in this year in all locations (Figure 10). Limited size classes were captured in 2015 in the upper reservoir. The largest Black Crappie collected was 388 mm (15.3 in.) and weighed 765 g (1.7 lbs), caught in the upper reservoir in 2014.

A high proportion of collected Black Crappie was equal to or greater than quality length (203 mm [8 in]). The objective PSD range for this species with management focused on a balanced fish community is 30-60 (Murphy and Willis, 1996). The PSD for this population ranged 78-91 over the last five years, much higher than the objective range. A PSD higher than the objective ranges shows the population comprises a high number of larger fish, possibly suggesting limited recruitment or gear bias (Goffaux et al., 2005). Although Black Crappie PSD is out of range, comparison with relative condition (Kn values frequently greater than 1.0) indicates limited competition and a healthy population (Figure 10).

6.2.3 Bluegill

Bluegill use many types of habitats including ponds, reservoirs, slow-moving creeks, and swamps, and are frequently associated with vegetated shorelines (NCWRC, 2016) (Table 10). They feed on zooplankton, aquatic insects, snails, fish eggs, and small fish (NCWRC, 2016). Bluegill spawn from May to August in nests constructed in shallow water on sand or gravel, often in colonies. Bluegill have a wide temperature tolerance, ranging from as low as just-above freezing (0.9°C [32°F]) to as high as 40°C (104°F [Table 10]). Similar to Largemouth Bass, Bluegill are tolerant of hypoxic conditions for short periods of time, with survival at DO concentrations as low as 0.5 mg/L.

Electrofishing catch-per-hour of Bluegill was low-to-moderate across years in all locations, except for higher rates from 2014-2016 in the mainstem reservoir (Figure 12). Bluegill catch rates were generally lower in tributaries (M=10.37, SE=3.16) than in the mainstem (M=18.42, SE=5.18), and they were variable in the upper reservoir (M=11.83, SE=3.32). Catch rates exhibit an increase in mainstem and tributary locations in the last few years.

Bluegill average relative condition ranges from slightly below the average standard (Kn=1.00) to well above average (Figure 12). Relative condition factors range from 0.97 to 1.11 (M=1.01, SE=0.03, n=403) for mainstem fish, 0.88 to 1.21 (M=1.02, SE=0.03, n=226) for tributary fish, and 0.75 to 1.20 (M=1.03, SE=0.03, n=210) for upper reservoir fish. Bluegill average condition is significantly lower in tributary locations compared to the mainstem reservoir (ANOVA, p=0.004), but does not vary significantly between upper reservoir and mainstem reservoir locations (ANOVA, p=0.98). Relative condition is variable across location and years but generally indicates a healthy Bluegill population.

The Bluegill length-frequency distribution is limited in some years due to low sample sizes (Figure 13). However, there is a range of size classes in 2011 and 2015, mainly below 170 mm (6.7 in.). The largest Bluegill collected was 201 mm (7.9 in.) and weighed 155 g (0.3 lb), caught in the upper reservoir in 2013.

All Bluegill collected within the last five years fall within the stock (80–149 mm [3.0–5.9 in]) or quality (150–249 mm [6.0–7.9 in]) length ranges. No Bluegill above 201 mm (7.9 in) were captured in any location and, therefore, no preferred, memorable, or trophy size fish were recorded. The objective PSD range for this species with management focused on a balanced fish community is 20-60 (Murphy and Willis, 1996). The PSD for this population ranged 19-45 over the last five years, generally within the acceptable range.

6.2.4 Striped Bass

Striped Bass is an anadromous, schooling species which prefers channels of large coastal rivers and lakes (Table 10). Adults return to estuaries, ocean, or reservoirs after spawning (NCWRC, 2016). The Striped Bass population in Lake Oconee is stocked (Table 5) and there is no evidence of successful natural reproduction in the area. Striped bass feed on zooplankton, aquatic insects, snails, fish eggs, and small fish as juveniles, and fish and shellfish as adults (NCWRC, 2016). Striped Bass juveniles have a higher thermal tolerance than adults, up to 32°C (90°F) (Crance, 1984). Adults prefer water temperatures up to 25°C (77°F) and may be able to tolerate temperatures as high as 29°C (84°F) depending on other conditions such as DO concentration and forage availability (Coutant, 2013). Adult Striped Bass can become stressed at DO concentrations around 4.0 mg/L (Crance, 1984) and mortality is usually observed at concentrations below 2.0 mg/L (Coutant, 2013).

Gillnetting catch-per-night was low across years in all locations (Figure 14). Striped Bass catch rates were lowest or absent in tributary locations (M=0.93, SE=1.33), generally followed by the upper reservoir (M=1.29, SE=0.00), and highest in the mainstem reservoir (M=3.26, SE=1.38). No Striped Bass were caught in tributary locations from 2010-2014. Catch was highest in the mainstem reservoir in 2008 (M=7.33, SE=3.18), likely due to high stocking rates in 2007 (Table 5).

Striped Bass average relative condition in Lake Oconee is consistently below the average standard (Figure 14). Average relative condition ranges from 0.88 to 0.98 (M=0.91, SE=0.02, n=76) for mainstem fish, 0.89 to 0.93 (M=0.91, SE=0.10, n=17) for tributary fish, and 0.84 to 0.95 (M=0.90, SE=0.02, n=14) for upper reservoir fish. Relative condition did not show significant variance for this species among reservoir locations (ANOVA, p>0.01). Relative condition appears generally low, however sample sizes are limited. No Striped Bass were caught in 2010 or 2016 because the primary method for Striped Bass capture is gillnetting. Only electrofishing was performed in 2010 and fall gillnetting had not yet occurred in 2016. Moreover, captures were low or absent in many locations, especially in tributaries and the upper reservoir.

Striped Bass length-frequency distributions by reservoir location were pooled due to low sample sizes (Figure 15). Regardless, length-frequency interpretation is limited due to low catch rates across all years. The smallest Striped Bass caught was 152 mm (6.0 in) in 2011. The largest Striped Bass caught was 650 mm (25.6 in) in 2012.

Although sample sizes are small, many Striped Bass collected within the last five years were below the range of stock size (less than 305 mm [12 in]). No Striped Bass were caught at preferred length (762 mm [30 in]) or above. Considering the low catch rates and low relative condition, it appears that a lack of suitable habitat may be limiting the Striped Bass population in Lake Oconee. Summer water temperatures exceeding 28°C throughout the reservoir in many years is likely a principal factor limiting the survival and growth of the Striped Bass population (see Section 6.3).

6.2.5 Hybrid Bass

Hybrid Bass is a popular stocking fish in southeastern reservoirs due to a large forage base of gizzard and threadfin shads (Hodson, 1989). Hybrid Bass prefer slow moving streams and rivers, large reservoirs, lakes and ponds (NCWRC, 2011b) (Table 10). Juvenile bass feed upon zooplankton and insects, switch to eating fish at a small size, feed heavily on shad, and grow rapidly (Hodson, 1989; Mettee et al., 1996). Hybrid Bass rarely reproduce (NCWRC, 2011b), but spawning can occur between March and May when temperatures reach 12-20°C (55-70°F) (Hodson, 1989). Hybrid Bass have a wider tolerance range to temperature and DO than Striped Bass (Ohio Department of Natural Resources [ODNR], 2013; Hodson, 1989). Hybrid Bass can survive a temperature range of 4-33°C (39-91°F), but optimal growth is between 25-27°C (77-81°F) (Hodson, 1989). Hybrid Bass can also survive in waters with DO concentrations as low as 1.0 mg/L for short periods, but optimal levels range 6-12 mg/L (Hodson, 1989).

Gillnetting catch-per-night was low-to-moderate depending on location (Figure 16). Hybrid Bass catch rates were highest in mainstem locations (M=8.62, SE=2.47), followed by tributary (M=2.47, SE=3.10) and upper reservoir (M=2.29, SE=0.25). No Hybrid Bass were caught in upper reservoir locations from 2010-2012 or in 2015 (2016 fall gillnetting had not yet been conducted). An unusually high catch rate was seen in 2011 in the mainstem reservoir (M=24.0, SE=8.08), followed by a sharp decline in 2012.

Hybrid Bass average relative condition is marginally above the average standard (Kn>1.00) (Figure 16). Average relative condition ranged from 0.88 to 1.07 for mainstem fish (M=1.01, SE=0.03, n=179), 0.96 to 1.13 (M=1.03, SE=0.03, n=68) for tributary fish, and 0.85 to 1.14 (M=1.04, SE=0.08, n=27) for upper reservoir fish. There are no significant trends in average condition across reservoir locations (ANOVA, $p>0.01$).

Hybrid Bass length-frequency distributions are variable across years, with limited analysis due to low sample sizes in some years (2012, 2014, and 2015) (Figure 17). Most individuals are greater than 200 mm (8 in) and years with higher sample sizes exhibit a range of size classes.

Most Hybrid Bass collected were greater than stock length (200 mm [8 in]). The PSD for this population ranged 18-67 over the last five years. Most years were within the objective range for predators (40-70) with the exception of 2013 (PSD=18), which had a high amount of stock-size fish and few fish larger than 12 in (305 mm). Hybrid Bass typically have higher average condition at higher PSD, suggesting the population does well with adequate prey abundances and generally little influence from competition of other basses.

6.3 Analysis of Lake Oconee Habitat

A key aquatic resource issue identified by stakeholders for relicensing of the Wallace Dam Project is the effects of continued project operations on summer reservoir water quality and habitat for sport fish species such as Largemouth Bass and Striped Bass. Georgia Power operates Wallace Dam to provide generation during peak demand hours. During the summer, Wallace Dam generates about 7 to 8 hours across the afternoon peak demand period. At night, the reversible turbine units pump water back up and into Lake Oconee, when the cost of power is lower, for reuse in the next day's generation cycle.

Georgia Power documented the extent of mixing in Lake Oconee that occurs as a result of pumped storage operations in the Water Resources Study. Unlike typical large southeastern reservoirs, which undergo summer thermal stratification in the deepest areas of the reservoir, seasonal and monthly water temperature profiles in the forebay of Wallace Dam showed the water column to be well mixed or only weakly stratified during much of the summer. Vertical stratification becomes weakly developed in the spring and early summer, but by August, the amount of cooler water diminishes and the water column exhibits only narrow temperature variation from the surface to the bottom. The effects of mixing on temperature are most evident in the mainstem reservoir and the tributary embayments closest to Wallace Dam. Appendix D provides seasonal, monthly, and hourly vertical profiles of DO and water temperature from the Water Resources Study to support the following discussion.

Most sport fish species found in Lake Oconee are warmwater species capable of tolerating high water temperatures and relatively low DO levels (Table 10). Largemouth Bass, sunfishes, and Channel Catfish have wide tolerance ranges; they are able to survive temperatures up to 40°C (104°F) and severe hypoxia as low as 1.0 mg/L. Blue Catfish are also able to tolerate high temperatures but are slightly more sensitive to low DO levels, becoming stressed at concentrations below 4.0 mg/L. Black Crappie do well at high temperatures (up to 32°C [90°F]), and can tolerate (even spawn at) DO concentrations as low as 2.5 mg/L. Hybrid Bass can tolerate temperatures up to 33°C (90°F) and DO as low as 1.0 mg/L for short periods. However, Striped Bass have much lower thermal tolerances and higher sensitivity to low DO compared to warmwater fishes or Hybrid Bass. While juvenile Striped Bass have a higher thermal tolerance, up to 32°C (90°F), adult Striped Bass prefer temperatures around 25°C (77°C) or less and begin to experience mortality above 28 or 29°C (82-84°F) (Crance, 1984; Coutant, 1985, 2013).

Seasonal vertical profiles of Lake Oconee from 2003-2016 (Appendix D, Figures 6a-6i) show the extent of vertical mixing that occurs in the mainstem reservoir (Stations OC1, OC3, OC5, and OC6), tributary embayments (Stations OC2, OC4, and OC9), and upper end of the reservoir (Stations OC7 and OC8). Vertical lines on the plots at water temperature of 29°C and DO concentration of 4.0 mg/L serve as relevant screening values for habitat analysis. The 29°C threshold screens summer Striped Bass habitat suitability. Based on habitat suitability criteria described by Crance (1984), adult Striped Bass habitat becomes unsuitable at temperatures of 29.4°C and higher. Largemouth Bass and other sunfishes tolerate much warmer temperatures (Table 10). The DO value of 4.0 mg/L, the minimum instantaneous water quality criterion (applicable at a depth of 1 meter), serves as a general screening value, although it is conservative because most resident sport fishes, including Largemouth Bass and Striped Bass, tolerate lower DO concentrations (Table 10).

6.3.1 Striped Bass

Summer water temperature profiles for Lake Oconee are sufficient to explain the limiting nature of habitat suitability for Striped Bass, as reflected in the population characteristics analyzed above. Most of the summer profiles are from August (Appendix D, Figure 6). The entire water column at mainstem Stations OC1, OC3, OC5, and OC6 reached temperatures higher than the suitability criterion of 29°C for adult Striped Bass in at least 9 of 14 summers (64 percent) from 2003 to 2016 (Appendix D, Figure 6). Similarly, water temperatures reached temperatures higher than 29°C throughout the water column in 8 of 14 summers in the tributary embayments (Stations OC2, OC4, and OC9) and 7 of 14 summers in the upper end of the reservoir (Stations OC7 and OC8).

The monthly vertical profiles measured in 2015-2016 confirm this trend (Appendix D, Figures 5a-5i). Temperature profiles from the forebay (Station OC1) in August 2015, and July and August 2016, were isothermal or nearly so at about 30°C. Temperatures were as high or warmer at other mainstem and tributary stations. In addition, the hourly vertical profiles measured during 24-hour sampling events in July and August 2016 (Appendix D, Figures 10 and 11) demonstrated the prevalence of warm conditions throughout the reservoir, with the entire water column exceeding 29°C in virtually every area of the reservoir.

By comparison, DO concentrations higher than 4.0 mg/L were widely available in the upper water column at all stations in all summers, with the exception of one summer monitoring event in the forebay (Station OC1; July 2014) (Appendix D, Figure 6a). The monthly and hourly monitoring data also showed widespread availability of summer DO concentrations well above 4.0 mg/L (Appendix D, Figures 5, 10, and 11). Thus, although suitable DO conditions were available throughout much of the reservoir, by late July and August, temperatures often exceeded temperature criteria defining suitable adult Striped Bass habitat.

6.3.2 Largemouth Bass

Based on the known temperature and DO tolerances of Largemouth Bass (Table 10), the seasonal, monthly, and hourly water quality monitoring data collected by Georgia Power show that summer water quality conditions in Lake Oconee support the survival and growth of Largemouth Bass. The catch rates, relative condition, and length-frequency distribution of Largemouth Bass in Lake Oconee indicate the presence of an overall healthy population.

Moreover, the average weight of tournament bass caught in Lake Oconee consistently ranks among the top five reservoirs in Georgia (GBCF, 1996-2014).

6.3.3 Conclusion

Although concerns have been expressed about how the Lake Oconee fish community may be affected by low DO concentrations due to water column mixing caused by pumpback operations, the results of the literature review suggest that most of the resident sport fish species are tolerant of the existing summer habitat conditions. Furthermore, recent and historic water quality sampling does not show widespread summer low-DO conditions in Lake Oconee, although DO levels may intermittently fall below 4.0 mg/L near the surface in the forebay during summer pumpback operations. The GDNR standardized fisheries survey data also indicate a healthy and balanced freshwater fish community, with the exception of Striped Bass. The Striped Bass population exhibits low catch rates and low relative condition factors in all reservoir locations, despite being stocked annually. While Striped Bass have a narrower tolerance range, available evidence indicates that it is the naturally high water temperatures, and not low DO concentrations, that limit the availability of suitable summer habitat for Striped Bass in Lake Oconee.

6.4 Analysis of Tailrace Habitat

As part of the Water Resources Study, continuous DO and temperature monitoring data recorded in the Wallace Dam tailrace from July 2015 to September 2016 were aligned with operational data to examine the effects of project operations on tailrace water quality. Weekly plots of the monitoring data are presented and discussed in the separate Water Resources Study Report. During June, July, and early August periods of both summers, there were daily DO depressions in the tailrace to values below 4.0 mg/L. Pumpback on the same days corresponded with increases in tailrace DO values to above 4.0 mg/L. Additionally, some DO recovery was likely due to daytime photosynthesis in the water column of the tailrace. Summer water temperature in the tailrace frequently was greater than 29°C and commonly exceeded 30°C. Hourly temperature readings exceeded 29°C about 60 percent of the time in July and 90 percent of the time in August.

Two hourly tailrace monitoring events conducted in August 2016 characterized variation in tailrace water quality over the course of summer pumpback and generation operations (see Water Resources Study Report). The ranges of values recorded indicated water quality to be relatively evenly distributed across the tailrace channel.

A variety of warmwater sport fish species typical of southeastern reservoirs likely use the Wallace Dam tailrace area throughout the summer, which includes a deep mainstem channel, large rocks and overhanging vegetation providing cover along the shorelines, and two small coves along the east side of the channel with more protected littoral-zone habitats. However, the continuous tailrace monitoring data and temperature suitability criteria for adult Striped

Bass (Crance, 1984) indicate that the tailrace area is unlikely to provide suitable adult Striped Bass habitat for much of the summer. Water temperatures frequently exceed 29°C and thermal refugia are unlikely to persist in the channel or adjacent coves due to the high generation and pumping flows through the reach. Hybrid Bass, which are generally more tolerant of warmer temperatures and lower DO levels than Striped Bass (Table 10), are more likely to use the tailrace as summer habitat.

Resident warmwater fishes in the tailrace area, many of which are habitat-generalist species capable of tolerating wider ranges of temperature, DO levels, and flow conditions, are likely to use tailrace habitats during the summer, especially in response to changing prey densities with generation and pumpback cycles. Channel Catfish, Bluegill, Threadfin Shad, Redbreast Sunfish, Largemouth bass, and other species likely find suitable summer habitat within the tailrace area. Based on historical Georgia WRD electrofishing data, collected annually in September, sportfish abundance (e.g. Largemouth Bass, Bluegill, Redbreast Sunfish, and Black Crappie) immediately below the Wallace Dam tailrace does not differ considerably from other locations in Lake Sinclair. In addition, native mussel species inhabit the reach. The tailrace mussel survey conducted in August 2016 (Section 5.2) yielded 1,479 live specimens of freshwater mussels representing four native species, including two species endemic to the Altamaha River basin (Dinkins, 2016b). The greatest number of live mussels was found about 300 m downstream of the dam on the same side of the river as the Wallace Dam powerhouse. Thus, the tailrace area supports self-sustaining populations of aquatic species representative of a balanced community. In addition, it provides important recreational fishing opportunities below Wallace Dam.

7.0 FISH ENTRAINMENT EVALUATION

Fish entrainment refers to the incorporation of fish with intake water flow entering and passing through the hydroelectric turbines. Fish approaching the powerhouse intake in Lake Oconee during generation or the downstream side of the powerhouse during pumpback may become entrained and subjected to risks of turbine-induced injury or mortality. The following analysis characterizes the potential for fish entrainment and turbine-induced mortality at the Wallace Dam Project.

7.1 Project Facilities

Wallace Dam is about 2,395 ft long and 120 ft high above streambed (Figure 4). Its principal structures include an earth and concrete gravity dam, a semi-outdoor type powerhouse integral with the dam, a five-gate spillway, and a 20,000-ft-long excavated tailrace into Lake Sinclair. The intake is integral with the powerhouse and has an invert elevation of 343.0 ft PD, which is 92 ft below Lake Oconee full pool elevation of 435 ft PD. The normal tailwater elevation is 340 ft PD.

The powerhouse is located immediately downstream of the dam on the east side of the river (Figure 4). It contains six turbine-generator units, including two conventional units and four pumped storage units (Table 11). They are numbered 1 through 6 from west to east. Units 1, 2, 5, and 6 are reversible. There are six penstocks with a maximum diameter of 25.5 ft. Steel trash racks in front of the intake in the dam forebay consist of vertical bars with clear spacing between bars ranging from 14.5 to 15.5 inches.

The nameplate generating capacity of the Wallace Dam Project is 321.3 MW, and the total turbine hydraulic capacity is 50,545 cfs at full gate operations (Table 11). The total hydraulic capacity at best gate is 44,750 cfs, about 89 percent of full gate operations. Normal operation is to generate at best gate unless there is a need for more hydraulic or power capacity.

The Wallace Dam powerhouse operates at a rated net head of 89 ft. Table 12 summarizes turbine design characteristics. Units 1, 2, 5, and 6 are vertical-shaft, Francis type, reversible pump turbines each rated 73,000 horsepower (hp) at 89 ft net head generating and 83,000 hp at 103 ft total dynamic head pumping. Their rated speed is 85.8 revolutions per minute (rpm). The four-unit pumping capacity totals 26,800 cfs. Units 3 and 4 are vertical-shaft, modified propeller type turbines each rated 78,000 hp at 89 ft net head and with rated speed of 120 rpm. The inlet diameter to the turbines is 253 inches (21.1 ft) for the reversible units and 202 inches (16.8 ft). The turbines operate with peripheral runner velocities of 95 and 106 feet per second (fps).

7.2 Factors Influencing Fish Entrainment and Mortality

The number, species, and life stages of fish entrained at a hydroelectric development are related to a variety of physical factors near the dam and powerhouse. These may include plant flow, intake forebay configuration, intake depth, intake approach velocities, trash rack spacing, plant operating mode, and proximity to fish spawning, rearing, and feeding habitats (EPRI, 1992; FERC, 1995a). Biotic factors also affect entrainment, including diurnal and/or seasonal patterns of fish migration and dispersal, fish size and swimming speed, behavior, life history requirements, and density-dependent influences (e.g., resource availability) on fish populations in upstream habitats (EPRI, 1992; FERC, 1995a; Cada et al., 1997).

Injury and mortality of fish passing through hydroelectric turbines can occur via the following mechanisms (Cada, 1990; Cada et al., 1997; Odeh, 1999; and Cada, 2001):

- Mechanical effects (strike and grinding) – Direct strikes or collisions with structures within the turbine system, such as moving runner blades, fixed guide and stay vanes, and flow-straightening walls in the draft tube; and grinding when fish are drawn through narrow openings or gaps between fixed and moving structures.

- Pressure changes – Rapid and extreme pressure decreases that occur momentarily on the downstream side of the runner and into the draft tube. In a matter of seconds, water pressures within the turbine may increase to several times atmospheric pressure and then drop to sub-atmospheric pressures. The main cause of pressure-related mortality is injury to the swim bladder from rapid decompression.

- Cavitation – The rapid formation of vapor bubbles caused by sub-atmospheric pressures within a turbine. Cavitation can occur downstream from the runner, in areas of increasing local velocities, in areas with abruptly changing flow direction, and along roughened or irregular surfaces (e.g., blade surface). As cavitation bubbles stream to areas of higher pressure, they collapse violently, creating localized shock waves. Rapid exposure to these high-pressure shock waves can injure entrained fish.

- Turbulence – Irregular motions of the water occurring throughout turbine passage. Intense, small-scale turbulence can distort and compress portions of the fish's body, while larger-scale turbulence, such as vortices in the draft tube, can spin and disorient fish, leaving them more susceptible to predators in the tailrace.

- Shear stress – Fluid-induced forces applied parallel to the fish's surface, experienced by a fish passing between two water masses of different velocities or sliding along a solid structure such as an intake wall or turbine blade (Nietzel et al., 2000). Fish encounter shear forces related to velocity gradients within the turbine system as they move from one velocity zone to the next.

Survival of turbine-passed fish depends on physical characteristics of the turbine system, such as head, turbine size and design, runner speed, number of runner blades, wicket gate openings and overhangs, runner blade angle, clearances between runner blades and housing, flow through the turbine, and water passage routes through the turbine (Cada, 1990; Odeh, 1999; Cada and Rinehart, 2000; Cada, 2001; EPRI, 2011). These factors can be sources of mechanical injury to fish (from strikes and grinding) and also produce pressure changes and localized fluid forces (shear stress and turbulence) that may injure fish (Cada, 2001). Survival also depends on species, size, physiology, and behavior of entrained fish, and their distribution in the turbine intake, which influence the paths fish take in the turbine and the parts they encounter (Cada et al., 1997; Cada, 2001).

Maximum survival of entrained fish tends to occur near peak turbine operating efficiency, and smaller fish tend to suffer the least mortality (EPRI, 1992). Outside the peak range of operating efficiency, increased mortality appears to be related mainly to the effects of cavitation, pressure changes, shear stresses, turbulence, and narrow clearances between wicket gates at low gate settings (EPRI, 1992; Cada, 2001). The sizes of clearances between wicket gates, and between the trailing edge of the wicket gates and the turbine blades, are especially important to the passage of larger fish at high runner speeds (EPRI, 1992).

Actual pressures experienced by entrained fish depend on turbine design, flow rate, and head. High-head turbines, which tend to be smaller units, generally have a higher rate of pressure change per unit time than low-head turbines (Odeh, 1999). Pressure increases of the magnitude found in hydroelectric turbines are unlikely to directly injure or kill entrained fish. Rather, it is brief exposure to sub-atmospheric pressures downstream from the runner at high-head turbines that is more likely to injure fish having swim bladders (Cada et al., 1997). Negative pressure behind the runner may be only slightly less than pressures to which surface-dwelling fish are acclimated, but substantially lower than those to which bottom-dwelling fish are acclimated. Thus, bottom-dwelling fish may be more prone to pressure-related injury.

Design factors affecting cavitation include hydraulic head on the turbine runner, net head, surface irregularities on the turbine blades, and abrupt changes in flow direction (Cada, 1990; Odeh, 1999). Cavitation at hydroelectric facilities is difficult to predict but often occurs at high loads, when pressure drops within the turbine are greatest (Cada, 1990).

Although turbine passage may not directly injure fish, pressure changes, shear stress, and turbulence may nonetheless physically stress or disorient entrained fish, increasing their susceptibility to predation or disease (indirect mortality) (Cada et al., 1997). Predation in the tailrace is one of the most immediate sources of indirect mortality to entrained fish (Cada, 2001).

7.3 Potential Entrainment at Wallace Dam

This section characterizes the potential size distribution, species composition, and seasonal distribution of fish entrainment occurring at the Wallace Dam Project based on common trends and data from entrainment field studies completed at 47 other hydroelectric sites east of the Mississippi River. Site characteristics and fish entrainment rates estimated from site-specific studies are presented in Tables 13 and 14. Forty-three of the sites are from the EPRI (1997a) entrainment database; two are from the FERC (1995a) entrainment database (Abbeville and King Mill); one is evaluated in a FERC (1995b) environmental assessment (Stevens Creek); and one is currently undergoing FERC relicensing (Jocassee). Forty-five of the sites are conventional hydroelectric projects (Table 13) and two of the sites are pumped storage projects (Jocassee and Richard B. Russell) (Table 14).

The 47 sites in the entrainment database generally bracket the physical characteristics of the Wallace Dam Project. Table 15 compares the sites in the database, including 11 southeastern sites as a subset, with the physical characteristics of the Wallace Dam Project. Similar to Wallace Dam, 11 of the sites are located on southeastern rivers; 10 are in the Piedmont province and 1 is on the edge of the Blue Ridge province. These sites include Abbeville, Jocassee, King Mill, Richard B. Russell, and Stevens Creek in the Savannah River basin, South Carolina and Georgia; Gaston Shoals, Ninety-Nine Islands, Saluda, Hollidays Bridge, and Buzzard’s Roost in the Santee-Cooper River basin, South Carolina; and Luray in the Potomac River basin, Virginia.

Entrainment field studies conducted at the Jocassee and Richard B. Russell sites characterize pumpback and generation operations, as summarized in Table 14. Richard B. Russell also appears with the conventional sites in Table 13 because it was included in the EPRI (1997a) entrainment database for previous sampling of its conventional generation.

All 47 sites in the entrainment database are on warm- or cool-water river systems, and their impoundments share many of the same dominant resident fish species or genera. Dominant sport fishes typically include Largemouth or Smallmouth Bass, sunfishes, catfishes, Walleye, and/or Yellow Perch. Although entrainment sampling methods and analytical approaches varied considerably among sites, the study plans were developed in consultation with, and in most cases were approved by, state and/or federal resource agencies.

7.3.1 Size Distribution

Entrainment Samples from Other Projects

Small and/or young-of-year (YOY) fish less than 6 inches long likely comprise the majority of fish entrained by the Wallace Dam Project during generation and pumpback. In numerous studies at other hydroelectric sites in the eastern U.S., fish less than 4 inches long represented over 75 percent of estimated annual entrainment (EPRI, 1992, 1997a; FERC, 1995a, 1996).

Table 16 shows the size-class composition of entrainment samples from 42 hydroelectric developments (EPRI, 1997a). Overall, the proportion of fish less than 4 inches long averaged 68.4 percent. Fish less than 4 inches long comprised over 75 percent of entrainment samples at 24 sites, and over 90 percent at 9 sites. Fish less than 6 inches long exceeded 75 percent of the entrainment catch at 33 sites.

Among southeastern projects, fish under 4 inches long comprised 98 and 71 percent of entrainment samples at Buzzard's Roost and Richard B. Russell, respectively (Table 16). Entrainment samples collected at Gaston Shoals, Hollidays Bridge, Ninety-Nine Islands, and Saluda, consisted of more variably sized fish. The average proportion of fish less than 6 inches long was 59 percent at these 4 sites, while the average proportion of fish between 6 and 8 inches was 24 percent. However, the studies at all four sites concluded that some resident fish in the tailrace likely intruded into the tailrace sampling net (FERC, 1995a). Tailrace intrusion can result in overestimates of entrainment and produce a bias toward larger fish, because fish that intrude into a tailrace sampling net are typically species that prefer turbulent conditions and/or prey on fish exiting the turbines (EPRI, 1992, 1997b).

Size-class information summarized by FERC (1995a) showed that small to moderate-sized fish dominated entrainment samples at the Abbeville and King Mill projects adjacent to the Savannah River. Fish under 6 inches long comprised over 75 percent and 95 percent of entrainment samples at Abbeville and King Mill, respectively. Small fish also dominated entrainment samples at Stevens Creek on the Savannah River. Fish less than 3 inches long comprised 77 percent of the entrainment sample (FERC, 1995b).

Sampling of pumpback entrainment at Jocassee and Richard B. Russell reported similar findings with respect to the numerical dominance of small fish (Table 14). Fish under 6 inches long comprised 86 percent of the pumpback sample at Jocassee. Ninety-four percent of the pumpback sample at Richard B. Russell was less than 5.4 inches long.

Production of YOY fish in healthy reservoir systems with abundant littoral areas providing nursery habitat is often high. Many of these small fish disperse from upstream habitats in response to changing habitat needs and density-dependent influences on resource availability. Moreover, YOY fish generally are more susceptible than larger fish to being transported downstream during higher flow conditions and are less capable of escaping intake velocities as they approach dams.

Trash Rack Spacing

FERC's (1995a) entrainment assessment found no consistent associations between trash rack bar spacing and the size of entrained fish. Winchell et al. (2000) summarized trends in the EPRI (1997a) entrainment database and also found little difference in the size distributions of entrained fish from sites with very different trash rack spacing.

The steel trash racks in front of the intake in the Wallace Dam forebay consist of vertical bars with 14.5 to 15.5 inches clear spacing. Based on proportional relationships between body width and total length for representative sport fish species, virtually all species and size classes of fish residing Lake Oconee are able to pass through the racks at Wallace Dam. Nevertheless, field studies across a wide range of trash rack spacing indicate that the majority of entrained fish are small, the vast majority are much smaller than the length of fish that would be physically excluded by the trash rack spacing, and the size of entrained fish tends to be similar among sites in spite of differing trash rack spacing (FERC, 1995a; EPRI, 1997a). For example, the Richard B. Russell site has trash rack spacing of 8 inches, yet fish smaller than 6 inches comprised 89 percent of entrainment (conventional generation; Table 16), or roughly equivalent to the average proportion of entrained fish less than 6 inches long for all 42 sites in Table 16 (84.6 percent).

Winchell et al. (2000) recompiled fish size data from the EPRI (1997a) entrainment database to exclude clupeids (shads and herrings), whose high abundance at some sites might skew the entrainment size distribution toward smaller size classes, and American eels, which are capable of passing through narrowly spaced trash racks at relatively long fish lengths. Even after excluding these taxa, Winchell et al. (2000) found no apparent relationship between trash rack spacing and the size distribution of entrained fish.

The relatively low vulnerability of larger resident fish to turbine entrainment likely relates in part to the stronger swimming performance of larger fish (Wolter and Arlinghaus, 2003). Larger fish are usually much more capable than small fish of escaping the hydraulic forces of intake flow as they approach dams.

Intake Velocity

FERC (1995a) assessed fish entrainment test data from 45 sites using exploratory regression analysis and found no significant trends between entrainment rate and average intake velocity. Average intake velocities reported at 12 sites in the EPRI (1997a) entrainment database ranged from 0.7 to 2.4 fps (Table 13). FERC (1995a) reported average intake velocities at maximum flow for additional sites in South Carolina that were higher than those in the EPRI database, including average velocities of 5.8 fps at Ninety-Nine Islands and 7.2 fps at Saluda and Hollidays Bridge.

Average intake velocities at the Jocassee pumped storage site were higher for maximum pumpback in the tailrace (2.5 to 3.5 fps) than for maximum generation in the dam forebay (less than 1.5 fps) (Table 14). The higher intake velocities in the tailrace were likely due in part to the shallower depth of the tailrace (about 37 ft) compared to the more open forebay of the dam (55 ft) (Duke Energy Carolinas, LLC [Duke Energy], 2014).

7.3.2 Species Composition and Relative Abundance

The predominant species reported from entrainment sampling at other sites in the eastern U.S. include sunfishes (Centrarchidae), perches (Percidae), catfishes (Ictaluridae), minnows (Cyprinidae), and herrings and shads (Clupeidae). Table 17 summarizes percent composition of entrainment by family at 43 sites (EPRI, 1997a). Each of these five predominant families comprised on average over 10 percent of the entrainment samples. Sunfishes numerically dominated entrainment at 20 sites, followed by perches at nine sites, catfishes and herrings at five sites each, and minnows at two sites.

Sunfish relative abundance exceeded 29 percent at over half of the sites (Table 17). Perch abundance (mainly Yellow Perch, some Walleye, and to a lesser extent, darters) was highest at sites in the Northeast and upper Midwest. Catfish relative abundance exceeded 26 percent at 9 sites, including Gaston Shoals (41 percent) in South Carolina. Minnows were reported in samples from all but one site and averaged 13 percent of the entrainment composition. Clupeids were more variable in their occurrence, appearing in entrainment samples at 25 percent of the sites, but when present, their relative abundance tended to be high. Clupeid relative abundance exceeded 81 percent at 5 sites, including 2 in the Southeast (82 percent at Richard B. Russell [conventional generation], and 97 percent at Buzzard's Roost).

Southern Sites

Species composition of entrainment at the Wallace Dam Project is likely to be similar to that of other southeastern hydroelectric projects. Table 18 shows the relative abundance of the top five entrained species at each of nine hydroelectric sites in South Carolina and Georgia. All of these sites are located in Atlantic Coast drainages sharing many of the same numerically dominant families of fish, and many of the same species and popular sport-fishes (Swift et al., 1986; Hocutt et al., 1986; Rohde et al., 2009). The top five species at each site comprised 65.4 to 95.3 percent of the total entrainment, with the exception of Buzzard's Roost where Threadfin Shad alone comprised 96.8 percent of entrainment. At least 11 of the 17 species are known to occur in Lake Oconee, as indicated in Table 18.

Shad, sunfishes, and/or catfishes typically dominated entrainment at the southeastern hydroelectric sites (Table 18). At sites with higher densities of shad as forage fish, shad may strongly dominate entrainment composition, especially where over-winter survival of threadfin shad populations is variable due to cold-weather conditions. Cold-stress of Threadfin Shad begins at water temperatures of 9°C (Griffith, 1978), and can lead to winter kills that result in episodic entrainment events (FERC, 1995a). As cold-stressed fish become naturally moribund, they are unlikely to exhibit avoidance reactions or controlled body orientation to enable them to escape intake approach velocities (Cada et al., 1997). The highest Threadfin Shad entrainment observed at Buzzard's Roost occurred in January and February and may have included moribund fish from winter kills (FERC, 1995a). At sites where shad densities are lower, or in years following severe winter kill of Threadfin Shad when standing stocks of shad are low, sunfishes, catfishes, and perches may be more likely to dominate entrainment composition. Minnows and suckers (Catostomidae) also may be commonly entrained. Species of all of these families are well represented in Lake Oconee and the upper Oconee River basin (see fish species occurrence table in PAD).

Like conventional generation, pumpback entrainment at Richard B. Russell was also numerically dominated by Threadfin Shad (91 percent), followed by Blueback Herring (6 percent) (Table 14), reflecting the tremendous abundance of these forage species in large impoundments on the Savannah River (Nestler et al., 1999).

Sport Fishes

A substantial proportion of entrained fish at the Wallace Dam Project likely consists of small or YOY sport-fish species, including Bluegill, Black Crappie, other sunfishes, and catfishes. The sunfish, catfish, and perch families, each of which contains several common species classified as sport-fish or pan fish, together comprised over 50 percent of entrainment at 34 of the 43 sites (80 percent) listed in Table 17. These three families totaled over 50 percent of entrainment at 4 of 6 southeastern sites (Gaston Shoals, Ninety-Nine Islands, Hollidays Bridge, and Saluda). Shad strongly dominated entrainment at the other two southeastern sites (Richard B. Russell [conventional generation] and Buzzard's Roost). Otherwise, entrainment at Richard B. Russell consisted mostly of perches, sunfishes, and catfishes, and entrainment at Buzzard's Roost consisted mostly of perches, sunfishes, and temperate basses, the latter composed mainly of white perch (Tables 17 and 18).

Notably, Largemouth Bass, one of the region's premier sport-fishes, was absent from the top five entrained species at any of the southeastern projects (Table 18). Similarly, Striped Bass, White Bass, and Hybrid Bass were absent from the top entrained species. The relative abundance of sport fish species in pumpback entrainment at Richard B. Russel was also low, only 0.03 percent for Largemouth Bass, 0.02 percent for Striped Bass, and 0.01 percent for Hybrid Bass (Table 14). Ninety-seven percent of the entrained Striped Bass and 84 percent of the entrained Hybrid Bass were less than 15 inches long (Nestler et al., 1999). While these popular sport fishes are likely to occasionally be entrained at Wallace Dam, they do not appear to be especially susceptible to entrainment.

The potential for Striped Bass, Hybrid Bass, and White Bass in Lake Oconee to become entrained by Wallace Dam generation flows may be highest in the early summer, as the water column warms and fish actively seek cooler water deeper in the forebay. Lake Sinclair populations may become more susceptible to entrainment by pumpback operations in the early spring, when upstream migrant adults tend to congregate in the Wallace Dam tailrace area; however, these fish are also larger and thus more capable of escaping intake velocities.

Most fish species inhabiting Lake Oconee and the Wallace Dam tailrace area of Lake Sinclair are probably subject to at least occasional entrainment upon generation or pumpback. Other species attempting to migrate downstream, or that are transported downstream out of upstream reaches and tributaries in flood-flows, also may pass through the turbines.

7.3.3 Seasonal Distribution

Peak entrainment rates at the Wallace Dam Project most likely occur in spring and summer, following the spawning and rearing seasons of sunfishes, clupeids, yellow perch, catfishes, and other species with high reproductive potential, when young fish are abundant and tend to be dispersing from spawning and rearing areas into preferred habitats. The lowest entrainment rates for most species other than shad generally would be expected to occur from late fall through winter, when colder water temperatures tend to suppress fish movements.

Monthly variation in entrainment documented at South Carolina and Georgia sites in the entrainment database (FERC, 1995a, EPRI, 1997a) indicates the following trends in seasonal abundance:

- Sunfish and bass entrainment likely peaks between April and June. Multiple-spawning species such as Bluegill and other sunfish may show secondary peaks through summer and early fall.

- Clupeids exhibit more variable patterns of peak entrainment depending on the species, with trends toward peak entrainment rates occurring between late fall and spring. Threadfin Shad entrainment rates documented at the Buzzard’s Roost and Richard B. Russell sites were quite high. Over 8,000 Threadfin Shad per hour were sampled at Buzzard’s Roost in February, an extremely high rate apparently related to low water temperature stress (FERC, 1995a). Nearly all of these fish were juveniles less than 4 inches in length (EPRI, 1997a). The peak entrainment rate of 212 threadfin shad per hour at Richard B. Russell in November (conventional generation), while substantially lower than that at Buzzard’s Roost, was 10 times higher than peak clupeid entrainment rates observed at other sites. Thus, where large clupeid populations and/or the potential for cold-stress exists, the potential for clupeid entrainment may be relatively high.

- Patterns of Yellow Perch entrainment observed at the Buzzard’s Roost and Abbeville sites suggest that any Yellow Perch entrainment at Wallace Dam may reach its highest levels in late winter or early spring.

- Monthly variation in the entrainment of suckers (catostomids) at sites in South Carolina suggests that sucker entrainment at Wallace Dam may be highest in the spring. Entrainment of minnows (cyprinids) likely occurs throughout the spring and summer, and catfish entrainment may be most prevalent between spring and early fall.

7.3.4 Pumpback Operations

Fish were more likely to be entrained during pumpback than generation at the Richard B. Russell and Jocassee pumped storage sites (Table 14). Nestler et al. (1999) attributed higher entrainment during pumpback to more suitable habitat conditions in the tailrace, which was shallower, compared to the deep forebay of the upper reservoir during generation. Fish may also congregate in the tailrace during spawning or feeding and become susceptible to entrainment upon start-up of pumpback operations. The vast majority of entrained fish at Richard B. Russell during pumpback and generation were Threadfin Shad and Blueback Herring.

Hydroacoustic sampling at the Jocassee site estimated that annual pumpback entrainment was about 2.7 times higher than generation entrainment (Table 14). Monthly entrainment rates during generation ranged from 26,586 fish in June to 61,780 fish in November (Duke Energy, 2014). Monthly pumpback entrainment exhibited much more pronounced seasonal variation, ranging from 14,489 fish in February to 346,820 fish in July.

7.4 Potential Mortality at Wallace Dam

The results of turbine passage mortality (or survival) studies conducted at other hydroelectric sites indicate that the mostly small fish entrained by the Wallace Dam Project are likely to incur low rates of injury and mortality.

Important considerations in reviewing turbine passage mortality (or survival) tests are the size distribution of entrained fish and the controls used to distinguish mortality related to turbine passage from mortality related to handling and recapture stress of test fish (EPRI, 1992, 1997b). Small or YOY fish generally comprise a large proportion of naturally entrained fish. The probability of an entrained fish being struck by a turbine blade is a function of the length of the fish, as well as the number of runner buckets/blades, turbine speed, cross-sectional area of water passage, blade angle, and discharge (Von Raben, 1957, as given by Cada). Thus, smaller fish generally suffer lower levels of mortality from blade strikes, and also are less prone to injury resulting from shear stresses and rapid pressure changes (Cada, 1990). However, many mortality studies have necessarily used larger, introduced test fish than the average size fish naturally entrained because larger fish better tolerate cumulative stress of transport, handling, and recapture, which may confound estimated mortality resulting from turbine passage (EPRI, 1992). Therefore, some consideration of these factors is important in applying common trends from the mortality studies reviewed below.

Indirect mortality of fish resulting from sublethal injuries or disorientation incurred during turbine passage also was considered in the following analysis and is described in further detail in Section 7.4.4.

7.4.1 Francis Turbines

Survival of fish passing through turbine types with larger water passages, such as Kaplan, Francis, and bulb turbines, commonly exceeds 70 percent (Cada and Rinehart, 2000). Mortality studies conducted with resident fishes using adequate methods to control for handling stress and recapture injury typically have shown low fish mortality rates for low-head Francis turbines, as low as 1 to 2 percent and averaging about 6 percent (EPRI, 1992). For instance, at the Stevens Creek site on the Savannah River, which has vertical Francis turbines operating at 28 ft of head, RMC Environmental Services, Inc. (RMC, 1994) estimated latent turbine mortality (48 hours after passage) of 4.6 percent for resident sunfish (Bluegill, Redear Sunfish, Warmouth, and Redbreast Sunfish), 4.2 percent for resident Spotted Sucker and Yellow Perch, and 5.7 percent for Blueback Herring, which was used as a surrogate for American Shad. Other studies using adequate scientific control methods have documented similarly low mortality rates at a number of other sites using Francis turbines (e.g., RMC, 1992, 1993; Normandeau Associates, Inc., 1994).

Eicher Associates, Inc. (1987; as summarized by EPRI, 1992) examined data from 22 studies of salmonid (trout and salmon) mortality at Francis turbines operating at heads ranging from 40 ft to over 400 ft and found mortality to be positively correlated with both head and peripheral runner velocity. Salmonid species do not occur in the Oconee River basin, and they tend to be more sensitive than many warm-water fish species to injury and stress from turbine passage. For this reason, they may be a conservatively high predictor of potential mortality at Wallace Dam. The correlation between head and mortality of salmonids for Francis turbines, as plotted by EPRI (1992), predicts turbine-induced mortalities on the order of 16 percent at a rated head of 89 ft (rated net head at Wallace Dam). The relationship between peripheral runner velocity and mortality of salmonids predicts mortalities on the order of 30 percent at a peripheral runner velocity of 95 fps (Table 12).

Table 19 summarizes turbine passage survival estimates compiled by EPRI (1997a) for 12 hydroelectric sites in the eastern U.S. bracketing a similar range of head and Francis turbine characteristics as the four reversible Francis units at the Wallace Dam Project (Table 12). The studies at these sites used paired releases of treatment and control fish, and tag and recapture methods. Treatment fish were marked and introduced into the turbine penstock or intake and recaptured in the tailrace. Control fish were marked and released either into the draft tube or tailrace discharge and recaptured in the tailrace. Fish were recaptured using full-flow tailrace netting or dipnetting if fish were marked with self-inflating balloon tags. Fish were held for up to 48 hours after recapture to estimate latent survival; however, because of highly variable survival of control fish for many tests, only estimates of immediate turbine passage survival are presented in Table 19. High rates of control fish mortality diminish the reliability of test results for distinguishing fish mortality caused by turbine passage from that caused by the cumulative effects of stress from handling and recapture techniques (EPRI, 1992, 1997b).

Therefore, following the guidance of EPRI (1997a), test results for which control fish mortality exceeded 10 percent were excluded from 19.

Turbine passage survival estimates at the 12 studied sites with Francis turbines were highest for smaller size classes of fish and for turbines with rotational speeds less than 300 rpm (Table 19). Immediate survival rates averaged 85 percent for small fish (< 6 inches), 74 percent for moderate-sized fish (maximum size of test group > 6 inches and < 10 inches), and 62 percent for large fish (maximum size of test group > 10 inches). Survival rates were highest for the smallest size class tested at 9 of the 12 sites. Survival rates of the smallest size class tested averaged over 90 percent at 6 sites. Turbine speed at these 6 sites ranged from 90 to 257 rpm (Francis turbine speed at Wallace Dam is 86 rpm), and rated head varied from 42 to 100 ft. Turbine passage survival of Bluegill and catfish species at Ninety-Nine Islands, with a turbine speed of 225 rpm and rated head of 74 ft, averaged 97 percent and higher for all sizes of fish tested. Four other sites (Alcona, Finch Pruyn, E. J. West, and Hardy) showed average survival rates of over 80 percent for all size classes tested.

The lowest average survival rates of small fish were observed at High Falls (79 percent) and Hoist (46 percent), which had the highest turbine rotational speeds of all sites tested (Table 19). Turbine speeds at High Falls and Hoist were about 360 rpm, or about 4 times faster than the Francis turbines in use at Wallace Dam (86 rpm). Rated head at Hoist (142 ft) was higher than that at Wallace Dam (89 ft). The Hardy site also operated at a relatively high head of 100 ft but, in contrast to the Hoist site, showed average small fish survival of 91 percent and overall survival of about 89 percent for all size classes tested (Table 19). Turbine speed at Hardy (164 rpm) was less than half that at High Falls and Hoist, yet was about 2 times faster than that at Wallace Dam (86 rpm). Moreover, rated turbine flow and turbine diameter characteristics indicate that the Hardy turbine likely had larger passage routes than the High Falls turbine, increasing the probability that an entrained fish could avoid direct strikes and collisions with structures within the turbine system. Rated flow for the Francis turbines at Wallace Dam (Table 12) is even higher than that at the Hardy site (about 5.5 times greater for generation and 4.5 times greater for pumpback). These comparisons suggest that fish survival rates at Wallace Dam could be even higher than those reported at Hardy for the same size fish because of slower turbine speed and larger passage routes through the turbines, reducing the probability of direct strikes and collisions.

Turbine passage survival estimates were more variable for larger fish tested (Table 19). Immediate survival of large fish exceeded 80 percent at 5 of the 12 sites. Turbine speed at these five sites varied from 90 to 225 rpm, and head ranged from 43 to 100 ft. Survival of large fish at the Hardy site, with its relatively high-flow, low-speed turbine, averaged 85 percent. Survival was considerably lower for large fish tested at the higher speed turbines. Large fish survival averaged only 13 and 23 percent at the High Falls and Hoist sites, respectively. Hoist showed the lowest survival rates across all size classes tested, and it had both the highest turbine speed and highest head.

Turbine passage survival rates generally were similar between species within the same size class, especially within the small size class (Table 19). Winchell et al. (2000) reviewed the entire EPRI (1997a) turbine survival database and found no substantial differences in survival between species. At the 12 sites considered in Table 19, perches averaged the highest survival in the small (92 percent) and large (91 percent) size classes. Minnows averaged the highest survival rate in the moderate size class (93 percent), but the sample size of test groups was small. Species of trout and salmon (Salmonidae) averaged the lowest survival (78 percent) in the small size class, and either suckers or test groups containing suckers averaged the lowest survival in the moderate (64 percent) and large (39 percent) size classes.

Fish less than 6 inches long likely comprise the majority of entrained fish at Wallace Dam (see Section 7.3.1), and the survival of these small fish is likely to be quite high. The probability that juveniles entrained by Francis turbines will be struck by a blade or collide with other parts in the system is much lower than for larger fish. Based on the studies summarized in Table 19, average immediate survival of small fish may range between 81 and 97 percent. The High Falls and Hoist sites were excluded from this synopsis because their Francis turbines operate at much higher rotational speeds than the Wallace Dam Francis units, and the High Falls site has a much lower rated flow capacity. The median average survival rate of small fish, excluding High Falls and Hoist, was about 91 percent (i.e., median average mortality rate of about 9 percent).

Survival of moderate-sized and large fish at Wallace Dam likely depends more upon turbine characteristics affecting the size of clearances and passageways through the turbine system, such as rated flow, runner diameter, peripheral runner velocity, and number of blades. In turn, these factors influence the probability of injury due to blade strikes and collisions, rapid pressure changes, and hydraulic shear forces as larger entrained fish pass through the system. The survival estimates in Table 19 indicate that average immediate survival may range between 58 and 100 percent for moderate-sized fish, and between 39 and 98 percent for large fish. These ranges exclude High Falls and Hoist as non-representative of the Wallace Dam units because of their very high turbine speeds, and in the case of High Falls, its low rated flow capacity. The Prickett site also was excluded because its rated flow is much lower than that of the Wallace Dam units. Median average survival rates, excluding High Falls, Hoist, and Prickett, were about 85 and 83 percent for moderated-sized and large fish, respectively. These rates correspond to median average mortality rates of about 15 percent for moderate-sized fish and about 17 percent for large fish.

The wider ranges of average survival observed for moderate-sized and large fish at studied sites (Table 19) suggest that larger fish survival may be more variable than that for small fish at the Wallace Dam Project. Compared to the studied sites, the Wallace Dam turbines tend to operate toward the upper range of rated head, the lower range of turbine speed, the upper range of rated flow, and the upper range of runner diameter (see also Tables 12 and 19). Hence, survival rates of moderate-sized and large fish at Wallace Dam may tend toward the middle-to-upper end of the ranges of average survival observed at the studied sites because of the larger passage routes through the units. Moderate-sized and large fish likely comprise a small proportion of total entrainment at Wallace Dam compared to small fish.

7.4.2 Modified Propeller Turbines

Wallace Dam Units 3 and 4 use modified propeller turbines (Table 12), which are similar in their overall design characteristics to Kaplan turbines. Kaplan turbines are propeller-type turbines having adjustable blades that can be pivoted on the runner hub to maintain efficiency under different flow rates and flow angles. Because modified propeller turbines are similar in their overall axial-flow configuration to Kaplan units, the following analysis considers turbine passage survival studies of both Kaplan and fixed blade propeller turbines from the EPRI (1997a) database.

The mortality of fish passing through Kaplan and propeller turbines tends to be lower than that for Francis turbines, perhaps related in part to the tendency for Kaplan and propeller turbines to be used for larger units with lower head, larger hydraulic capacity, and lower rotational speeds (EPRI, 1992). Kaplan and propeller turbines also typically contain fewer blades than Francis turbines, and therefore, tend to provide larger passage routes for entrained fish, thereby reducing the probability of direct blade strikes or collisions with turbine parts. Eicher and Associates, Inc. (1987) reviewed 19 entrainment mortality studies conducted at sites with Kaplan turbines and, unlike Francis turbines, found no relationship between mortality and operating head or peripheral runner velocity.

Table 20 summarizes turbine passage survival estimates compiled by EPRI (1997a) for 19 turbines at 14 hydroelectric sites in the U.S. using Kaplan/propeller turbines. All of the tests at sites with Kaplan or propeller turbines in the EPRI (1997a) turbine entrainment survival database are summarized in Table 20 because of the lack of association between mortality and head or peripheral runner velocity. The studies used paired releases of treatment and control fish, and tag and recapture methods, as described above for the survival tests at Francis turbines. Because of highly variable survival of control fish used in latent survival tests, only estimates of immediate turbine passage survival are presented. Following the guidance of EPRI (1997a), test results for which control fish mortality exceeded 10 percent were excluded, with the exception of test results for American Shad and Blueback Herring. Test results based on control survival rates of 75 percent and higher were included for American shad and Blueback Herring because WRD has begun stocking American Shad in Lake Oconee (Table 5), Blueback Herring is closely related to American Shad and can be considered a surrogate, and the availability of test results for these species would otherwise be limited.

Compared to the 19 studied units in Table 20, the Wallace Dam modified propeller turbines operate toward the upper end of the range with respect to rated head, runner diameter, and peripheral runner velocity; the middle of the range with respect to rated flow; and the lower end of the range with respect to turbine rotational speed (Table 12). The Wallace Dam modified propeller units are most similar in size, hydraulic capacity, and rotational speed to units at the Safe Harbor, Rocky Reach, and Conowingo sites.

Turbine passage survival at the 14 studied sites with Kaplan and fixed blade propeller turbines was consistently high and similar for small and moderate-sized fish (Table 20). Immediate survival averaged 95 percent for both small fish ($\leq$ 6 inches) and moderate-sized fish (maximum size of test group > 6 inches and $\leq$ 10 inches), corresponding with average mortality of 5 percent. Average survival at individual sites ranged from 93 to 99 percent for small fish, and 86 to 100 percent for moderate-sized fish. Survival rates at Safe Harbor, Rocky Reach, and Conowingo, the sites having turbine characteristics similar to Wallace Dam, averaged 93 to 97 percent for small fish (juvenile Chinook salmon and American shad), and 96 percent for moderate-sized fish (Chinook salmon).

Immediate survival of large fish (maximum size of test group > 10 inches) averaged 88 percent, corresponding with average mortality of 12 percent. Survival estimates between individual sites were somewhat more variable, ranging from 77 to 100 percent at the three sites where large fish were tested, but the sample size at two of the sites consisted of only a single test result. Seventeen test results for large fish at the Herrings site averaged 88 percent survival. Large fish survival was lowest at Buzzard's Roost (77 percent), which had the highest turbine speed of the three turbines tested using large fish (Table 20).

Modified propeller turbine speed at Wallace Dam (120 rpm) is slightly lower than two of the tested sites (Townsend Dam and Herrings), and half that at Buzzard's Roost (Table 20). Moreover, the rated flow capacity of the Wallace Dam units is about seven times greater than that at Herrings and Buzzard's Roost, and four times greater than that at Townsend Dam. The slower rotational speed and larger rated flow of the Wallace Dam units generally indicate a lower probability of blade strikes and collisions than at the other sites. These comparisons suggest that immediate turbine passage survival of large fish at the Wallace Dam modified propeller units may exceed 88 percent.

Turbine passage survival rates for Kaplan and propeller turbines were similar between species within the same size class (Table 20). Many of the tests were conducted specifically for out-migrating juvenile salmonids, which tend to be relatively sensitive to injury from turbine passage compared to many warmwater species. Species of trout and salmon averaged 90 to 95 percent survival across all three size classes.

A retrospective analysis of 25 years of juvenile salmonid mortality studies conducted in the Snake-Columbia River basin revealed that turbine passage survival (including both direct and indirect effects) through Kaplan turbines averaged 87.3 percent with a 95 percent confidence interval of 85.6 to 89.0 percent (Bickford and Skalski, 2000). Direct (i.e., immediate) mortality estimated from nine balloon-tag replicate releases was 93.3 percent with a 95 percent confidence interval of 92.5 to 94.1 percent (Bickford and Skalski, 2000). Although salmonids do not occur in Lake Oconee or the Oconee River, these findings provide a conservative indication of potential survival of juvenile warmwater fishes entrained through the two modified propeller turbines at the Wallace Dam Project.

Several tests in the EPRI (1997a) database were conducted with juvenile American Shad (Hadley Falls, Safe Harbor, and Conowingo) to assess their vulnerability to turbine passage during out-migration (Table 20). Average immediate survival of juvenile American Shad less than 6 inches long was 96 percent, which was similar to that observed for salmonids at other studied sites. Immediate survival of other clupeids tested at the Herrings site (Alewife) and Crescent site (Blueback Herring) averaged 94 percent.

Potential turbine passage survival of resident fishes at the two propeller units at Wallace Dam is likely to be higher on average than that for the four Francis turbine units. Based on the common trends revealed by the EPRI database and other studies reviewed herein, reasonably conservative estimates of potential immediate mortality of entrained resident fish at the Wallace Dam propeller units may average in the range of 4 to 7 percent for small and moderate-sized fish, and up to 12 percent for large fish.

7.4.3 Latent Mortality

Latent survival estimates from the EPRI (1997a) turbine passage survival database are not presented herein because of the highly variable survival of control fish for many of the tests. High rates of control mortality not only reduce the reliability of test results but indicate the effects of cumulative stress (of transport, marking, introduction, turbine passage, recapture, and holding) that could exaggerate the mortality of test fish even after adjustment for control mortality (EPRI, 1992). Small fish and species sensitive to handling, such as clupeids, tend to be most susceptible to mortality from cumulative stress effects. For instance, Heisey et al. (1992) observed high mortality of both test and control fish in latent survival tests of juvenile American Shad caused by natural, rapid lowering of water temperatures from 22.5 to 9.0°C during the holding period. In their tests with high control survival, the 48-hour survival of test fish was 98 to 100 percent.

Rates of control survival less than 90 percent generally indicate levels of experimental stress that can lead to unreliable survival estimates (EPRI, 1997b). Winchell et al. (2000) summarized latent survival observed 48 hours after turbine passage from the EPRI (1997a) database, after excluding tests in which control fish survival was less than 90 percent (i.e., control mortality greater than 10 percent). They observed that 48-hour latent survival generally was about 3 to 4 percent lower than immediate survival for the combinations of fish size and turbine type where immediate survival was relatively high. Greater reductions tended to occur for turbines and fish sizes showing lower rates of immediate survival.

Of the turbine passage studies examined herein from the EPRI database, 8 of the 12 sites with Francis turbines (Table 19) and 10 of the 14 sites with Kaplan/propeller turbines (Table 20) included 48-hour latent survival tests with control survival exceeding 90 percent (EPRI, 1997a). For the Francis turbines, survival over the 48-hour holding period averaged 4.4 percent lower than the immediate survival (N=104) across all size classes of fish tested. For the Kaplan/propeller turbines, 48-hour survival averaged 2.9 percent lower than immediate survival (N=59).

7.4.4 Indirect Mortality

Little is known about the indirect mortality of entrained fish that may ultimately result from sublethal levels of injury, loss of equilibrium, or disorientation incurred during turbine passage (Cada and Rinehart, 2000). These stresses, although not immediately lethal, may make entrained fish more susceptible to predators in the tailwaters below the dam, at least temporarily, or disable them such that they are later more susceptible to disease (Cada, 2001). Indirect mortality may be increased by sub-optimal water temperatures, low DO concentrations, or other water quality factors (Cada et al., 1997). Although indirect mortality has not been rigorously studied in the field (Cada and Rinehart, 2000), laboratory experiments have determined that sublethal shear stress can reduce the ability of juvenile rainbow trout to avoid being eaten by predatory fish (Nietzel et al., 2000).

Bickford and Skalski (2000) suggested that the 6 percent difference they observed between independent estimates of immediate turbine passage survival (average of 93.3 percent) and longer-term turbine passage survival (average of 87.3 percent) for salmonid smolts in the Snake-Columbia River may have been due to subacute or chronic (i.e., indirect) mortality associated with turbine passage.

The short-term survival rates estimated by turbine passage studies are likely to overestimate longer-term survival to some degree, but the amount and significance of additional indirect mortality are presently unknown (Cada, 2001). At the Wallace Dam Project, one of the most immediate sources of indirect mortality to fish surviving turbine passage is likely to be predation by larger sport-fishes, such as Striped Bass, Hybrid Bass, Largemouth Bass, and Blue Catfish, in the tailrace area.

7.5 <u>Potential Implications to Striped Bass and Hybrid Bass Management</u>

Lake Oconee is managed as a Striped Bass and Hybrid Bass fishery, with stocking in recent years shifting to a greater proportion of Hybrid Bass. The populations of Striped Bass and Hybrid Bass in Lake Oconee are sustained through stocking; there is no evidence of successful Striped Bass reproduction in the area. Since 2013, annual stocking rates have averaged 291,543 fingerlings of Hybrid Bass and 97,444 fingerlings of Striped Bass, an approximately 3 to 1 ratio (Table 5). GDNR has expressed interest in Striped Bass and Hybrid Bass regarding turbine passage because of their migratory behavior.

Three species of temperate basses, including Striped Bass, were represented in entrainment samples at five of the eastern U.S. sites in the EPRI (1997a) database (Table 21). White Bass (*Morone chrysops*) and White Perch (*Morone americana*) were considered surrogates for Striped Bass because (1) Striped Bass were represented in entrainment samples at only three sites and (2) these species share behaviors of schooling in open waters and migrating upstream to spawn (Etnier and Starnes, 1993). Schools of Striped Bass and White Bass often follow and attack schools of forage fish, such as Threadfin Shad, and may be similarly vulnerable to entrainment when their pursuit of forage fishes takes them near the dam. All three species are classified in the same genus and thus are considered to be closely related.

The wide size range of entrained Striped Bass and closely related *Morone* species indicates the potential vulnerability of all life stages of Striped Bass to some entrainment, but the numbers of entrained fish were quite small (Table 17). FERC (1995a) surmised that the prevalence of larger Striped Bass in entrainment samples at Buzzard's Roost may have resulted from their limnetic schooling behavior and foraging among large schools of cold-stressed threadfin shad drifting near the intakes.

The high proportion of small temperate basses (<6 inches) entrained at several sites (Table 21) suggests the potential vulnerability of stocked striped bass fingerlings to entrainment at the Wallace Dam Project. However, turbine passage survival estimates of 92.3 percent for small (<6 inches) white perch at Buzzard's Roost (EPRI, 1997a) suggest that immediate survival of small juvenile Striped Bass and Hybrid Bass entrained at Wallace Dam may be on the order of 90 percent.

In summary, stocked fingerlings and small juveniles may be the size classes of Striped Bass and Hybrid Bass most susceptible to entrainment at Wallace Dam during generation because fingerlings are stocked annually at a rate of about 20 total fish per acre in Lake Oconee (Table 5). These young fish are likely to school in open waters and may exhibit downstream migratory behavior as juveniles. They become vulnerable to entrainment as they approach the dam; however, because of their small body size, the vast majority would be expected to survive turbine passage. Adult Striped Bass and Hybrid Bass, while large and potentially subject to higher turbine mortality rates if entrained, are facultative in their downstream migratory behavior and may not be as strongly inclined to migrate downstream, as evidenced by low numbers of Striped Bass in entrainment samples at other sites. In addition, adult Striped Bass have strong swimming capabilities and would be much more capable of escaping intake velocities. Furthermore, the Striped Bass habitat analysis in Section 6.0 indicates that summer habitat conditions are sub-optimal for adult fish, especially in the lower end of the reservoir near the dam. By late August in most years, water temperatures throughout the water column of the forebay become unsuitably warm for Striped Bass.

Adult Striped Bass and Hybrid Bass congregating in the Wallace Dam tailrace area in the spring may be susceptible to entrainment upon the start-up of pumpback operations, but these larger fish are more capable of escaping the intake velocities.

7.6 Discussion

Common trends and data from other studied hydroelectric sites, including several in Atlantic Coast drainages of South Carolina and Georgia, indicate that small and/or YOY fish likely comprise the majority of fish entrained by the Wallace Dam Project. Entrainment is likely to be numerically dominated by species of sunfishes, shads, perch, suckers, catfishes, minnows, and a few other species. Peak entrainment rates likely occur in spring and summer for most species, when young fish are most abundant and tend to be dispersing between habitats. Entrainment rates for Threadfin Shad and Gizzard Shad may increase into fall and winter. A substantial portion of entrainment likely consists of juvenile sport-fishes, including Bluegill, Black Crappie, Redbreast Sunfish, other sunfishes, catfishes, and Yellow Perch, but Largemouth Bass and Striped Bass probably represent relatively small proportions of sport-fish entrainment.

Entrainment studies from other pumped storage sites in South Carolina and Georgia indicate that more fish are likely to be entrained during pumpback operations than conventional generation at Wallace Dam because of the shallower depth and narrow width of the tailrace area and, thus, closer proximity of habitats used by fishes residing in the upper end of Lake Sinclair. In contrast, the open forebay and deep-water location of the intake in Lake Oconee is relatively distant from shoreline and littoral-zone habitats harboring smaller fish.

The vast majority of entrained fish, because of their small size, are likely to survive turbine passage. The mortality of these smaller fish is expected to be relatively low because they are less prone to mechanical injury from turbine passage than larger fish and less prone to injury resulting from shear stresses and rapid pressure changes (Cada, 1990). Trends in turbine passage survival at numerous studied hydroelectric sites with Francis turbines predict average immediate survival on the order of 91 percent for small fish and 83 to 85 percent for moderate-sized and large fish at the Wallace Dam Francis turbines (Units 1, 2, 5, and 6). Immediate turbine passage survival is likely to be somewhat higher for the Wallace Dam modified propeller turbines (Units 3 and 4), on the order of 95 percent for small and moderate-sized fish and 88 percent for large fish.

Entrainment losses of young fish, which typically exhibit high rates of natural mortality due to density-dependent factors (e.g., limited habitat space or food), may tend to be offset by increased survival of the young fish remaining in the reservoir due to reduced competition for limiting resources. Density-dependence is a fundamental concept in the study of fish population dynamics (Rose and Cowan, 2001). Compensatory density-dependence operates to offset the loss of individuals in populations, allowing populations to persist under conditions of increased mortality. Increased mortality in fish populations may occur from natural causes (food availability, predation, disease, etc.) or from anthropogenic activities, such as fishing, introductions of non-native species (e.g., Blue Catfish), or power plant operations. Compensatory density-dependence, which is a major underlying assumption in the management of fish populations, may be an important factor in offsetting losses of young fish to entrainment mortality, especially since most entrained fish are young, survive turbine passage, and otherwise experience high natural mortality rates.

The fact that entrainment occurs does not necessarily equate with high potential for adverse impacts of entrainment to resident fish populations. Entrainment may be higher at some sites simply because the resident fish populations are healthy and produce high relative abundance of juvenile fish that may become vulnerable to entrainment as they disperse between habitats or approach the dam. Lake Oconee supports a relatively diverse mix of naturally reproducing sport fishes, including Largemouth Bass, Black Crappie, Channel Catfish, Bluegill, Redear Sunfish, Redbreast Sunfish, and Yellow Perch. Overall, the reservoir supports a healthy fishery and exhibits an ecologically balanced community structure. Existing fisheries information does not provide any evidence suggesting that current levels of fish entrainment and turbine mortality may be resulting in significant adverse impacts to the fish community of the Oconee River, to the extent such effects may be reflected in the species richness of the fish community or in the condition, balance, or stability of populations. Thus, continued operation of the Wallace Dam Project is likely to result in only minor effects to fish populations and recreational fishing opportunities as a result of fish entrainment and turbine-induced mortality.

8.0 SUMMARY

8.1 Shoreline Habitat Survey

Georgia Power conducted a shoreline reconnaissance survey of Lake Oconee and the Wallace Dam tailrace area in June 2016 which qualitatively characterized shoreline aquatic habitat and available sources of littoral-zone cover for fish to 50 feet from the shoreline. A total of 140 representative sites on Lake Oconee and 6 sites in the tailrace were surveyed.

The most frequently observed sources of littoral-zone fish cover across the study area were overhanging vegetation, docks and piers, riprap, emergent vegetation, and large woody debris. Based on estimated proportional length of coverage of shoreline sites, riprap was the predominant source of fish cover, followed by overhanging vegetation and docks and piers. Riprap was most prevalent in the lower reservoir, middle reservoir, and Richland Creek sections of Lake Oconee, where residential and resort development are widespread and riprap is commonly used to stabilize shorelines. Overhanging vegetation was the predominant cover type in the less developed upper reservoir section.

8.2 Rare, Threatened, and Endangered Aquatic Species

The occurrence and distribution of four rare, threatened, and endangered aquatic species were assessed by reviewing existing sources of information and data. The findings included:

- Altamaha Shiner – this state threatened species has been reported from seven tributary watersheds upstream of Lake Oconee but has not been documented in Lake Oconee.

- Robust Redhorse – this state endangered sucker inhabits the Oconee River downstream of Sinclair Dam and a tributary of Lake Sinclair but recent routine electrofishing status surveys did not collect the species in rivers upstream of Wallace Dam, nor were any detected in focused searches in the Wallace Dam tailrace.

- Inflated Floater – although not listed as federal or state protected, this freshwater mussel previously was petitioned for federal listing and has since been withdrawn. Mussel surveys in 2016 found this species in both Lake Oconee and the tailrace area.

- Altamaha Arcmussel – a state threatened species known primarily from the Coastal Plain, there are no known records from project waters and it was not found during mussel surveys of Lake Oconee and the tailrace area in 2016.

8.3 Freshwater Mussel Survey

Two freshwater mussel surveys were conducted in summer 2016 in Lake Oconee and the Wallace Dam tailrace area. The surveys used an occupancy-based survey design developed by the Georgia Department of Natural Resources (GDNR) and included the techniques of visual observations while wading, hand grubbing, snorkeling, self-contained underwater breathing apparatus, and surface-supplied air. The surveys documented the occurrence of four native freshwater mussel species within the project boundary, none of which are listed as federally or state protected, including: Altamaha Slabshell, Inflated Floater, Paper Pondshell, and Variable Spike. All four species were found in both Lake Oconee and the tailrace area.

8.4 Summer Habitat for Sport Fish Species

The availability of suitable summer habitat for sport fish species in Lake Oconee, including Largemouth Bass and Striped Bass, was assessed using reservoir water quality data collected by Georgia Power, standardized fisheries survey data collected by GDNR, and temperature and dissolved oxygen (DO) preference criteria reported in the scientific literature. The analysis focused on the spatial and temporal extent of mixing that occurs in Lake Oconee as a result of summer pumpback and generation operations.

Most sport fish species residing in Lake Oconee are capable of tolerating seasonally high water temperatures and occasionally lower DO levels in summer. GDNR standardized fishery survey data for Lake Oconee indicate an overall healthy and balanced fish community typical of southeastern Piedmont reservoirs. Recent and historic water quality monitoring data show that although pumpback operations cause mixing of the entire water column of the lower mainstem reservoir by August, water temperature and DO conditions remain within acceptable ranges for most of the resident sport fish species.

Based on the documented temperature and DO tolerances of Largemouth Bass, the water quality monitoring data show that summer water quality conditions in Lake Oconee support the survival and growth of Largemouth Bass. The catch rates, relative condition, and length-frequency distribution of Largemouth Bass in Lake Oconee indicate the presence of an overall healthy population. In addition, the weight characteristics of tournament bass caught in Lake Oconee compare favorably to other Georgia reservoirs.

Summer temperature profiles for Lake Oconee sufficiently explain the limiting nature of habitat suitability for Striped Bass, as reflected in low catch rates and low relative condition of the population. Summer water temperatures exceeding 29°C throughout the reservoir in many summers is likely the principal factor limiting survival and growth of the population. Recent and historic water quality sampling do not show widespread summer low-DO conditions in Lake Oconee. Although suitable DO conditions were available throughout much of the reservoir, by late July and August, temperatures were often higher than temperature criteria defining suitable adult Striped Bass habitat. Thus, available evidence indicates that it is naturally high water temperatures, and not low DO concentrations that limit the availability of suitable summer habitat for Striped Bass in Lake Oconee.

A variety of warmwater sport fish species typical of southeastern reservoirs likely use Wallace Dam tailrace habitats during the summer, especially in response to changing flow conditions with pumpback and generation cycles. Continuous tailrace monitoring data indicate that the tailrace is unlikely to provide suitable adult Striped Bass habitat for much of the summer due to water temperatures exceeding 29°C. However, resident fishes in upper Lake Sinclair, many of which are habitat-generalist species, are likely to use tailrace habitats in the summer despite daily DO depressions in parts of June, July, and early August. The tailrace mussel survey in August 2016 found four native species of mussels, with the greatest numbers occurring a short distance downstream of the powerhouse. Thus, the tailrace area supports self-sustaining populations of aquatic species representative of a balanced community.

8.5 Fish Entrainment

Common trends and data from other studied hydroelectric sites, including several in South Carolina and Georgia and two pumped storage projects, indicate that small and/or young-of-year fish likely comprise the majority of fish entrained by the Wallace Dam Project. Entrainment is likely to be numerically dominated by species of sunfishes, shads, perch, suckers, catfishes, and minnows. Peak entrainment rates likely occur in the spring and summer for most species, when young fish are most abundant and tend to be dispersing between habitats, but entrainment rates for shad may peak in the fall and winter. More fish are likely to be entrained during pumpback operations than conventional generation because of the shallower depth and narrower width of the tailrace, closer proximity of shallow-water habitats, and the seasonal behavior of some fish, such as Striped Bass and Hybrid Bass, to congregate in the tailrace. In contrast, the open forebay and deep-water location of the Lake Oconee intake is relatively distant from shoreline and littoral-zone habitats.

The vast majority of entrained fish are small and likely to survive turbine passage. Trends in turbine passage survival studies at numerous hydroelectric sites predict average immediate survival rates at Wallace Dam in the range of 91 to 95 percent for small fish and 83 to 88 percent for moderate-sized and large fish, depending on the unit type. Overall, Lake Oconee supports a healthy fishery and evidence is lacking to suggest that current levels of fish entrainment and turbine mortality may be adversely affecting the fish community of the Oconee River. Continued operation of the Wallace Dam Project is likely to result in only minor impacts to fish populations and recreational fishing opportunities as a result of fish entrainment and turbine-induced mortality.

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TABLES

TABLE 1

Littoral-zone Fish Cover by Lake Oconee Section and Tailrace Area

Study Area Section	Docks and Piers	Riprap	Bedrock and Boulders	Emergent Vegetation	Submersed Vegetation	Overhanging Vegetation	Large Woody Debris	Standing Timber
Frequency of Occurrence (Percent): [a]								
Lower Reservoir (LR)	66	60	3	29	0	51	17	3
Middle Reservoir (MR)	57	40	0	6	0	63	23	11
Upper Reservoir (UR)	40	31	6	31	3	80	31	3
Richland Creek (RC)	43	49	14	26	0	54	17	6
Tailrace (TR)	0	50	33	17	0	67	33	0
Total (N=146)	**49**	**45**	**7**	**23**	**1**	**62**	**23**	**5**
Proportion of Shoreline Length Surveyed (Percent): [b]								
Lower Reservoir (LR)	17	46	0	7	0	11	3	3
Middle Reservoir (MR)	10	27	0	1	0	20	2	6
Upper Reservoir (UR)	8	14	1	6	<1	42	8	3
Richland Creek (RC)	10	31	2	7	0	14	2	3
Tailrace (TR)	0	47	27	15	0	57	3	0
Total (73,000 ft)	**11**	**30**	**2**	**6**	**<1**	**23**	**4**	**3**

[a] Each reservoir section had 35 shoreline survey sites and the tailrace had 6 sites, for a total of 146 sites.

[b] The survey length of each reservoir section was 17,500 ft and the survey length in the tailrace was 3,000 ft, for a total survey length of 73,000 ft.

TABLE 2

Littoral-zone Fish Cover by Shoreline Vegetative Buffer Zone Condition

Shoreline Vegetative Buffer Zone Condition[a]	Docks and Piers	Riprap	Bedrock and Boulders	Emergent Vegetation	Submersed Vegetation	Overhanging Vegetation	Large Woody Debris	Standing Timber
Frequency of Occurrence (Percent):								
Natural (N=65)	9	14	12	18	0	92	45	12
Landscaped-Natural (N=39)	90	67	3	26	3	49	8	0
Landscaped (N=42)	74	74	2	26	0	29	2	0
Total (N= 146)	**49**	**45**	**7**	**23**	**1**	**62**	**23**	**5**
Proportion of Shoreline Length Surveyed (Percent):								
Natural (32,500 ft)	2	8	3	6	0	44	8	8
Landscaped-Natural (19,500 ft)	19	48	1	6	<1	10	1	0
Landscaped (21,000 ft)	17	49	1	5	0	4	<1	0
Total (73,000 ft)	**11**	**30**	**2**	**6**	**<1**	**23**	**4**	**3**

[a] Shoreline vegetative buffer zone condition definitions were as follows:

- Natural: heavily vegetated, less than 20 percent of natural vegetation removed.
- Landscaped-Natural: disturbed and cleared up to 50 percent; some trees and understory remaining.
- Landscaped: cleared of more than 50 percent natural vegetation or underbrush completely removed.

TABLE 3

Rare, Threatened, and Endangered Aquatic Species in the Oconee River in the Vicinity of the Wallace Dam Project[a]

Scientific Name	Common Name	Federal Status	Georgia Status[b]	Petitioned Status[c]	Habitat[d]	County
Alasmidonta arcula	Altamaha Arcmussel	None	**T**	Withdrawn	Sloughs, oxbows, or depositional areas in large creeks to large rivers below the Fall Line.	None in vicinity
Pyganodon gibbosa	Inflated Floater	None	None	Withdrawn	Rivers and backwater in soft substrates such as mud, silts, or fine sands.	Greene, Hancock, Putnam, Morgan
Cyprinella xaenura	Altamaha Shiner	None	**T**	Withdrawn	Medium-sized to large streams in runs or pools over sand to gravel substrate.	Greene, Morgan, Putnam
Etheostoma parvipinne	Goldstripe Darter	None	**R**	None	Small streams, spring seeps, and runs with aquatic vegetation; occurs below the Fall Line.	Hancock
Moxostoma robustum	Robust Redhorse	None	**E**	**Petitioned**	Medium to large rivers, shallow riffles to deep flowing water; moderately swift current.	Putnam
Moxostoma sp. 4	Brassy Jumprock	None	None	None	Silty to rocky pools and slow runs of large creeks and small to medium rivers, and impoundments.	Morgan, Hancock, Putnam

Sources:

[a] This list is for RTE aquatic species with known element of occurrence records in the Oconee River basin in Hancock, Greene, Morgan, or Putnam Counties, Georgia.

[b] Georgia state status: **E** = Georgia endangered; **T** = Georgia threatened; **R** = Georgia Rare; **U** = Georgia unusual.

[c] In April 2010, CBD and its allies petitioned FWS to list 404 southeastern species as endangered or threatened species under the Endangered Species Act. In December 2015, CBD withdrew 14 species from the petition in light of new information.

[d] Habitat descriptions from GDNR (2016a), NatureServe (2015).

TABLE 4

Summary of Freshwater Mussel Survey Results for Lake Oconee (July 2016) and the Wallace Dam Tailrace Area (August 2016)

Scientific Name	Common Name	Main Channel			Tributary Embayments/Coves			Total Number of Mussels
		Number of Live Mussels	Relative Abundance (Percent)	Frequency of Occurrence (Percent)[a]	Number of Live Mussels	Relative Abundance (Percent)	Frequency of Occurrence (Percent)[a]	
Lake Oconee:		**(N = 10 sites)**			**(N = 20 sites)**			
Elliptio hopetonensis	Altamaha Slabshell	207	86.3	60	45	39.1	50	252
Elliptio sp. cf. *icterina*	Variable Spike	2	0.8	20	1	0.9	5	3
Pyganodon gibbosa	Inflated Floater	17	7.1	40	49	42.6	85	66
Utterbackia imbecillis	Paper Pondshell	14	5.8	60	20	17.4	40	34
	Total	**240**			**115**			**355**
Wallace Dam Tailrace Area:		**(N = 9 sites)**			**(N = 2 sites)**			
Elliptio hopetonensis	Altamaha Slabshell	1,425	98.1	100	17	65.4	100	1,442
Elliptio sp. cf. *icterina*	Variable Spike	17	1.2	56	0	0.0	0	17
Pyganodon gibbosa	Inflated Floater	8	0.5	33	2	7.7	100	10
Utterbackia imbecillis	Paper Pondshell	3	0.2	33	7	26.9	100	10
	Total	**1,453**			**26**			**1,479**

Source: Dinkins (2016a, 2016b).

[a] Frequency of occurrence is the proportion of surveyed sites (N) where the species was found.

TABLE 5

Lake Oconee Fish Stocking Data, 2005-2016

	Striped Bass		Hybrid Bass		American Shad	
Year	**Number Stocked**	**Fish per Acre**	**Number Stocked**	**Fish per Acre**	**Number Stocked**	**Fish per Acre**
2005	190,000	10	192,871	10	--	--
2006	146,315	8	197,123	10	--	--
2007	298,526	16	64,456	3	--	--
2008	264,565	14	189,243	10	--	--
2009	119,800	6	191,737	10	--	--
2010	150,033	8	165,375	9	--	--
2011	194,493	10	194,822	10	--	--
2012	32,250	2	174,265	9	--	--
2013	96,900	5	310,413	16	--	--
2014	97,560	5	268,422	14	--	--
2015	97,589	5	292,426	15	945,757	49
2016	97,725	5	294,911	15	746,269	39
Total	**1,785,756**		**2,536,064**		**1,692,026**	
Average	**148,813**		**211,339**		**846,013**	

Source: GDNR (Nelson, 2014, 2016, personal communication).

TABLE 6

Bass Tournament Statistics for Lake Oconee, 1996-2014

Year	Number of Tournaments Analyzed	Number of Angler Hours	Bass Weighed-in/ Angler Hour	Lbs. Weighed-in/ Angler Hour	Average Bass Weight (lbs)	Average Largest Bass (lbs)	Percent Bass as Largemouth
1996	60	NA	0.134	0.261	1.98	4.03	99.3
1997	61	8,946	0.144	0.253	1.80	4.01	97.3
1998	64	8,602	0.112	0.207	1.95	3.51	96.4
1999	69	10,202	0.122	0.221	1.87	3.76	96.2
2000	64	8,742	0.169	0.295	1.76	3.60	98.0
2001	73	11,106	0.188	0.362	1.93	3.68	100.0
2002	96	12,443	0.184	0.393	2.08	3.72	96.4
2003	90	11,656	0.203	0.386	1.94	4.08	98.6
2004	95	12,930	0.200	0.394	2.01	4.36	97.9
2005	85	10,978	0.216	0.426	2.02	4.57	98.3
2006	82	10,283	0.203	0.391	1.93	4.01	97.7
2007	69	9,161	0.213	0.416	2.02	4.41	93.3
2008	68	7,774	0.241	0.443	1.88	4.20	97.3
2009	62	6,979	0.231	0.432	1.87	4.13	94.5
2010	46	5,486	0.198	0.390	1.99	3.89	93.4
2011	42	4,392	0.185	0.358	1.96	3.81	99.3
2012	33	3,721	0.230	0.459	1.99	4.56	96.0
2013	29	2,794	0.254	0.511	2.00	3.93	100.0
2014	28	2,724	0.274	0.563	2.08	4.64	98.8

Source: GBCF (1996-2014).

TABLE 7

Fish Species Collected from Mainstem, Tributary, and Upper Reservoir Locations by GDNR in 2015

Family/Common Name	Mainstem	Tributary	Upper Reservoir
HERRINGS AND SHADS:			
American Shad	X		
Gizzard Shad	X	X	X
Threadfin Shad[a]	X	X	
MINNOWS:			
Common Carp[a]		X	
NORTH AMERICAN CATFISHES:			
Blue Catfish[a]	X	X	X
Channel Catfish	X	X	X
Flathead Catfish[a]	X	X	X
TEMPERATE BASSES:			
White Bass[a]			X
Striped Bass	X	X	X
Hybrid Bass[a]	X	X	
SUNFISHES:			
Redbreast Sunfish	X	X	
Bluegill	X	X	X
Longear Sunfish[a]		X	X
Redear Sunfish	X	X	X
Black Crappie	X	X	X
Largemouth Bass	X	X	X
PERCHES:			
Yellow Perch[a]		X	
Total Taxa and Hybrid	13	15	11

Source: GDNR standardized fishery survey database.

[a] Introduced, non-native to the Altamaha River basin (Lee et al., 1980).

TABLE 8

Total Catch of Sport Fish Species of Interest via Electrofishing and Gillnetting by GDNR, 2011-2015

Year	Species					Total
	LMB	BCR	BLG	STB	WXS	
Electrofishing:						
2011	49%	25%	15%	0%	2%	91%
2012	79%	9%	7%	1%	0%	96%
2013	69%	19%	8%	0%	0%	96%
2014	60%	22%	11%	0%	0%	93%
2015	52%	15%	21%	0%	0%	88%
Gillnetting:						
2011	1%	22%	0%	1%	6%	30%
2012	1%	22%	0%	2%	1%	26%
2013	1%	20%	2%	1%	7%	31%
2014	1%	22%	1%	1%	4%	29%
2015	1%	17%	0%	4%	5%	27%

Source: GDNR standardized fishery survey database.

[a] LMB = Largemouth Bass; BCR = Black Crappie; BLG = Bluegill; STB = Striped Bass; WXS = Hybrid Bass.

TABLE 9

Analysis of Variance Table for Relative Condition Factors of Sport Fish Species in Lake Oconee

Source	Df	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Pr(>F)
Location	2	3.03	1.52	100.10	<0.0001	***
Species	4	17.42	4.36	287.54	<0.0001	***
Year	8	1.76	0.22	14.52	<0.0001	***
Location:Species	8	0.77	0.10	6.33	<0.0001	***
Residuals	7557	114.46	0.02			

TABLE 10
Habitat Use of Representative Sport Fish Species Residing in Lake Oconee

Family/Species	Adult Habitat	Spawning Requirements	Temperature Tolerance	Dissolved Oxygen Tolerance
Catfishes				
Channel Catfish (*Ictalurus punctatus*)	Deep pools of large streams, rivers, ponds, lakes, and reservoirs over a variety of substrates (1, 2).	Spawns May-July in nests in sheltered areas of rivers around piles of drift logs, undercut banks, or in cavities (1, 4). Eggs demersal and adhesive, guarded and fanned by parents; fry remain in nest for several days, protected by male (4).	Dependent on acclimation temperature and rate of change, but can be as high as 37.6–40.3°C (12, 15).	Critical levels range 0.95–1.08 mg/L depending on temperature (25–35°C) (9,12).
Blue Catfish (*Ictalurus furcatus*)	Open waters of large reservoirs and main channels, backwaters, and embayments of large rivers with mud or silt substrate (11)	Spawns April – June in similar habitat to Channel Catfish: cavity nests; protected areas behind rocks, rootwads, depressions, and undercuts (11). Eggs and fry are demersal and guarded male (11).	Can tolerate temperatures up to 40°C (14). Optimal temperature range for egg incubation is 25-27°C (14).	Adults become stressed at DO concentrations below 4.0 mg/L, but levels as low as 2.0 mg/L can be tolerated for short periods (14).
Temperate Basses				
Striped Bass (*Morone saxatilis*)	Anadromous, schooling; channels of large coastal rivers, lakes, impoundments, and connecting rivers; adults return to estuaries, ocean, or reservoirs after spawning; stocked into many reservoirs (1, 2).	Ascends freshwater coastal rivers or tributary rivers (of reservoirs); spawns March-early June in near-surface spawning aggregations; broadcast eggs in moderate to strong current over rapids and boulders (1, 3). Eggs semi-buoyant and non-adhesive, drifting downstream 2-3 days and requiring suspension above bottom to survive until hatching; streams must be of sufficient length to suspend eggs until hatching; larvae drift for several days (1, 3, 13).	Juveniles have a higher thermal tolerance than adults, around 29-32°C; Adults prefer temperatures near 25°C or less, and experience mortality near 28°C or greater (13).	Adults become stressed at 4.0 mg/L (13) and experience mortality at less than 2.0 mg/L (Coutant, 2013)
Hybrid Bass (*Morone saxatilis* x *Morone chrysops*)	Large open waters and reservoirs, slow moving streams, lakes and ponds. Seldom found in shallow areas with aquatic vegetation (20, 21).	Ohio Department of Natural Resources reports that Hybrid Bass cannot reproduce and populations are supported solely by stocking (21). However, Hodson (1989) reports that hybrids are fertile and spawning runs have been seen at temperatures 12-20°C (55-70°F) in mid-March through May, sometimes in clear, shallow rocky shoals 1-3 feet deep. Eggs are semi-buoyant and not adhesive, relying on turbulent flow until hatching (20).	Hybrid Bass do well in a range of environmental conditions. Hybrids are generally more tolerant of higher temperatures than Striped Bass (21). Hybrid Bass can survive a temperature range of 4-33°C (39-91°F), but optimal growth is between 25-27°C (77-81°F; 20).	Dissolved oxygen as low as 1.0 mg/L can be tolerated for short periods, but optimal levels range from 6.0-12.0 mg/L (20).

TABLE 10
Habitat Use of Representative Sport Fish Species Residing in Lake Oconee

Family/Species	Adult Habitat	Spawning Requirements	Temperature Tolerance	Dissolved Oxygen Tolerance
Sunfishes				
Bluegill (*Lepomis macrochirus*)	Pools and backwaters of creeks and small to large rivers, swamps, oxbows, and vegetated shores of all types of impoundments (1, 2).	Spawns May-August (peak generally in June) in nests constructed in shallow water on sand or gravel; frequently nests in colonies (1, 3). Eggs demersal and adhesive; male guards nest until fry leave and migrate from littoral to limnetic zone (1, 3, 4).	Dependent on acclimation temperature; but critical thermal maxima reported as low as 0.9°C and high as 37-40°C (15, 16).	Critical levels range 0.5–0.9 mg/L depending on temperature (25–35°C) (9, 17).
Redear Sunfish (*Lepomis microlophus*)	Clear, vegetated ponds, reservoirs, and lowland swamps; sluggish, vegetated pools of streams and rivers (1, 3, 5).	Spawns spring to mid-summer in nests in shallow water near vegetation on sand, mud, or gravel, often in colonies (1, 4, 5). Eggs demersal and adhesive; male guards nest until fry depart; fry occur in shallow water among submersed vegetation (5).	Critical thermal maxima reported at 34.1°C (15, 16).	Found in waters with moderate hypoxia 0.5-5.0 mg/L (17).
Largemouth Bass (*Micropterus salmoides*)	Clear, low-velocity waters of lakes, ponds, oxbows, reservoirs, and large streams and rivers; usually in association with vegetation, logs, stumps, or other cover (1, 4).	Spawns April-June in nests constructed on gravel or other firm substrates along margins of coves or quiet pools at depths of 0.3 to 0.6 m and sometimes greater (1, 4). Eggs demersal; male guards nest until fry depart; fry occur in calm water near flooded vegetation or other cover (1, 6).	Critical thermal maxima reported as low as 33.4 up to 40.1°C (15, 16).	Avoids water with DO concentrations around 2.0 mg/L (8, 10), but is not an absolute barrier (8). Critical levels range 0.92–1.40 mg/L depending on temperature (25–35°C) (9). Embryo development was and hatching survival at DO as low as 1.28 mg/L (19).
Black Crappie (*Pomoxis nigromaculatus*)	Clear backwater and pools of streams, reservoirs, ponds, oxbows, and lakes; often among vegetation, fallen trees, and stumps (1, 4).	Spawns late February-early May in nests constructed in shallow to moderately deep pools on sand or fine gravel, usually near vegetation (1, 4). Eggs demersal and adhesive; male guards nest until fry depart; fry move to nearby shallow, vegetated areas in calm water (4, 7).	Preferred temperatures likely around 23-32°C, with optimal growth at the upper end of the range (18).	Successful spawning and survival occurred as low as 2.5 mg/L; suitable levels assumed to be similar to other typical freshwater species such as LMB (18).

1 – Jenkins and Burkhead, 1993
2 – Rhode et al., 2009
3 – Marcy et al., 2005
4 – Boschung and Mayden, 2004
5 – Twomey, 1984
6 – Stuber et al., 1982
7 – Edwards et al., 1982
8 – Burleson et al., 2001
9 – Moss and Scott, 1961
10 – Brown et al., 2015
11 – Graham, 1999
12 – Tucker and Hargreaves, 2004*
13 – Crance ,1984
14 – Wyatt et al., 2006
15 – Beitinger et al., 2000
16 – Lutterschmidt & Hutchinson, 1997
17 – Killgore and Hoover, 2001
18 – Edwards et al. 1982
19 – Dudley & Eipper, 1975.
20 – Hodson, 1989
21 – ODNR, 2013

TABLE 11
Design Characteristics of the Wallace Dam Turbine Units

Unit	Nameplate Capacity (MW)	Maximum Hydraulic Capacity (cfs)	Best Gate Hydraulic Capacity (cfs)	Commercial Operation Date
1[a]	52.20	8,390	7,200	1980
2[a]	52.20	8,825	7,250	1980
3	56.25	8,600	7,900	1980
4	56.25	8,600	7,900	1980
5[a]	52.20	8,210	7,250	1980
6[a]	52.20	7,920	7,250	1979
Total	**321.3**	**50,545**		NA

[a] Pumped storage units.

TABLE 12
Turbine Characteristics of the Wallace Dam Powerhouse

Unit	Turbine Type	Turbine Arrangement	Turbine Operating Speed (rpm)	Unit Hydraulic Capacity (cfs)[a]	Number of Runners per Turbine	Runner Inlet Diameter (inches)	Number of Runner Buckets/ Blades	Bucket Spacing at Inlet (inches)	Peripheral Runner Velocity (fps)
1	Francis (reversible)	Vertical	85.8	8,390 (6,700)	1	253	6	132	95
2	Francis (reversible)	Vertical	85.8	8,825 (6,700)	1	253	6	132	95
3	Modified Propeller	Vertical	120	8,600	1	202	8	80	106
4	Modified Propeller	Vertical	120	8,600	1	202	8	80	106
5	Francis (reversible)	Vertical	85.8	8,210 (6,700)	1	253	6	132	95
6	Francis (reversible)	Vertical	85.8	7,920 (6,700)	1	253	6	132	95
			Total – Generation	**50,545**					
			Total – Pumpback	**26,800**					

Source: Southern Company Generation Hydro Services

[a] Hydraulic capacity of the pump-turbines in pumping mode is shown in parentheses.

TABLE 13
Site Characteristics and Fish Entrainment Rates at 46 Hydroelectric Developments East of the Mississippi River

Site Name	State	River	Reservoir Area (acres)	Reservoir Volume (acre-ft)	Total Plant Hydraulic Capacity (cfs)	Hydraulic Capacity of Sampled Units (cfs)	Operating Mode[a]	Average Velocity at Trash Rack (fps)	Trash Rack Clear Spacing (inches)	Entrainment Rate	
										Time (fish/hr)	Time & Flow (fish/hr/1,000 cfs of unit capacity)
Abbevile	SC	Savannah	1,425	25,650	390	--	PK	--	2.6	12.4	--
Belding	MI	Flat	--	--	416	416	--	--	2	4.4	10.7
Bond Falls	MI	W.B. Ontonagon	--	--	900	450	PK	--	3	26.9	59.7
Brule	WI	Brule	545	8,880	1,377	916	PK-partial	1	1.62	5.4	5.9
Buzzard's Roost	SC	Saluda	11,404	270,000	3,930	1,310	--	--	3.625	1043.1	796.3
Caldron Falls	WI	Peshtigo	1,180	--	1,300	650	PK	--	2	5.7	8.8
Centralia	WI	Wisconsin	250	--	3,640	550	ROR	2.3	3.5	16.2	29.4
Colton	NY	Raquette	195	620	1,503	450	PK	--	2	0.6	1.2
Crowley	WI	N.F. Flambeau	422	3,539	2,400	1,200	ROR	1.4	2.375	6.9	5.7
E. J. West	NY	Sacandaga	25,940	792,000	5,400	5,400	--	--	4.5	7.4	1.4
Feeder Dam	NY	Hudson	--	--	5,000	2,000	PK	--	2.75	1.6	0.8
Four Mile Dam	MI	Thunder Bay	1,112	2,500	1,500	500	ROR	--	2	3.4	6.9
Gaston Shoals	SC	Broad	300	2,500	2,211	837	--	--	1.5	5.8	7.0
Grand Rapids	MI/WI	Menominee	250	--	3,870	2,216	ROR	--	1.75	3.9	1.7
Herrings	NY	Black	140	--	3,610	1,203	ROR	--	4.125	1.0	0.8
High Falls - Beaver River	NY	Beaver	145	1,058	900	300	--	0.7	1.81	1.0	3.3
Higley	NY	Raquette	742	4,446	2,045	2,045	PK	--	3.63	5.7	2.8
Hillman Dam	MI	Thunder Bay	988	1,600	270	270	ROR	--	3.25	10.9	40.4
Hollidays Bridge	SC	Saluda	466	6,000	4,396	370	--	--	--	2.8	7.5
Johnsonville	NY	Hoosic	450	6,430	1,288	1,288	PK	--	2	10.4	8.1
King Mill	GA	Savannah	--	--	--	--	ROR	1.48	2	15.8	--
Kleber	MI	Black	270	3,000	400	400	ROR	1.41	3	38.2	95.4
Lake Algonquin	NY	Sacandaga	--	--	750	750	--	--	1	0.7	1.0
Luray	VA	S.F. Shenandoah	--	--	1,477	369	ROR	--	2.75	0.5	1.5
Minetto	NY	Oswego	350	4,730	7,500	4,500	PULSE	2.4	2.5	85.8	19.1

TABLE 13
Site Characteristics and Fish Entrainment Rates at 46 Hydroelectric Developments East of the Mississippi River

Site Name	State	River	Reservoir Area (acres)	Reservoir Volume (acre-ft)	Total Plant Hydraulic Capacity (cfs)	Hydraulic Capacity of Sampled Units (cfs)	Operating Mode[a]	Average Velocity at Trash Rack (fps)	Trash Rack Clear Spacing (inches)	Entrainment Rate	
										Time (fish/hr)	Time & Flow (fish/hr/1,000 cfs of unit capacity)
Moshier	NY	Beaver	365	7,339	660	660	PK	--	1.5	26.4	40.0
Ninety-Nine Islands	SC	Broad	433	2,300	4,800	584	--	--	1.5	5.7	9.8
Ninth Street Dam	MI	Thunder Bay	9,884	2,600	1,650	550	ROR	--	1	56.4	102.6
Norway Point Dam	MI	Thunder Bay	10,502	3,800	1,775	575	ROR	--	1.69	20.2	35.2
Potato Rapids	WI	Peshtigo	288	--	1,380	500	ROR	--	1.75	5.9	11.9
Raymondville	NY	Raquette	50	264	1,640	1,640	PK	--	2.25	13.3	8.1
Richard B. Russell	GA/SC	Savannah	31,770	1,297,513	60,000	7,200	PK	--	8	134.3	18.7
Saluda	SC	Saluda	556	7,228	812	227	--	--	--	4.8	21.1
Sandstone Rapids	WI	Peshtigo	150	--	1,300	650	PK	--	1.75	7.7	11.8
Schaghticoke	NY	Hoosic	164	1,150	1,640	1,640	ROR	--	2.125	1.7	1.1
Shawano	WI	Wolf	155	1,090	850	850	ROR	--	5	5.5	6.5
Sherman Island	NY	Hudson	305	6,960	6,600	4,950	PK	--	3.125	0.9	0.2
Stevens Creek	GA/SC	Savannah	2,400	23,700	8,000	--	PULSE	--	3.00-3.50	4.6	--
Thornapple	WI	Flambeau	295	1,000	1,400	700	ROR-mod	1.22	1.69	5.8	8.3
Tower	MI	Black	102	620	404	404	ROR	0.82	1	5.1	12.7
Townsend Dam	PA	Beaver	--	--	4,400	4,400	ROR	--	5.5	527.2	119.8
Twin Branch	IN	St. Joseph	1,065	--	3,200	1,200	ROR	--	3	2.1	1.8
Warrensburg	NY	Schroon	--	--	1,350	1,350	--	--	--	1.0	0.8
White Rapids	MI/WI	Menominee	435	5,155	3,994	2,450	PK-partial	1.9	2.5	8.2	3.3
Wisconsin River Division	WI	Wisconsin	240	1,120	5,150	431	ROR	1.4	2.19	10.7	24.7
Youghiogheny	PA	Youghiogheny	2,840	149,300	1,600	1,600	ROR	0.7	10	208.3	130.2

Sources: EPRI (1997a); FERC (1995a) for Abbeville and King Mill; FERC (1995b) for Stevens Creek.

[a] PK = peaking; PULSE = pulsed (intermittent operation for re-regulation and/or to maximize turbine efficiency); ROR = run-of-river.

TABLE 14
Summary of Fish Entrainment Field Studies Conducted at Two Southeastern Pumped Storage Hydroelectric Developments.

<table>
<tr><th>Site Characteristics</th><th>Study Methods</th><th>Summary of Findings</th></tr>
<tr><td colspan="3">Jocassee Pumped Storage Station:</td></tr>
<tr><td>Location: Keowee River, SC
Dam height: 385 ft
Reservoir area: 7,980 acres
Reservoir volume: 1,206,798 acre-ft
Total hydraulic capacity, generation: 36,200 cfs
Total hydraulic capacity, pumpback: 31,720 cfs

Sources: Duke Energy (2014); Degan and Mueller (2013); Normandeau Associates, Inc. (2013)</td><td>Study period: Jul 2012-Jun 2013
Hydroacoustic monitoring to estimate entrainment numbers and fish size
Current velocity measurements at intakes
Size-specific mortality rates estimated from literature</td><td><u>Conventional generation</u>:
• Mean intake velocities at forebay: < 1.5 fps
• Maxim intake velocities at forebay: > 4 fps
• Estimated annual entrainment: 552,894 fish
• Fish size: 71% < 6 inches length
• Monthly entrainment rates: 55 to 189 fish per hour
• Literature-based survival estimate: 97.6%
<u>Pumpback</u>:
• Mean intake velocities in tailrace: 2.5 to 3.5 fps
• Maximum intake velocities in tailrace: 5 to 6 fps
• Total annual entrainment: 1,519,102 fish
• Fish size: 86% < 6 inches length
• Monthly entrainment rates: 61 to 468 fish per hour
• Literature-based survival estimate: 98.4%</td></tr>
<tr><td colspan="3">Richard B. Russell Dam and Lake Pumped Storage:</td></tr>
<tr><td>Location: Savannah River, GA/SC
Reservoir area: 31,700 acres
Reservoir volume: 1,297,513 acre-ft
Total hydraulic capacity, generation: 60,000 cfs
Total hydraulic capacity, pumpback: 30,000 cfs

Sources: Nestler et al. (1999); USACE (1998)</td><td>Study period: Apr-Oct 1996 (Phase III monitoring – pumpback was primary focus)
Entrainment sampling of pumpback using full or partial recovery netting
Prior netting surveys (Phase II monitoring, Aug 1993-Aug 1994) used to expand estimates to full year and to conventional generation
Mortality testing using full recovery netting but did not control for stress due to capture, handling, and holding</td><td><u>Pumpback</u>:
• Fish size: 1.5-3.4 inches (90%), 3.5-5.4 inches (4%), 5.5-8.4 inches (6%), >8.4 inches (0.2%)
• Numerically dominant species: Threadfin Shad (90.9%), Blueback Herring (6.4%), White Perch (1.3%), Black Crappie (0.7%)
• Sport fish entrainment: Largemouth Bass (0.03%), Striped Bass (0.02%), Hybrid Bass (0.01%)
• Estimated annual entrainment: 10.1 million fish in dry year; 1.2 million fish in wet year
• Estimated annual entrainment mortality:[a] 6.10 million fish in average year, 8.07 million fish in dry year, 1.13 million fish in wet year
<u>Conventional generation</u>:
• Numerically dominant species: Threadfin Shad (87%), Blueback Herring (6.7%), Yellow Perch (4.2%)
• Estimated annual entrainment: 4,184,197 fish in average year; 5,918,426 fish in dry year; 2,015,597 fish in wet year
• Mean annual entrainment rate: 877 fish per hour</td></tr>
</table>

[a] Annual mortality overestimated because testing did not adequately control for stress due to netting, handling, and holding.

TABLE 15
Comparison of Sites in Entrainment Database and the Wallace Dam Project

Physical Characteristic	Entrainment Database: All 47 Sites	Entrainment Database: 11 Southeastern Sites[a]	Wallace Dam Project
Reservoir Area (acres)	50 – 31,770	300 – 31,770	19,050
Reservoir Volume (acre-ft)	264 – 1,297,513	2,300 – 1,297,513	370,000
Total Hydraulic Capacity (cfs)	270 – 60,000	390 – 60,000	50,545
Unit Hydraulic Capacity (cfs)	227 – 7,200	227 – 7,200	7,920 – 8,825
Operating Modes[b]	PK, PULSE, ROR, PS	PK, PULSE, ROR, PS	PS
Trash Rack Clear Spacing (inches)	1 - 10	1.5 - 8	14.5 – 15.5

Sources: EPRI (1997a); FERC (1995a, 1995b); Southern Company Generation Hydro Services

[a] The 11 southeastern sites are Abbeville, Buzzard's Roost, Gaston Shoals, Hollidays Bridge, Jocassee, King Mill, Luray, Ninety-Nine Islands, Richard B. Russell, Saluda, and Stevens Creek.

[b] PK = peaking; PS = pumped storage; PULSE = pulsed; ROR = run-of-river.

TABLE 16
Percent Fish Entrainment Composition by Size Class at 42 Hydroelectric Developments (Modal Size Class at Each Site in Bold Underline)

Site Name	State	River	Trash Rack Clear Spacing (inches)	Percent Composition by Size Class (inches)						
				<4	4-6	6-8	8-10	10-15	15-30	>30
Belding	MI	Flat	2	**<u>87.3</u>**	6.5	3.8	1.1	1.0	0.2	0.03
Bond Falls	MI	W.B. Ontonagon	3	**<u>98.1</u>**	1.2	0.4	0.1	0.1	0.0	0.0
Brule	WI	Brule	1.62	**<u>76.1</u>**	17.1	4.4	1.1	1.0	0.3	0.0
Buzzard's Roost	SC	Saluda	3.625	**<u>97.9</u>**	1.5	0.4	0.1	0.1	0.01	0.0
Caldron Falls	WI	Peshtigo	2	**<u>64.9</u>**	26.8	7.2	0.5	0.5	0.05	0.0
Centralia	WI	Wisconsin	3.5	**<u>97.2</u>**	1.3	0.3	0.9	0.3	0.1	0.0
Colton	NY	Raquette	2	**<u>79.4</u>**	13.8	5.3	0.4	0.1	1.0	0.0
Crowley	WI	N.F. Flambeau	2.375	**<u>81.2</u>**	7.5	7.2	3.5	0.5	0.04	0.01
E. J. West	NY	Sacandaga	4.5	**<u>94.2</u>**	1.0	0.6	0.3	3.2	0.7	0.0
Feeder Dam	NY	Hudson	2.75	**<u>45.1</u>**	10.0	32.4	8.3	2.8	1.3	0.1
Four Mile Dam	MI	Thunder Bay	2	**<u>32.0</u>**	24.4	18.1	12.8	12.7	0.0	0.0
Gaston Shoals	SC	Broad	1.5	**<u>31.6</u>**	28.4	22.0	12.3	4.6	1.1	0.0
Grand Rapids	MI/WI	Menominee	1.75	**<u>82.3</u>**	9.3	4.5	1.5	2.0	0.4	0.0
Herrings	NY	Black	4.125	**<u>63.2</u>**	12.9	10.6	6.9	5.0	1.3	0.1
High Falls - Beaver River	NY	Beaver	1.81	19.6	**<u>37.2</u>**	36.9	4.5	1.5	0.3	0.0
Higley	NY	Raquette	3.63	**<u>97.3</u>**	1.6	0.8	0.2	0.1	0.03	0.0
Hillman Dam	MI	Thunder Bay	3.25	**<u>81.3</u>**	8.8	5.5	2.3	2.1	0.0	0.0
Hollidays Bridge	SC	Saluda	--	**<u>44.1</u>**	35.1	13.5	4.5	2.7	0.0	0.0
Johnsonville	NY	Hoosic	2	**<u>75.9</u>**	15.3	7.1	1.4	0.4	0.01	0.0
Kleber	MI	Black	3	35.6	**<u>53.7</u>**	7.4	2.5	0.6	0.2	0.0
Lake Algonquin	NY	Sacandaga	1	**<u>80.4</u>**	12.5	4.4	1.2	1.3	0.2	0.0
Minetto	NY	Oswego	2.5	21.1	**<u>66.8</u>**	11.1	0.7	0.2	0.03	0.01
Moshier	NY	Beaver	1.5	**<u>84.8</u>**	10.2	4.9	0.1	0.003	0.0	0.0
Ninety-Nine Islands	SC	Broad	1.5	10.9	**<u>34.5</u>**	26.9	16.7	8.7	2.2	0.0
Ninth Street Dam	MI	Thunder Bay	1	**<u>52.0</u>**	39.6	4.0	4.0	0.3	0.0	0.0

TABLE 16
Percent Fish Entrainment Composition by Size Class at 42 Hydroelectric Developments (Modal Size Class at Each Site in Bold Underline)

Site Name	State	River	Trash Rack Clear Spacing (inches)	Percent Composition by Size Class (inches)						
				<4	**4-6**	**6-8**	**8-10**	**10-15**	**15-30**	**>30**
Norway Point Dam	MI	Thunder Bay	1.69	**<u>89.0</u>**	5.8	1.2	2.3	1.7	0.0	0.0
Potato Rapids	WI	Peshtigo	1.75	**<u>89.4</u>**	4.5	3.1	1.0	1.7	0.4	0.0
Raymondville	NY	Raquette	2.25	**<u>87.0</u>**	3.1	3.4	0.5	2.1	3.8	0.02
Richard B. Russell	GA/SC	Savannah	8	**<u>70.9</u>**	18.0	8.6	1.8	0.3	0.3	0.0
Saluda	SC	Saluda	--	22.6	28.7	**<u>35.2</u>**	7.0	4.8	1.7	0.0
Sandstone Rapids	WI	Peshtigo	1.75	**<u>91.7</u>**	3.5	3.5	0.9	0.3	0.02	0.0
Schaghticoke	NY	Hoosic	2.125	**<u>80.0</u>**	8.1	6.5	3.0	1.3	1.1	0.0
Shawano	WI	Wolf	5	**<u>38.8</u>**	28.6	19.7	8.1	3.8	1.0	0.02
Sherman Island	NY	Hudson	3.125	**<u>73.1</u>**	6.9	13.7	3.9	2.2	0.3	0.0
Thornapple	WI	Flambeau	1.69	**<u>77.7</u>**	8.8	4.1	3.4	5.4	0.7	0.04
Tower	MI	Black	1	**<u>55.3</u>**	18.5	14.5	5.4	3.9	2.4	0.0
Townsend Dam	PA	Beaver	5.5	**<u>93.3</u>**	4.4	1.0	1.2	0.1	0.0	0.0
Twin Branch	IN	St. Joseph	3	**<u>64.9</u>**	14.8	8.1	5.0	6.4	0.9	0.0
Warrensburg	NY	Schroon	--	34.6	**<u>35.7</u>**	20.3	5.6	2.6	1.2	0.0
White Rapids	MI/WI	Menominee	2.5	**<u>75.5</u>**	11.5	6.1	4.0	2.6	0.3	0.0
Wisconsin River Division	WI	Wisconsin	2.19	**<u>94.4</u>**	0.8	0.2	0.2	3.8	0.7	0.0
Youghiogheny	PA	Youghiogheny	10	**<u>99.2</u>**	0.3	0.3	0.2	0.02	0.01	0.0
			Average	**68.4**	**16.2**	**9.3**	**3.4**	**2.3**	**0.6**	**0.01**

Source: EPRI (1997a).

TABLE 17
Percent Entrainment Composition by Family at 43 Hydroelectric Developments (Top Family at Each Site in Bold Underline)

Site Name	State	River	Centrarchidae (Sunfishes)	Percidae (Perches)	Ictaluridae (Catfishes)	Cyprinidae (Minnows)	Clupeidae (Herrings)	Catostomidae (Suckers)	Esocidae (Pikes)	Salmonidae (Trouts)	Moronidae (Temperate Basses)	Anguillidae (Freshwater Eels)
Richard B. Russell	GA/SC	Savannah	5.0	8.2	3.9	0.35	**<u>81.6</u>**	0	0	0.009	0.89	0
Gaston Shoals	SC	Broad	35.7	0.80	**<u>41.0</u>**	7.8	2.9	11.8	0	0	0	0
Ninety-Nine Islands	SC	Broad	**<u>29.1</u>**	0.49	28.4	5.1	27.9	9.0	0	0	0	0
Buzzard's Roost	SC	Saluda	0.67	1.7	0.27	0.01	**<u>97.0</u>**	0.001	0	0	0.33	0.003
Hollidays Bridge	SC	Saluda	**<u>33.3</u>**	3.6	19.8	12.6	29.7	0.90	0	0	0	0
Saluda	SC	Saluda	**<u>56.1</u>**	2.2	5.7	13.5	18.3	0.43	0	0	3.9	0
Luray[a]	VA	S.F. Shenandoah	0	0	0	0	0	0	0	0	0	100.0
High Falls - Beaver River	NY	Beaver	9.8	**<u>35.6</u>**	26.2	23.5	0	0.19	2.0	1.6	0	0
Moshier	NY	Beaver	0.37	8.5	0.58	0.03	0	0.004	0.01	0.02	0	0
Herrings	NY	Black	**<u>34.6</u>**	14.0	1.3	17.4	0	1.9	14.4	0	0	0.13
Johnsonville	NY	Hoosic	**<u>67.8</u>**	2.8	5.2	21.9	0	1.9	0	0.31	0	0
Schaghticoke	NY	Hoosic	**<u>48.6</u>**	9.7	5.4	31.7	0.13	3.0	0	0.21	0	1.2
Feeder Dam	NY	Hudson	**<u>60.3</u>**	9.0	16.9	10.0	0	0.21	0.55	0.74	0	0.12
Sherman Island	NY	Hudson	**<u>43.2</u>**	9.1	3.9	36.4	0	0.14	0.25	0.17	0	0
Minetto	NY	Oswego	3.0	0.10	0.07	0.33	**<u>95.5</u>**	0.003	0	0.01	0.74	0.02
Colton	NY	Raquette	**<u>47.7</u>**	16.1	13.9	11.3	0	0.50	3.7	0.20	0	0.79
Higley	NY	Raquette	7.5	**<u>91.2</u>**	0.62	0.38	0	0.01	0.005	0.01	0	0
Raymondville	NY	Raquette	12.0	3.9	0.73	**<u>37.0</u>**	0	1.4	0.08	0	0	5.0
E. J. West	NY	Sacandaga	16.8	**<u>81.3</u>**	0.19	1.4	0	0.05	0	0.11	0	0
Lake Algonquin	NY	Sacandaga	**<u>56.1</u>**	19.8	5.6	13.9	0	2.7	0.38	1.7	0	0
Warrensburg	NY	Schroon	**<u>39.8</u>**	14.7	27.9	8.6	0	3.0	2.3	1.5	0	0
Townsend Dam	PA	Beaver	0.09	0.17	0.07	0.05	**<u>99.4</u>**	0.04	0.0003	0.001	0.04	0
Youghiogheny	PA	Youghiogheny	0.52	0.11	0.001	0	**<u>99.4</u>**	0.01	0	0.002	0	0
Twin Branch	IN	St. Joseph	17.8	4.8	**<u>56.0</u>**	8.6	0	7.0	0.53	0.04	1.8	0
Kleber	MI	Black	**<u>64.0</u>**	24.8	2.1	1.8	0	6.5	0.05	0.20	0	0

TABLE 17
Percent Entrainment Composition by Family at 43 Hydroelectric Developments (Top Family at Each Site in Bold Underline)

Site Name	State	River	Centrarchidae (Sunfishes)	Percidae (Perches)	Ictaluridae (Catfishes)	Cyprinidae (Minnows)	Clupeidae (Herrings)	Catostomidae (Suckers)	Esocidae (Pikes)	Salmonidae (Trouts)	Moronidae (Temperate Basses)	Anguillidae (Freshwater Eels)
Tower	MI	Black	**31.9**	24.0	17.2	14.3	0	7.2	1.6	1.5	0	0
Belding	MI	Flat	**48.6**	7.1	2.1	12.1	0	25.2	0.42	0.01	0	0
Four Mile Dam	MI	Thunder Bay	**42.8**	16.4	31.7	5.4	0	1.1	0.73	0.44	0	0
Hillman Dam	MI	Thunder Bay	13.5	23.4	1.4	**45.5**	0	6.5	0.51	0.55	0	0
Ninth Street Dam	MI	Thunder Bay	4.5	**46.9**	6.9	6.9	0.01	34.6	0.01	0.02	0	0.002
Norway Point Dam	MI	Thunder Bay	4.0	5.0	**84.3**	5.2	0	0.65	0.49	0.04	0	0
Bond Falls	MI	W.B. Ontonagon	12.1	**43.0**	1.3	35.7	0	2.1	0.15	0.08	0	0
Grand Rapids	MI/WI	Menominee	10.9	**38.3**	6.6	20.5	0	6.2	4.2	0.31	0	0
White Rapids	MI/WI	Menominee	**38.9**	19.8	6.2	29.9	0	4.4	0.04	0.03	0	0
Brule	WI	Brule	13.1	**60.0**	0.70	21.5	0	2.3	0.09	0.22	0	0
Thornapple	WI	Flambeau	**44.0**	15.5	6.7	22.0	0	4.5	0.70	0	0	0
Crowley	WI	N.F. Flambeau	11.2	**74.3**	6.6	3.4	0	2.4	0.01	0.41	0	0
Caldron Falls	WI	Peshtigo	41.7	**48.1**	0.63	4.9	0	2.8	0	0.73	0	0
Potato Rapids	WI	Peshtigo	**41.0**	10.1	0.26	16.0	0	30.3	1.4	0.19	0	0
Sandstone Rapids	WI	Peshtigo	**51.3**	9.1	2.1	3.4	0	31.1	1.0	0.41	0	0
Centralia	WI	Wisconsin	7.6	0.62	**80.9**	10.3	0	0.27	0	0	0	0
Wisconsin River Division	WI	Wisconsin	31.6	1.6	**50.7**	11.1	0	0.63	0.63	0	0	0
Shawano	WI	Wolf	**58.1**	5.1	6.5	18.4	0	8.0	0.98	1.4	0	0
		Average	**28.5**	**19.3**	**13.8**	**13.1**	**13.1**	**5.3**	**0.9**	**0.3**	**0.2**	**0.2[b]**

Source: EPRI (1997a).

[a] Only entrainment data for eels were reported for the Luray site.

[b] Luray site not included in average, because detailed data were not provided for other species and families.

TABLE 18
Percent Relative Abundance of the Top Five Entrained Species at Nine Hydroelectric Sites in South Carolina and Georgia
(Black Triangles Indicate Species Known to Occur in Lake Oconee)

	Savannah River Basin				Santee-Cooper River Basin				
FAMILY and Species Common Name	**Abbeville**	**King Mill**	**Richard B. Russell**	**Stevens Creek**	**Buzzard's Roost**	**Gaston Shoals**	**Hollidays Bridge**	**Ninety-Nine Islands**	**Saluda**
CLUPEIDAE (HERRINGS):									
Threadfin shad◄	11.3	35.4	62.0	48.9	96.8	--	--	15.0	--
Gizzard shad◄	--	5.4	--	--	--	--	29.7	11.9	18.3
Blueback herring	--	9.1	19.4	--	--	--	--	--	--
CENTRARCHIDAE (SUNFISHES):									
Bluegill◄	29.2	7.9	2.6	18.0	0.6	15.5	24.3	22.6	49.6
Redbreast sunfish◄	--	--	--	--	--	11.0	--	--	--
ICTALURIDAE (CATFISHES):									
Channel catfish◄	--	--	--	--	--	13.1	11.7	18.0	--
White catfish◄	2.0	--	3.1	--	0.3	8.6	6.3	--	2.6
Snail bullhead◄	--	--	--	--	--	17.2	--	--	--
Brown bullhead◄	7.8	--	--	--	--	--	--	--	--
PERCIDAE (PERCHES):									
Yellow perch◄	44.4	--	8.2	7.1	1.5	--	--	--	--
Blackbanded darter◄	--	--	--	4.3	--	--	--	--	--
CYPRINIDAE (MINNOWS):									
Spottail shiner	--	12.8	--	--	--	--	--	--	6.1
Whitefin shiner	--	--	--	--	--	--	5.4	--	--
Sandbar shiner	--	--	--	--	--	--	--	--	6.5
CATOSTOMIDAE (SUCKERS):									
Striped jumprock◄	--	--	--	--	--	--	--	5.3	--
MORONIDAE (TEMPERATE BASSES):									
White perch	--	--	--		0.3	--	--	--	--
ANGUILLIDAE (FRESHWATER EELS):									
American eel	--	--	--	4.6	--	--	--	--	--
Total	**94.7**	**70.6**	**95.3**	**82.9**	**99.5**	**65.4**	**77.4**	**72.8**	**83.1**

Sources: EPRI (1997a); FERC (1995a) for Abbeville and King Mill; FERC (1995b) for Stevens Creek.

TABLE 19
Turbine Passage Survival Estimates at Sites with Francis Turbine Characteristics Similar to the Wallace Dam Project

	Turbine Characteristics						Estimated Percent Survival by Species and Size Class[a]				
									Size Class (Maximum Size in Inches)		
Site, State	Rated Head (ft)	Rated Flow (cfs)	Speed (rpm)	Runner Diameter (inches)	Peripheral Runner Velocity (fps)	No. of Runner Blades	Family	Species Tested	<u><</u>6	<u><</u>10	>10
Sandstone Rapids, MI	42	650	150	87	57	NG	Centrarchidae	Bluegill and hybrid sunfish	88.6		
								Bluegill and hybrid sunfish	96.2		
								Bluegill and hybrid sunfish	100.0		
								Bluegill and hybrid sunfish	92.0		
								Bluegill and hybrid sunfish	87.8		
							Cyprinidae & Catostomidae	Minnows and suckers	81.8	83.3	27.3
								Minnows and suckers	77.7	81.4	79.4
								Minnows and suckers	99.4	74.5	58.3
								Minnows and suckers	95.9	83.9	54.5
								Minnows and suckers	90.1	61.9	42.4
								Minnows and suckers		90.5	53.7
								Minnows and suckers		71.7	
								Sandstone Rapids Average	**90.9**	**78.2**	**52.6**
Alcona, MI	43	1600	90	100	39	16	Catostomidae	White sucker			96.3
								White sucker			88.3
							Centrarchidae	Bluegill	100.0	100.0	
								Bluegill	78.0	86.3	
							Cyprinidae	Golden shiner	93.9	90.9	
								Spottail shiner	94.3		
							Esocidae	Grass pickerel			96.7
								Northern pike			55.8
							Percidae	Walleye			95.6
								Yellow perch		100.0	
								Yellow perch		62.5	
								Yellow perch		45.2	
							Salmonidae	Rainbow trout	100.0		92.9

TABLE 19
Turbine Passage Survival Estimates at Sites with Francis Turbine Characteristics Similar to the Wallace Dam Project

Site, State	Turbine Characteristics						Estimated Percent Survival by Species and Size Class[a]				
									Size Class (Maximum Size in Inches)		
	Rated Head (ft)	Rated Flow (cfs)	Speed (rpm)	Runner Diameter (inches)	Peripheral Runner Velocity (fps)	No. of Runner Blades	Family	Species Tested	≤6	≤10	>10
								Alcona Average	**93.2**	**80.8**	**87.6**
Higley, NY	45	695	257	48	53	13	Catostomidae	White sucker	90.7	69.0	42.9
								White sucker	71.4	54.3	
							Centrarchidae	Bluegill	85.1		
								Largemouth bass		39.2	37.5
							Percidae	Yellow perch	91.9		
								Yellow perch	96.6		
							Salmonidae	Brook trout	91.5		
								Brook trout	76.5		
								Rainbow trout		74.6	35.4
								Rainbow trout		51.1	38.6
								Higley Average	**86.2**	**57.7**	**38.6**
Finch Pruyn, NY	49	4600	225	41	40.2	NG	Centrarchidae	Smallmouth bass		94.1	92.6
								Smallmouth bass		81.5	70.7
								Smallmouth bass		94.9	
								Smallmouth bass		90.9	
								Finch Pruyn Average		**90.4**	**81.7**
Prickett, MI	54	326	257	53	60		Catostomidae	White sucker		69.9	
								White sucker		35.7	
							Centrarchidae	Bluegill	97.6		
								Bluegill	92.5		
								Bluegill	85.7		
								Prickett Average	**91.9**	**52.8**	
Holtwood, PA (Unit #3)	61.5	3500	103	112	50	17	Clupeidae	American shad	83.5		
Holtwood, PA (Unit #10)	62	NG	94.7	NG	NG	16		American shad	89.4		
								Holtwood Average	**86.4**		

TABLE 19
Turbine Passage Survival Estimates at Sites with Francis Turbine Characteristics Similar to the Wallace Dam Project

	Turbine Characteristics						Estimated Percent Survival by Species and Size Class[a]				
									Size Class (Maximum Size in Inches)		
Site, State	Rated Head (ft)	Rated Flow (cfs)	Speed (rpm)	Runner Diameter (inches)	Peripheral Runner Velocity (fps)	No. of Runner Blades	Family	Species Tested	≤6	≤10	>10
E. J. West, NY	63	2450	113	131	64	15	Catostomidae	White sucker		77.3	72.2
								White sucker			76.7
							Centrarchidae	Bluegill	69.6		
								Bluegill	59.2		
								Largemouth bass		95.5	100.0
								Largemouth bass		81.6	87.0
							Cyprinidae	Golden shiner	85.0	92.5	
							Salmonidae	Rainbow trout	87.0	94.5	93.5
								Rainbow trout	97.1	90.9	93.2
								Rainbow trout	87.4		
								E. J. West Average	**80.9**	**88.7**	**87.1**
Ninety-Nine Islands, SC	74	584	225	NG	NG	NG	Centrarchidae	Bluegill	100.0		
								Bluegill	100.0		
								Bluegill	100.0		
								Bluegill	89.3		
							Ictaluridae	Catfish spp		100.0	100.0
								Catfish spp		100.0	96.2
								Ninety-Nine Islands Average	**97.3**	**100.0**	**98.1**
Caldron Falls, WI	80	650	226	72	71	NG	Centrarchidae	Bluegill and hybrid sunfish	98.1	86.7	
								Bluegill and hybrid sunfish	100.0	93.4	
								Bluegill and hybrid sunfish	99.9		
								Bluegill and hybrid sunfish	90.6		
								Bluegill and hybrid sunfish	94.1		
							Cyprinidae & Catostomidae	Minnows and suckers	88.3	88.4	81.1
								Minnows and suckers	61.3	33.3	45.0
								Minnows and suckers	99.1	72.3	59.7

TABLE 19

Turbine Passage Survival Estimates at Sites with Francis Turbine Characteristics Similar to the Wallace Dam Project

	Turbine Characteristics						Estimated Percent Survival by Species and Size Class[a]				
									Size Class (Maximum Size in Inches)		
Site, State	Rated Head (ft)	Rated Flow (cfs)	Speed (rpm)	Runner Diameter (inches)	Peripheral Runner Velocity (fps)	No. of Runner Blades	Family	Species Tested	≤6	≤10	>10
								Minnows and suckers	57.2	80.0	46.9
								Minnows and suckers	97.4	46.5	25.9
								Minnows and suckers		78.4	46.5
								Caldron Falls Average	**88.6**	**72.4**	**50.9**
High Falls, WI	83	275	359	39	61	NG	Centrarchidae	Bluegill and hybrid sunfish	95.5	61.4	
								Bluegill and hybrid sunfish	72.1	62.2	
								Bluegill and hybrid sunfish	74.5	61.3	
								Bluegill and hybrid sunfish	82.4		
							Cyprinidae & Catostomidae	Minnows and suckers	83.0	48.1	16.0
								Minnows and suckers	86.1	52.8	25.5
								Minnows and suckers	89.1	51.1	23.5
								Minnows and suckers	66.5	58.5	2.6
								Minnows and suckers	57.1	37.8	1.8
								Minnows and suckers		44.4	6.3
								High Falls Average	**78.5**	**53.1**	**12.6**
Hardy, MI	100	1500	164	84	60	16	Catostomidae	White sucker		76.9	90.9
							Centrarchidae	Bluegill	97.1	95.8	
								Largemouth bass	94.9		
							Cyprinidae	Golden shiner	98.0	95.8	
							Esocidae	Northern pike			88.0
							Percidae	Walleye			80.0
								Yellow perch		94.7	98.0
							Salmonidae	Rainbow trout	73.1		66.7
								Hardy Average	**90.8**	**90.8**	**84.7**
Hoist, MI	142	NG	360	NG	NG	NG	Centrarchidae	Bluegill	16.8		
								Bluegill	76.5		
							Salmonidae	Brook trout	43.6		

TABLE 19
Turbine Passage Survival Estimates at Sites with Francis Turbine Characteristics Similar to the Wallace Dam Project

	Turbine Characteristics						Estimated Percent Survival by Species and Size Class[a]				
									Size Class (Maximum Size in Inches)		
Site, State	**Rated Head (ft)**	**Rated Flow (cfs)**	**Speed (rpm)**	**Runner Diameter (inches)**	**Peripheral Runner Velocity (fps)**	**No. of Runner Blades**	**Family**	**Species Tested**	**≤6**	**≤10**	**>10**
								Brown trout	45.2		22.8
								Hoist Average	**45.6**		**22.8**
								Average for All Sites	**85.0**	**74.3**	**61.5**

Sources: EPRI (1997a) for all sites; also EPRI (1992) for turbine characteristics of Finch Pruyn site.
NG = not given.
[a] Each estimate represents immediate survival based on the number of fish recovered in tests with control survival rates of 90 percent or higher.

TABLE 20

Turbine Passage Survival Estimates at Sites with Kaplan and Propeller Turbines

	Turbine Characteristics							Estimated Percent Survival by Species and Size Class[a]				
										Size Class (Maximum Size in Inches)		
Site, State	**Turbine Type**	**Rated Head (ft)**	**Rated Flow (cfs)**	**Speed (RPM)**	**Runner Diameter (in)**	**Peripheral Runner Velocity (ft/sec)**	**No. of Runner Blades**	**Family**	**Species Tested**	**≤6**	**≤10**	**>10**
Townsend Dam, PA	Kaplan	16	2200	152	113	75	3	Centrarchidae	Largemouth bass	100.0	86.0	
								Salmonidae	Rainbow trout	94.4		100.0
									Townsend Dam Average	**97.2**	**86.0**	**100.0**
Herrings, NY	Propeller	20	1203	139	113	68	NG	Anguillidae	American eel			82.1
								Catostomidae	White sucker	81.4	90.0	92.2
									White sucker	98.2	93.3	88.3
									White sucker	96.9	88.8	88.4
									White sucker	100.0	96.6	61.0
									White sucker			90.9
									White sucker			87.8
								Centrarchidae	Bluegill	100.0		
									Bluegill	98.1		
									Bluegill	100.0		
									Largemouth bass		97.3	61.1
									Largemouth bass		96.4	93.5
									Largemouth bass		100.0	92.5
									Largemouth bass		93.2	
								Clupeidae	Alewife	90.7		
									Alewife	94.6		
								Percidae	Yellow perch	81.8	97.6	96.2
									Yellow perch	94.7	98.7	97.4
									Yellow perch	94.7		
									Walleye	100.0	75.2	
								Salmonidae	Rainbow trout	90.0	100.0	84.8
									Rainbow trout	95.5	87.5	87.3
									Rainbow trout	78.3		98.7

TABLE 20
Turbine Passage Survival Estimates at Sites with Kaplan and Propeller Turbines

	Turbine Characteristics							Estimated Percent Survival by Species and Size Class[a]				
										Size Class (Maximum Size in Inches)		
Site, State	Turbine Type	Rated Head (ft)	Rated Flow (cfs)	Speed (RPM)	Runner Diameter (in)	Peripheral Runner Velocity (ft/sec)	No. of Runner Blades	Family	Species Tested	≤6	≤10	>10
									Rainbow trout			98.6
									Rainbow trout			100.0
									Herrings Average	**93.4**	**93.4**	**88.3**
Twin Branch, IN	Kaplan	21	400	NG	60	NG	NG	Centrarchidae	Bluegill		97.3	
								Salmonidae & Ictaluridae	Chinook/channel catfish	100.0		
									Chinook/channel catfish	98.6		
									Steelhead/channel catfish		86.2	
									Twin Branch Average	**99.3**	**91.7**	
Crescent, NY	Kaplan	27	1520	144	108	68	5	Clupeidae	Blueback herring	96.0		
									Crescent Average	**96.0**		
Chalk Hill, WI	Kaplan	28	1331	150	102	67	4	Centrarchidae	Bluegill	96.9		
									Bluegill	97.4		
								Salmonidae & Catostomidae	White sucker/rainbow trout	91.2	97.4	
									Chalk Hill Average	**95.2**	**97.4**	
Crowley, WI	Kaplan	28	1200	150	93	61	NG	Catostomidae	White sucker	100.0	100.0	
								Centrarchidae	Largemouth bass	98.0		
								Percidae	Walleye		100.0	
									Crowley Average	**99.0**	**100.0**	
Hadley Falls, MA (Unit #1)	Kaplan	50	4000	128	170	95	5	Clupeidae	American shad	100.0		
									American shad	97.3		
Hadley Falls, MA (Unit #2)	Propeller	50	3750	150	156	102	5	Clupeidae	American shad	89.0		
									Hadley Falls Average	**95.4**		
Wilder, VT/NH	Kaplan	51	4500	113	108	53	5	Salmonidae	Atlantic salmon		96.0	
									Wilder Average		**96.0**	

TABLE 20
Turbine Passage Survival Estimates at Sites with Kaplan and Propeller Turbines

	Turbine Characteristics							Estimated Percent Survival by Species and Size Class[a]				
										Size Class (Maximum Size in Inches)		
Site, State	**Turbine Type**	**Rated Head (ft)**	**Rated Flow (cfs)**	**Speed (RPM)**	**Runner Diameter (in)**	**Peripheral Runner Velocity (ft/sec)**	**No. of Runner Blades**	**Family**	**Species Tested**	**≤6**	**≤10**	**>10**
Buzzard's Roost, SC	Kaplan	55	1310	240	NG	NG	NG	Centrarchidae	Bluegill	93.1	100.0	
									Bluegill	96.0	89.3	
									Bluegill	93.1	93.1	
								Ictaluridae	Bullhead spp		100.0	77.4
									Bullhead spp		96.3	
								Moronidae	White perch		92.3	
									Buzzard's Roost Average	**94.1**	**95.2**	**77.4**
Safe Harbor, PA (Unit #7)	Kaplan	55	8300	109	220	105	5	Clupeidae	American shad	98.0		
Safe Harbor, PA (Unit #9)	Propeller	55	9200	77	240	81	7	Clupeidae	American shad	97.8		
									American shad	95.8		
									Safe Harbor Average	**97.2**		
Wanapum, WA	Kaplan	80	NG	86	285	107	5	Salmonidae	Coho salmon		89.7	
									Coho salmon		94.9	
									Coho salmon		92.4	
									Coho salmon		96.8	
									Coho salmon		94.8	
									Coho salmon		100.0	
									Coho salmon		88.5	
									Coho salmon		96.8	
									Wanapum Average		**94.2**	
Rocky Reach, WA (Unit #8)	Propeller	87	21000	86	311	116	5	Salmonidae	Chinook salmon	93.2		
									Rocky Reach Unit #8 Average	**93.2**		
Conowingo, MD/PA	Kaplan	90	10000	120	225	118	6	Clupeidae	American shad	94.9		
									Conowingo Average	**94.9**		
Rocky Reach, WA (Unit #3)	Kaplan	92	16000	90	280	110	6	Salmonidae	Chinook salmon		93.9	

TABLE 20

Turbine Passage Survival Estimates at Sites with Kaplan and Propeller Turbines

Site, State	Turbine Type	Rated Head (ft)	Rated Flow (cfs)	Speed (RPM)	Runner Diameter (in)	Peripheral Runner Velocity (ft/sec)	No. of Runner Blades	Family	Species Tested	Size Class (Maximum Size in Inches) ≤6	≤10	>10
									Chinook salmon		94.7	
Rocky Reach, WA (Unit #5)	Kaplan	92	16000	90	280	110	6	Salmonidae	Chinook salmon		97.3	
									Chinook salmon		98.6	
									Chinook salmon		97.6	
									Chinook salmon		89.9	
									Chinook salmon		97.6	
									Chinook salmon		95.2	
Rocky Reach, WA (Unit #6)	Kaplan	92	16000	90	280	110	6	Salmonidae	Chinook salmon		91.2	
									Chinook salmon		97.6	
									Chinook salmon		96.2	
									Chinook salmon		93.2	
									Chinook salmon		96.5	
									Chinook salmon		97.3	
								Rocky Reach Unit #s 3, 5, and 6 Average			**95.5**	
Lower Granite, WA	Kaplan	98	19000	90	312	122	6	Salmonidae	Chinook salmon		95.7	
									Chinook salmon		94.9	
									Chinook salmon		95.3	
									Chinook salmon		97.8	
									Chinook salmon		97.5	
									Chinook salmon		97.2	
									Chinook salmon		94.6	
									Lower Granite Average		**96.1**	
									Average for All Sites	**95.0**	**94.8**	**88.3**

Estimated Percent Survival by Species and Size Class[a] applies to columns Family through >10; Turbine Characteristics applies to columns Turbine Type through No. of Runner Blades.

Source: EPRI (1997a). NG = not given.

[a] Each estimate represents immediate survival based on the number of fish recovered in tests with control survival rates of 90 percent or higher, with the exception of American shad and blueback herring, for which control survival rates were 75 percent or higher.

TABLE 20

Turbine Passage Survival Estimates at Sites with Kaplan and Propeller Turbines

	Turbine Characteristics							Estimated Percent Survival by Species and Size Class[a]				
										Size Class (Maximum Size in Inches)		
Site, State	**Turbine Type**	**Rated Head (ft)**	**Rated Flow (cfs)**	**Speed (RPM)**	**Runner Diameter (in)**	**Peripheral Runner Velocity (ft/sec)**	**No. of Runner Blades**	**Family**	**Species Tested**	**≤6**	**≤10**	**>10**

TABLE 21

Percent Composition by Size Class of Striped Bass and Surrogate Species Entrained at Five Hydroelectric Developments (Modal values appear in bold underline)

				Percent Composition by Size Class (inches)						
Species[a]	**Site Name**	**State**	**River**	**<4**	**4-6**	**6-8**	**8-10**	**10-15**	**15-30**	**>30**
Striped bass	Buzzard's Roost	SC	Saluda	0.0	0.0	5.7	39.9	**51.3**	3.0	0.0
	Richard B. Russell	GA/SC	Savannah	0.0	**56.6**	0.0	0.0	21.7	21.7	0.0
	Townsend Dam	PA	Beaver	0.0	0.0	**50.0**	**50.0**	0.0	0.0	0.0
White bass (S)	Buzzard's Roost	SC	Saluda	0.0	0.0	0.0	**84.2**	15.8	0.0	0.0
	Minetto	NY	Oswego	**57.8**	38.8	0.0	0.0	3.4	0.0	0.0
	Saluda	SC	Saluda	0.0	0.0	0.0	0.0	**100.0**	0.0	0.0
	Townsend Dam	PA	Beaver	4.4	4.3	11.9	**75.7**	3.7	0.0	0.0
White perch (S)	Buzzard's Roost	SC	Saluda	11.3	23.8	27.1	**28.4**	9.4	0.0	0.0
	Minetto	NY	Oswego	**72.2**	5.7	13.6	7.0	1.4	0.1	0.0
	Richard B. Russell	GA/SC	Savannah	15.8	**77.9**	3.9	2.0	0.4	0.0	0.0
	Saluda	SC	Saluda	0.0	0.0	40.0	**60.0**	0.0	0.0	0.0

Source: EPRI (1997a).

[a] S = surrogate species for striped bass in the genus *Morone*.

FIGURES

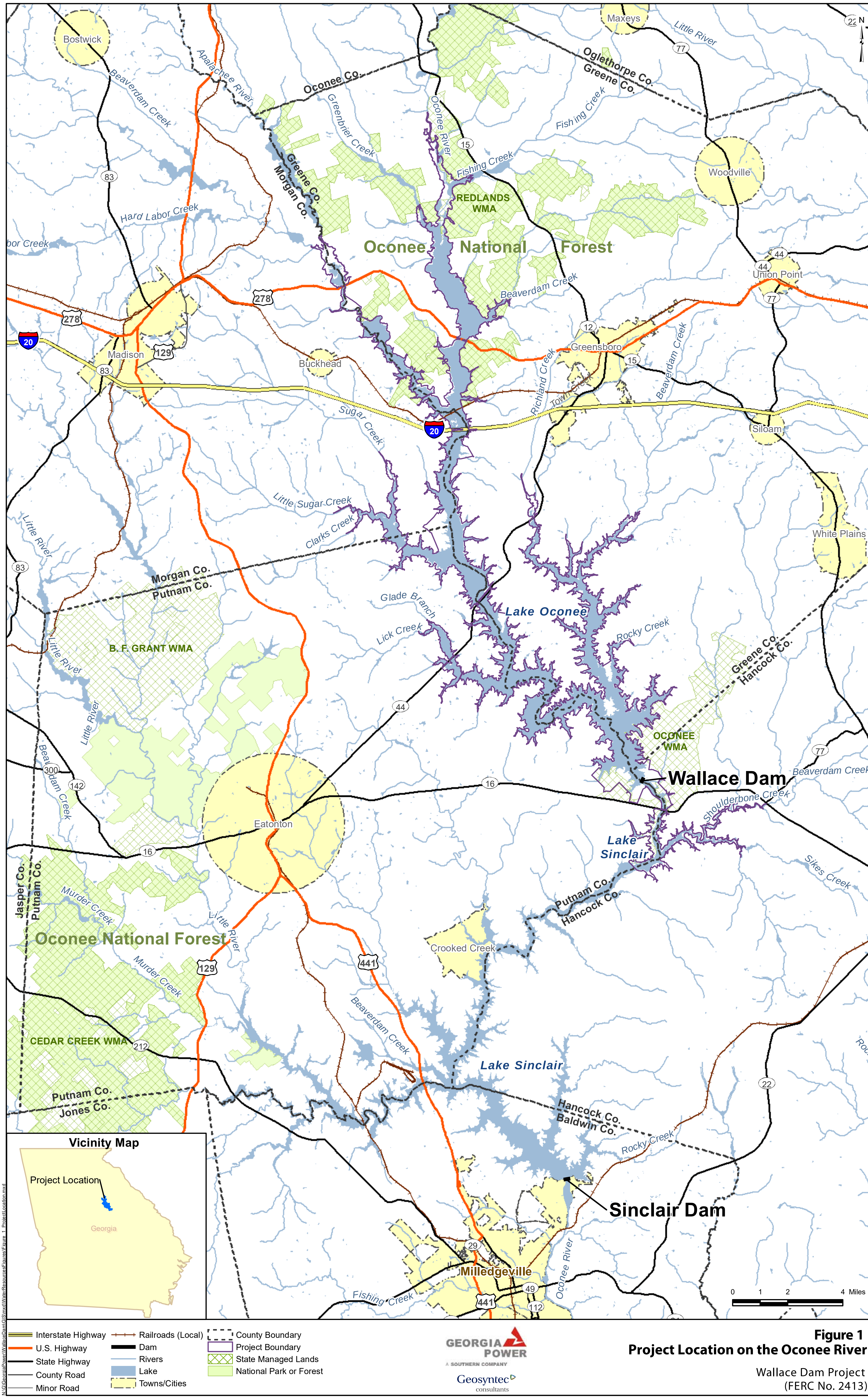

Figure 1
Project Location on the Oconee River

Wallace Dam Project
(FERC No. 2413)

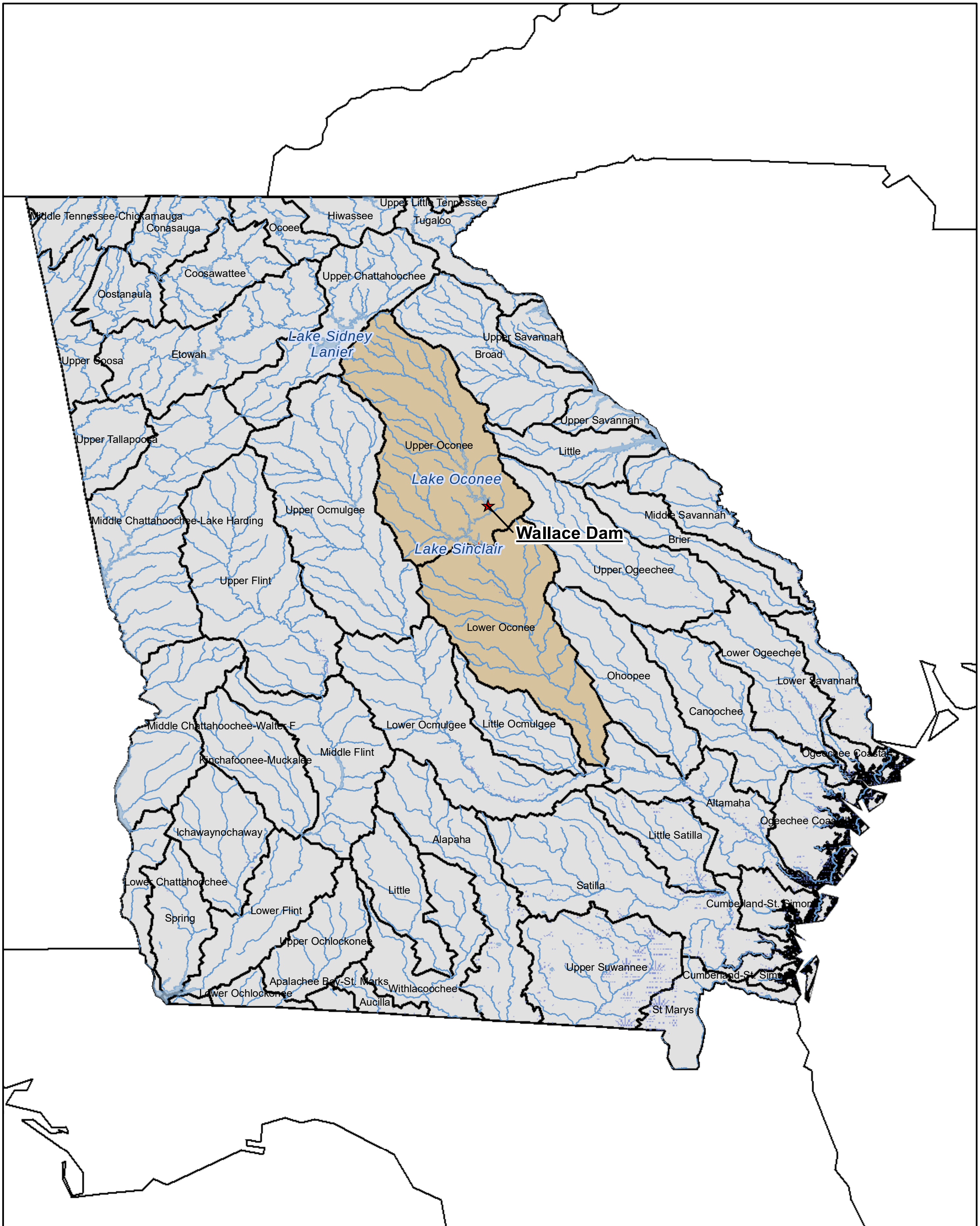

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Figure 2
Project Location in the Oconee River Basin

Wallace Dam Project
(FERC No. 2413)

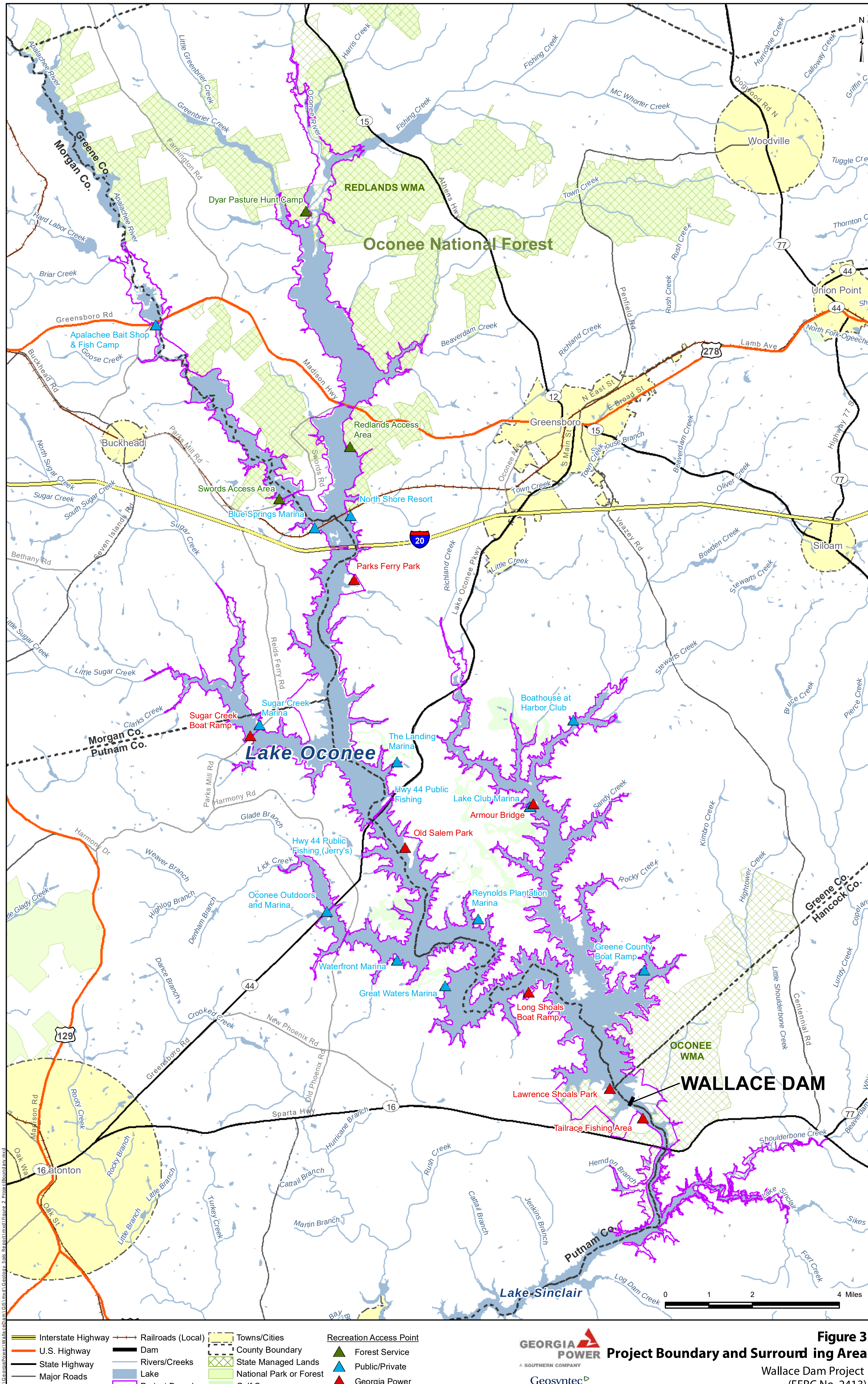

Figure 3
Project Boundary and Surround ing Area
Wallace Dam Project
(FERC No. 2413)

Project Boundary

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Figure 4
Project Facilities
Wallace Dam Project
(FERC No. 2413)

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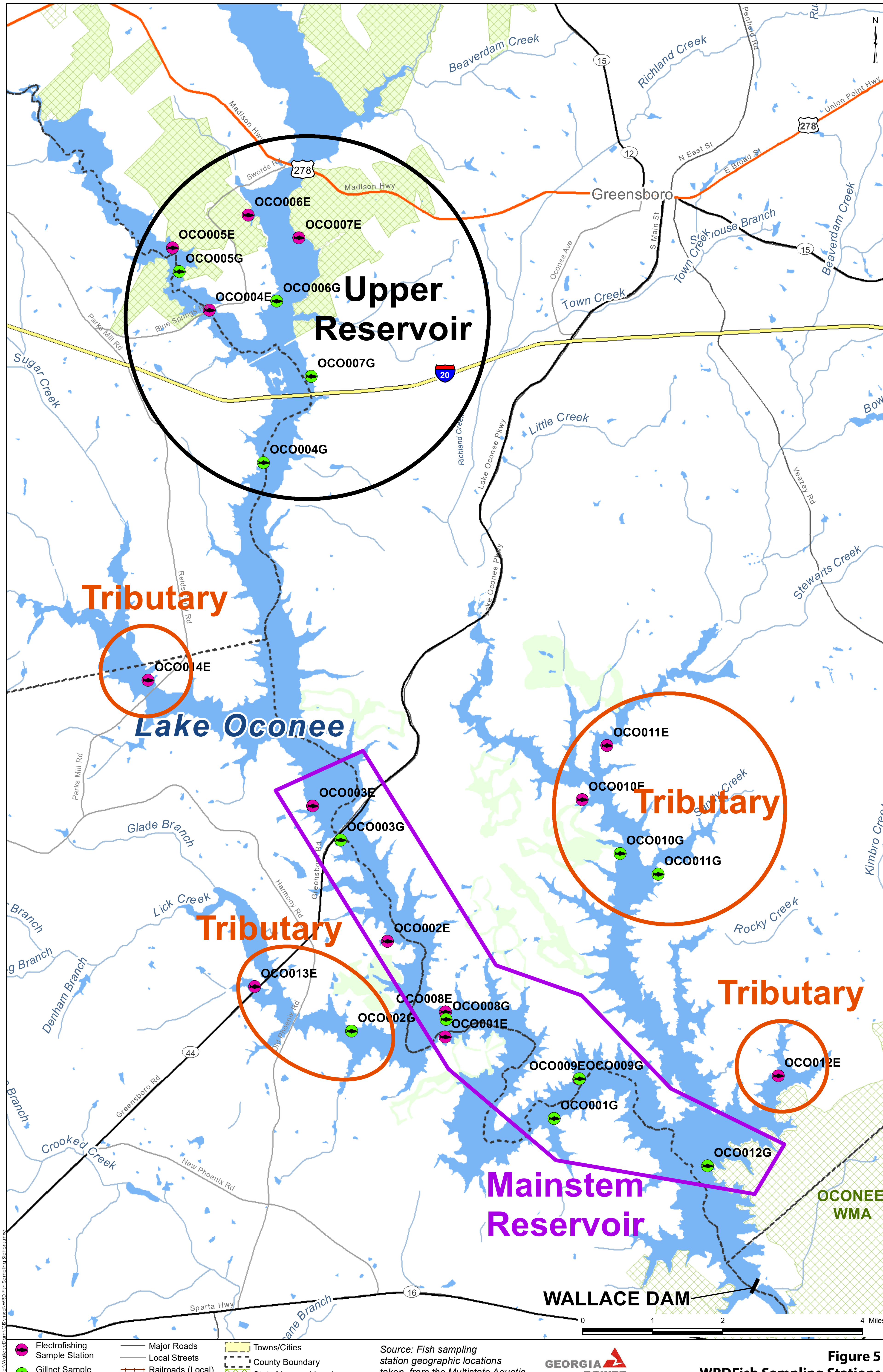


Figure 5
WRDFish Sampling Stations
Wallace Dam Project
(FERC No. 2413)

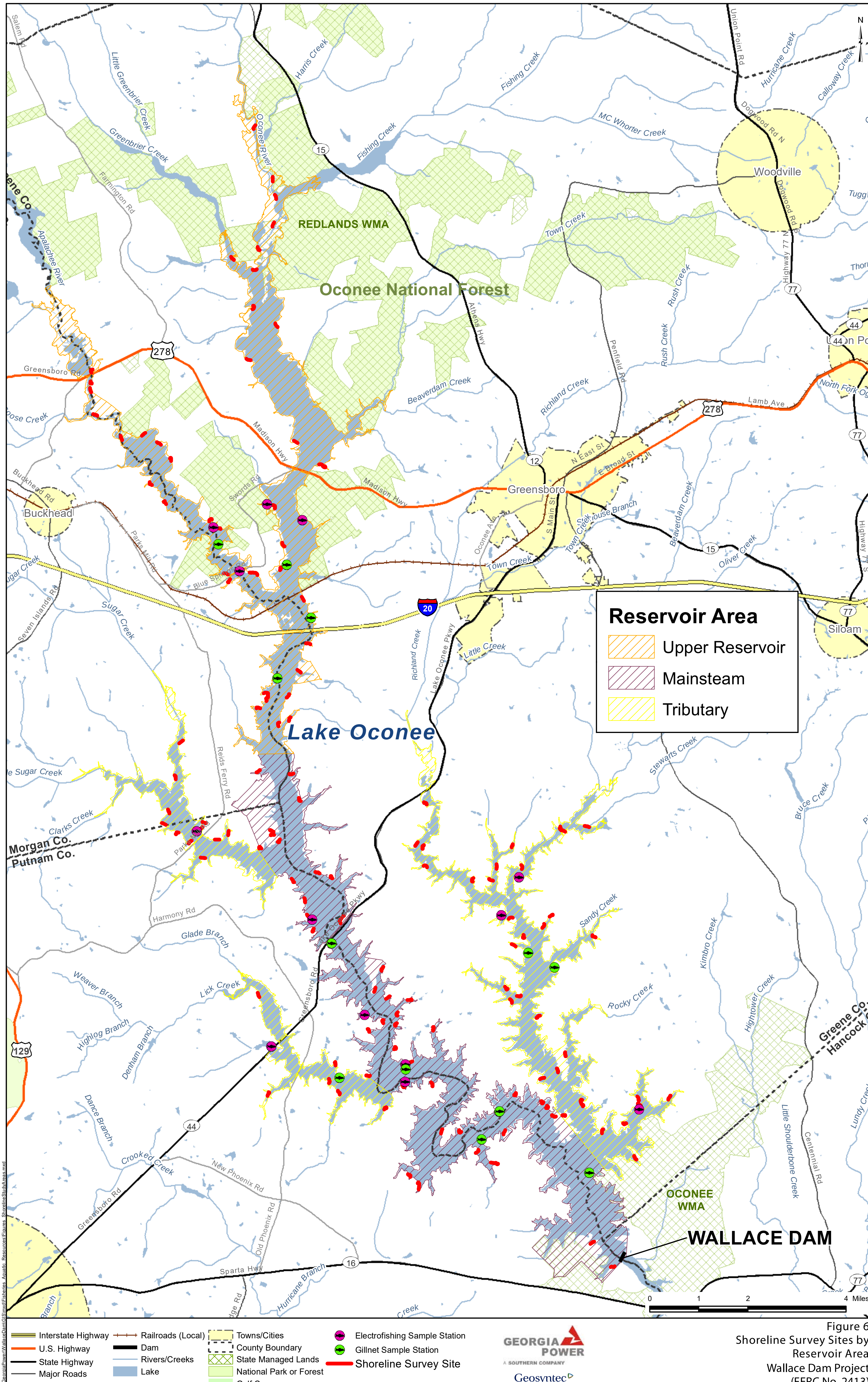
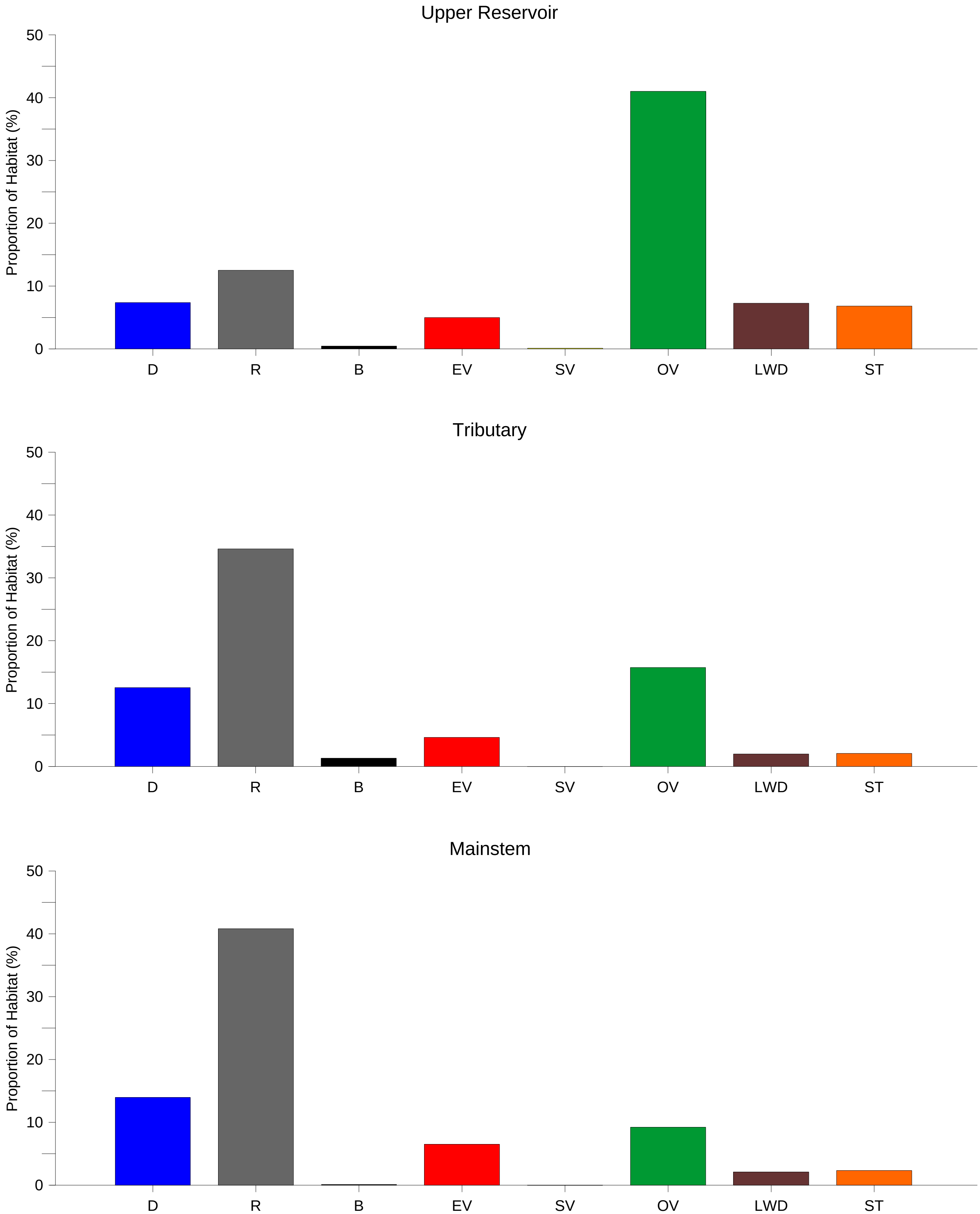


Figure 6
Shoreline Survey Sites by
Reservoir Area
Wallace Dam Project
(FERC No. 2413)



D = docks/piers/boatslips; R = riprap; B = bedrock and boulders; EV = emergent vegetation;
SV = submersed vegetation; OV = overhanging vegetation; LWD = large woody debris; ST = standing timber

Figure 7
Littoral Zone Fish Habitat by Sportfish Habitat Areas
Wallace Dam Project
(FERC No. 2413)

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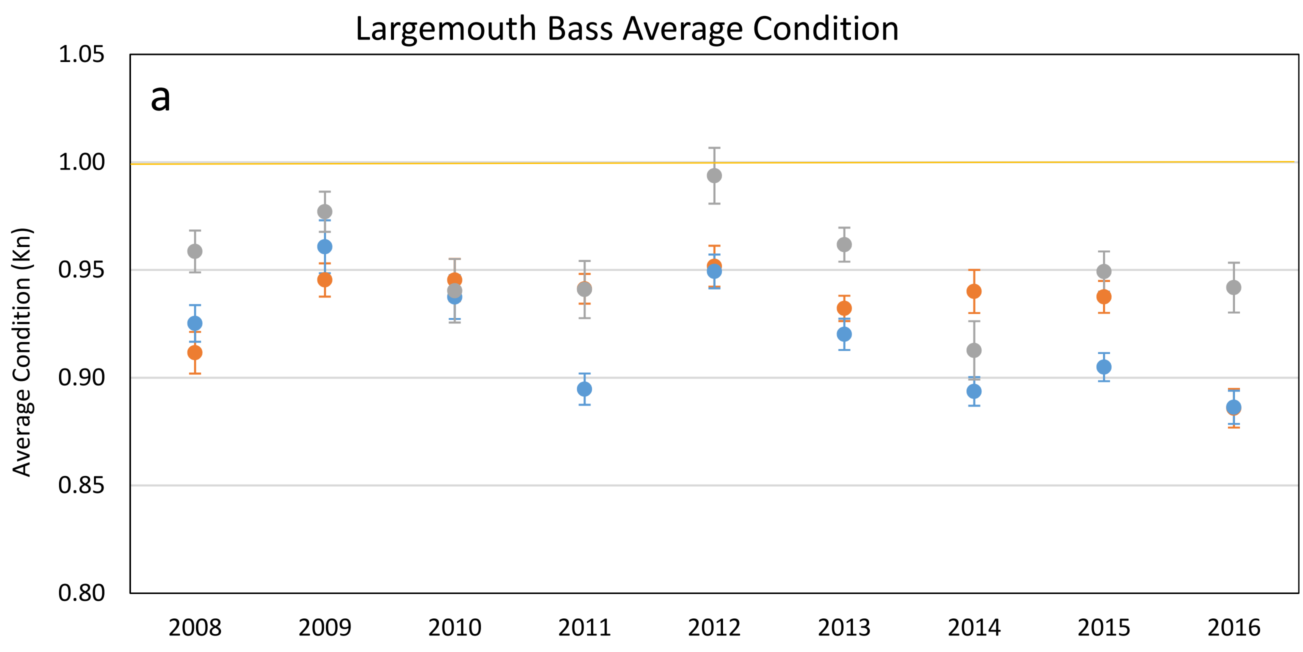

Bars are standard error bars. Years 2011 and 2016 contain only electrofishing data (panel a).

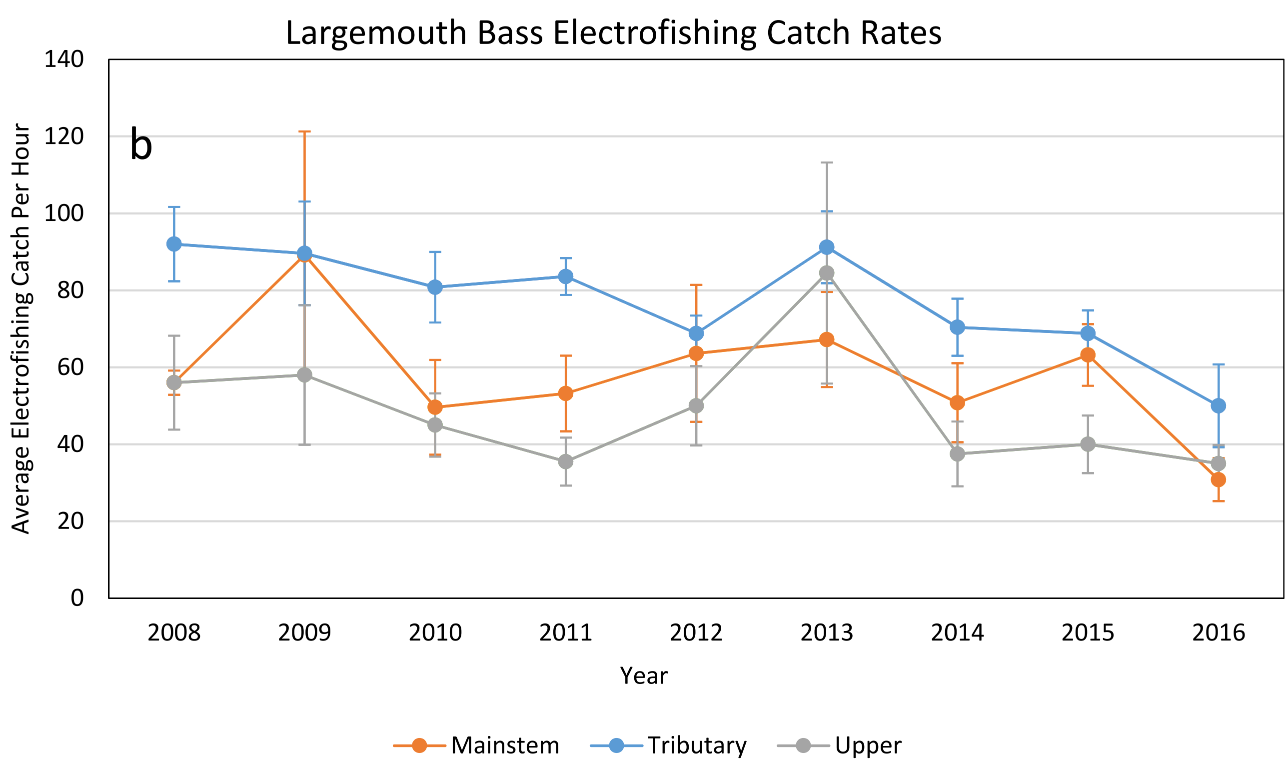

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Figure 8
Largemouth Bass Average Condition and Catch Rates
Wallace Dam Project (FERC No. 2413)

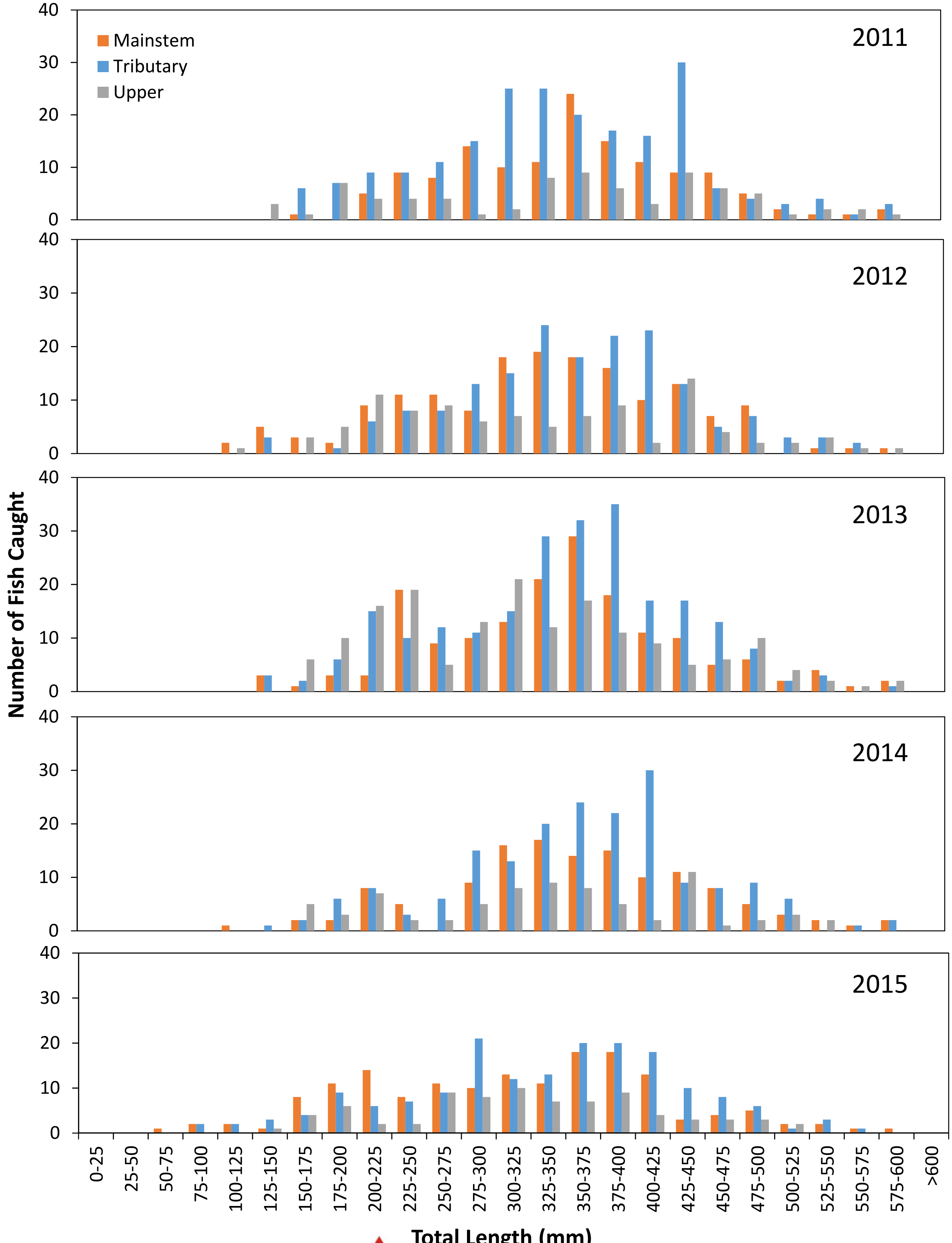
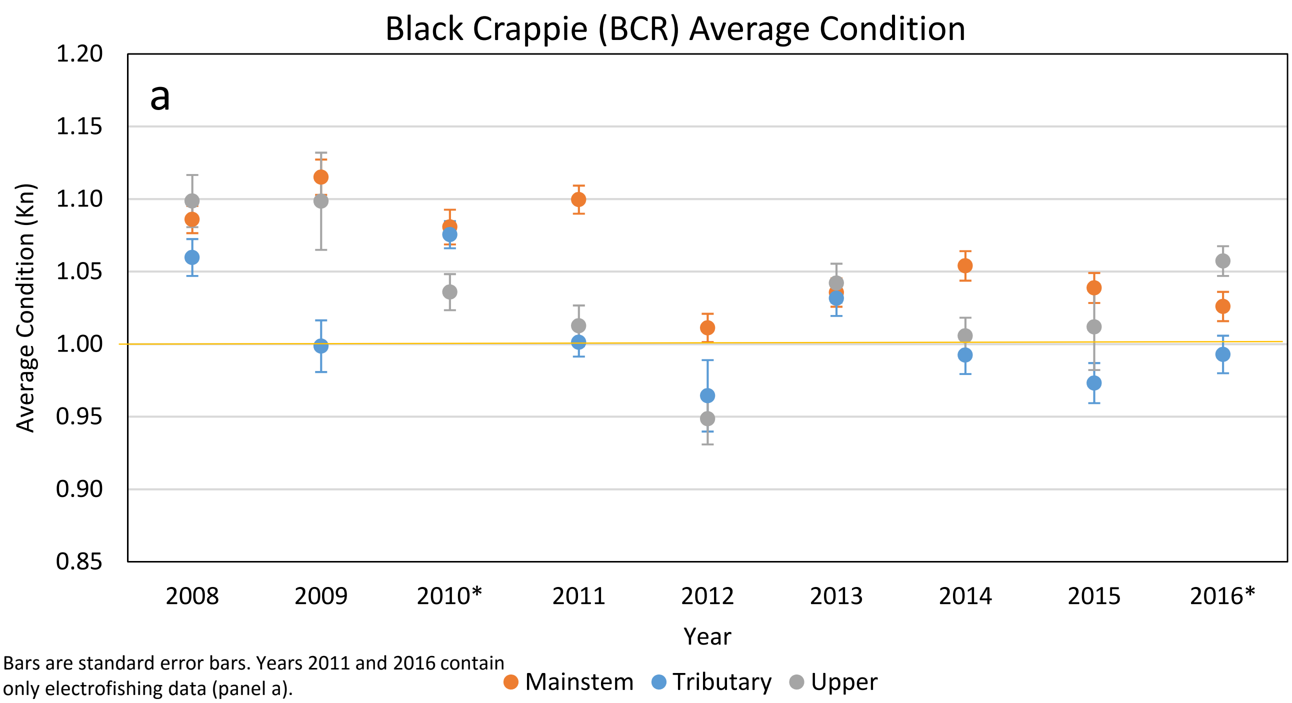


Figure 9
Length-frequency Distribution of Largemouth Bass
Wallace Dam Project (FERC No. 2413)



Bars are standard error bars. Years 2011 and 2016 contain only electrofishing data (panel a).

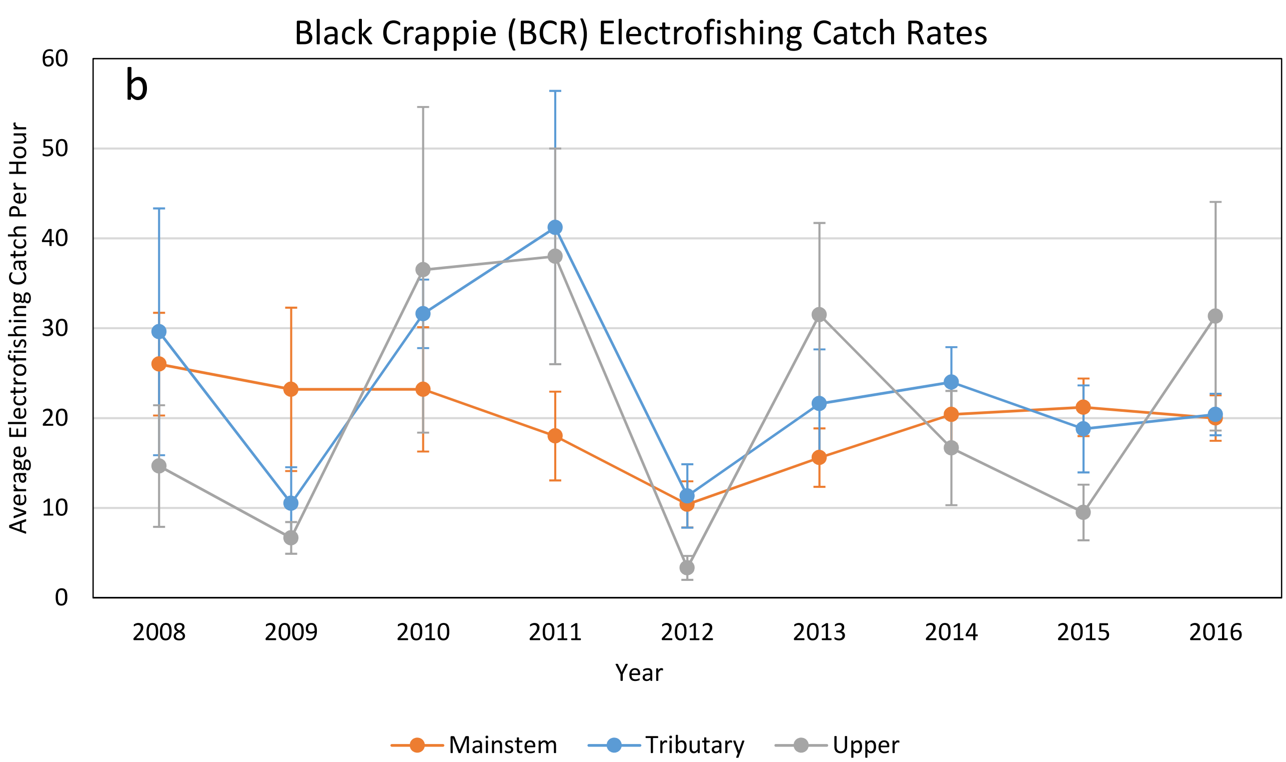


Figure 10
Black Crappie Average Condition and Catch Rates
Wallace Dam Project (FERC No. 2413)

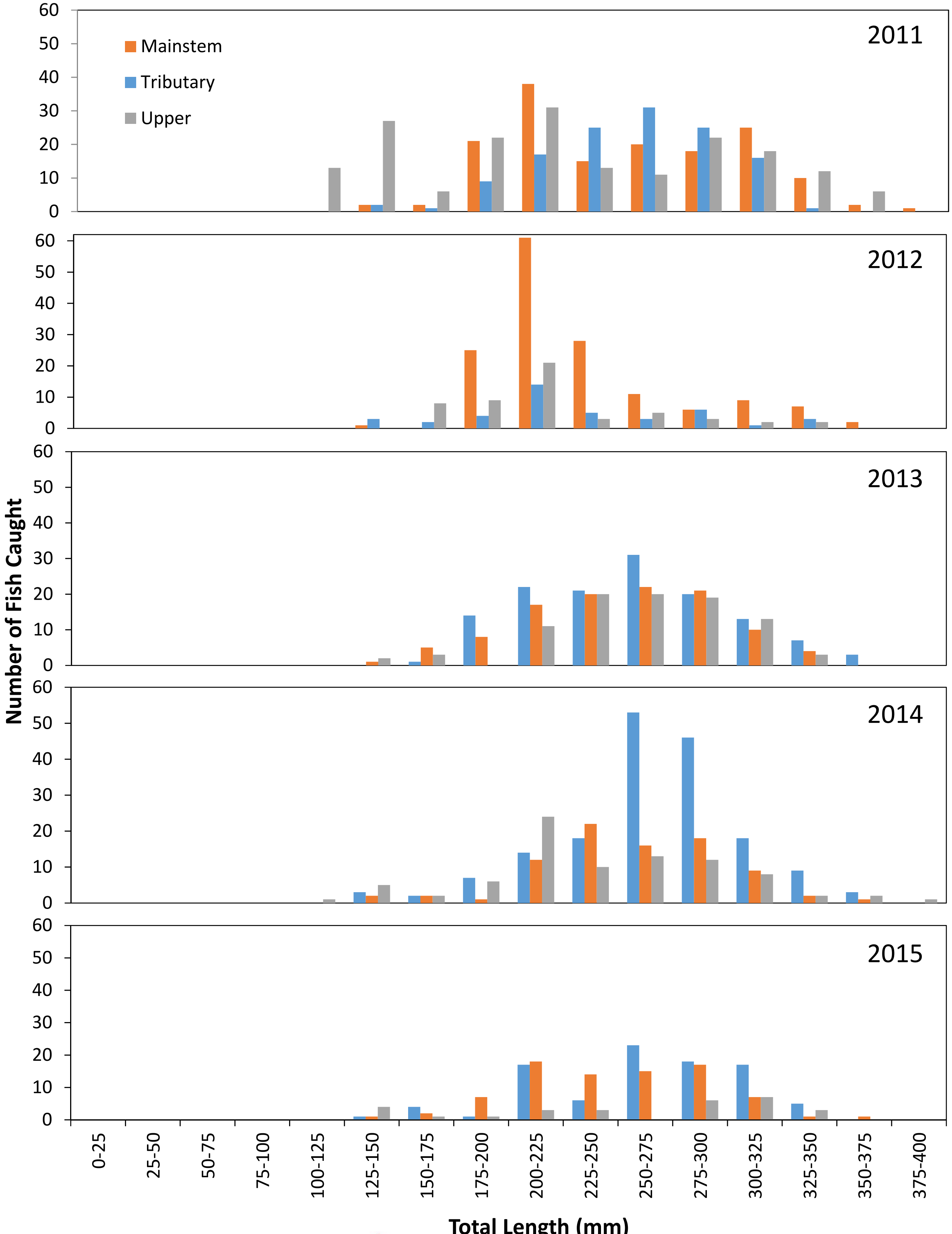
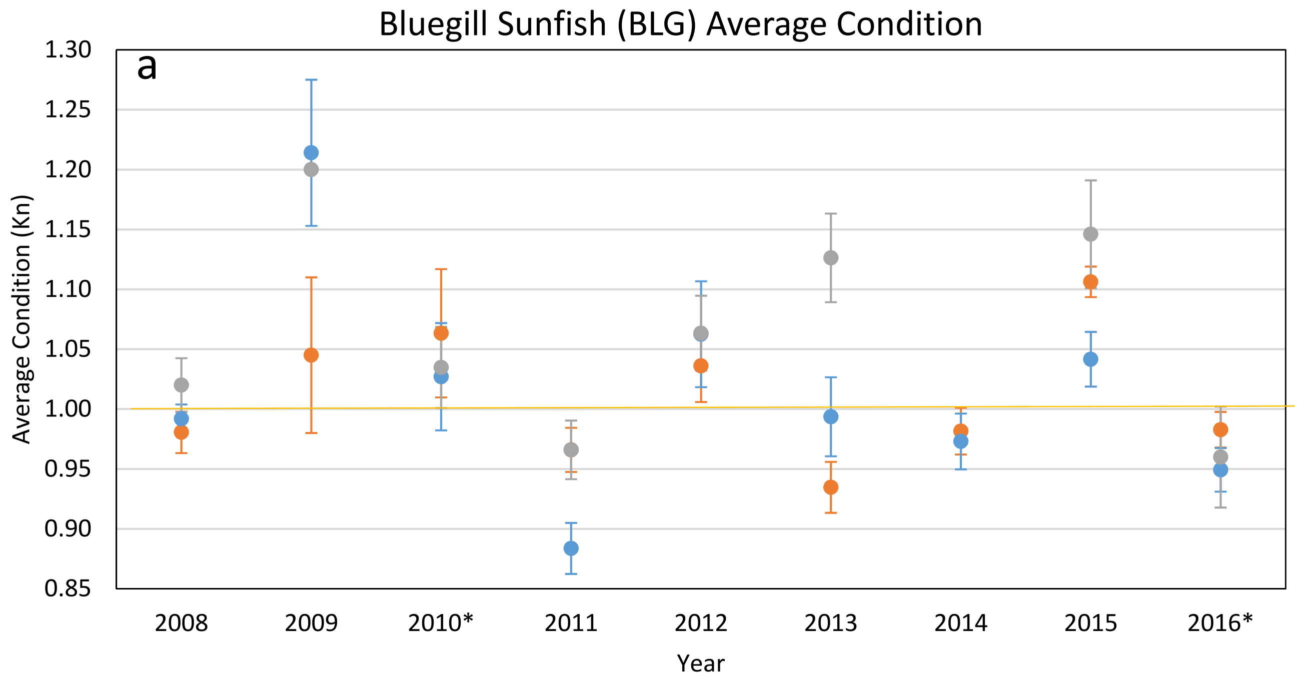


Figure 11
Length-frequency Distribution of Black Crappie
Wallace Dam Project (FERC No. 2413)



Bars are standard error bars. Years 2011 and 2016 contain only electrofishing data (panel a).

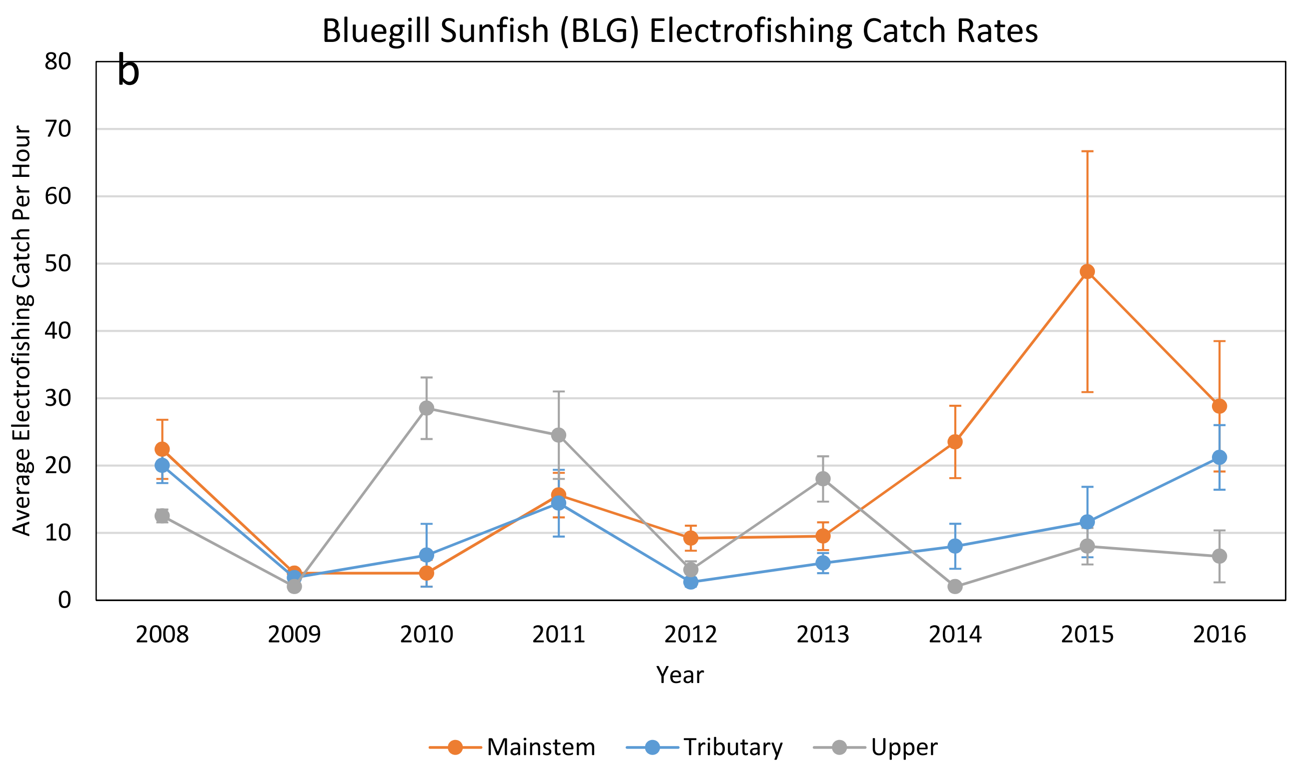


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Figure 12
Bluegill Sunfish Average Condition and Catch Rates
Wallace Dam Project (FERC No. 2413)

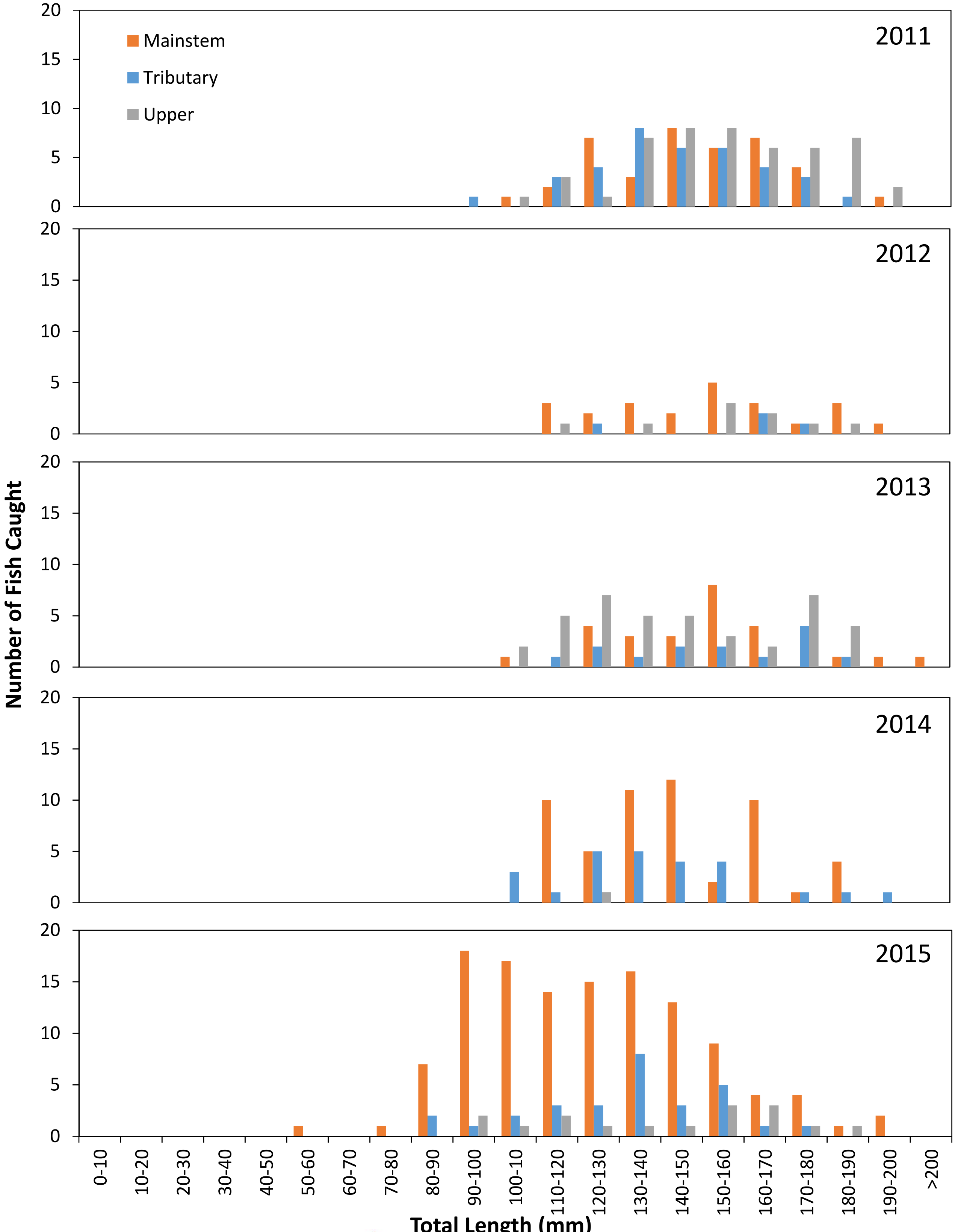

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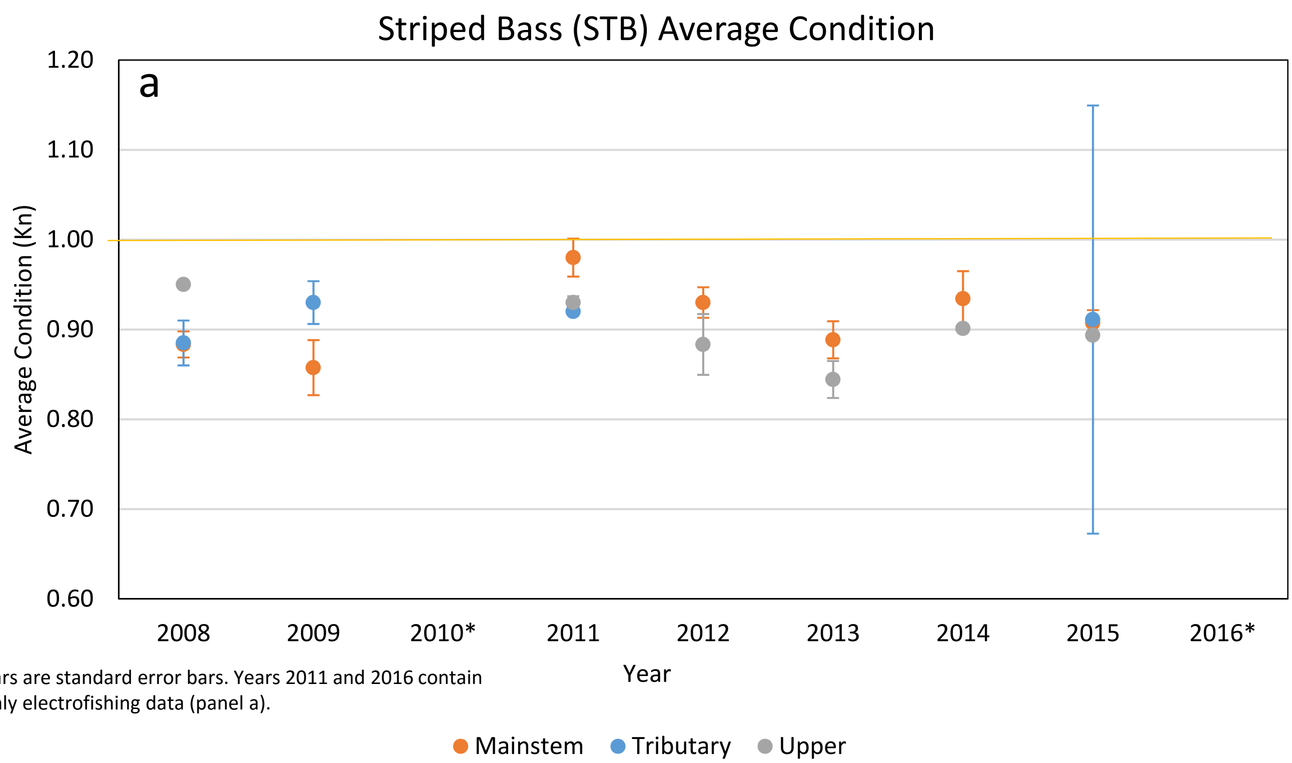
Figure 13
Length-frequency Distribution of Bluegill Sunfish
Wallace Dam Project (FERC No. 2413)



Bars are standard error bars. Years 2011 and 2016 contain only electrofishing data (panel a).

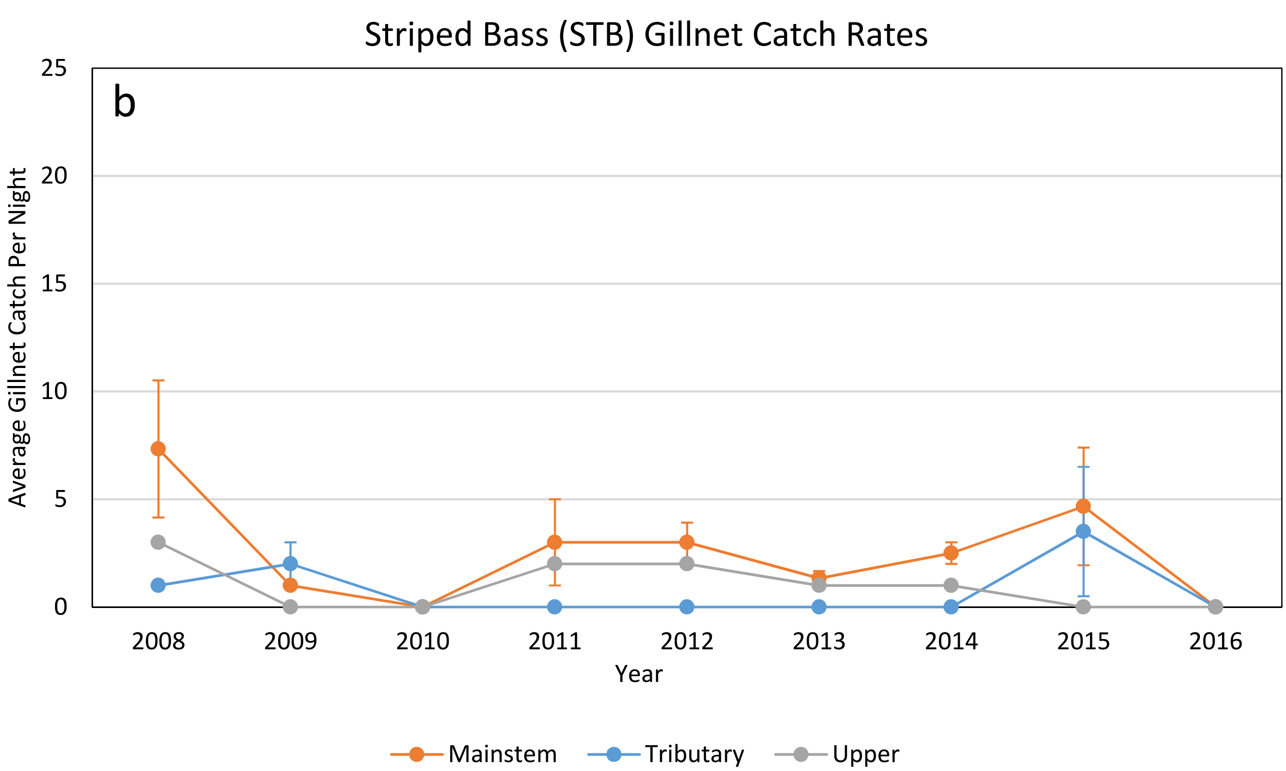


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Figure 14
Striped Bass Average Condition and Catch Rates
Wallace Dam Project (FERC No. 2413)

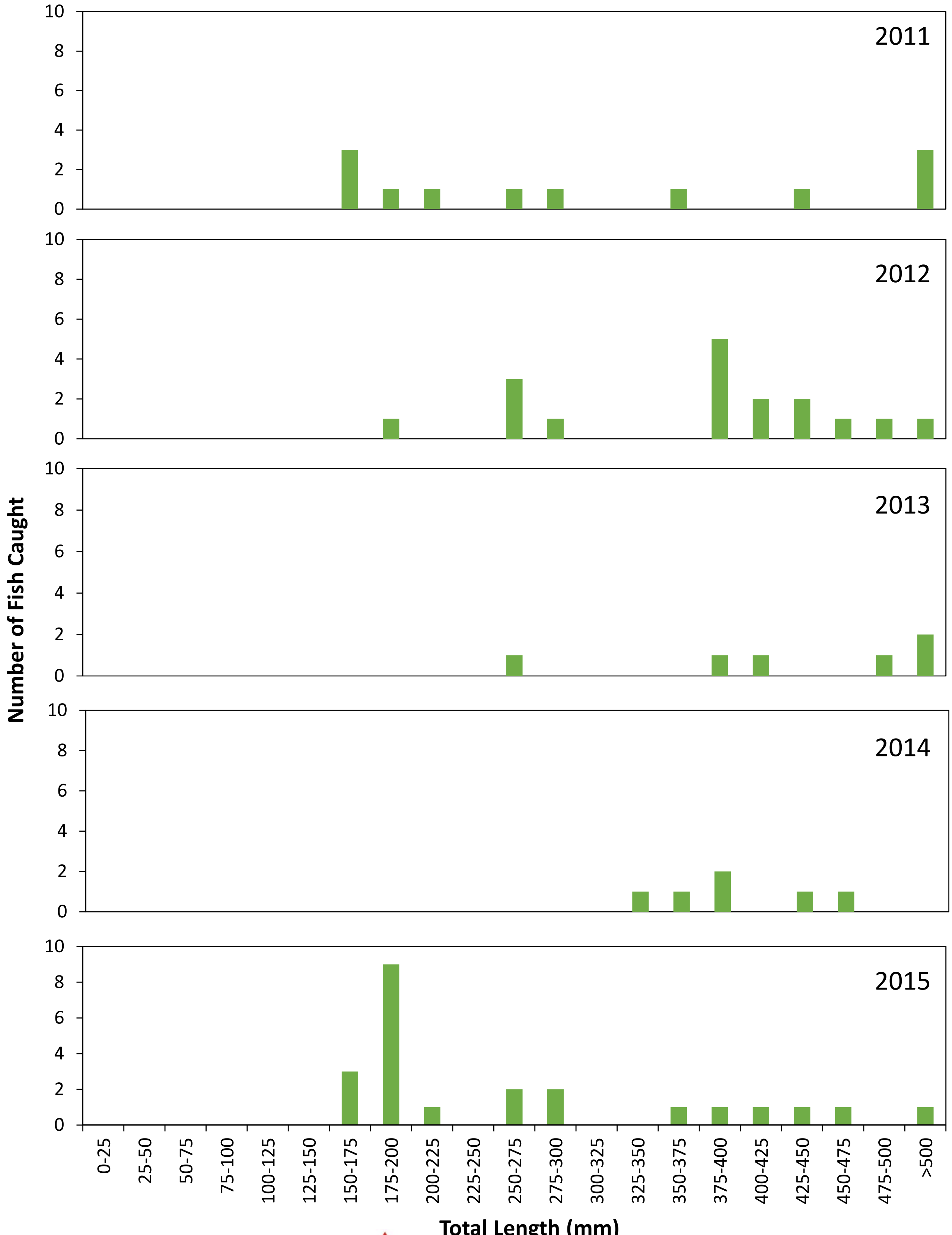

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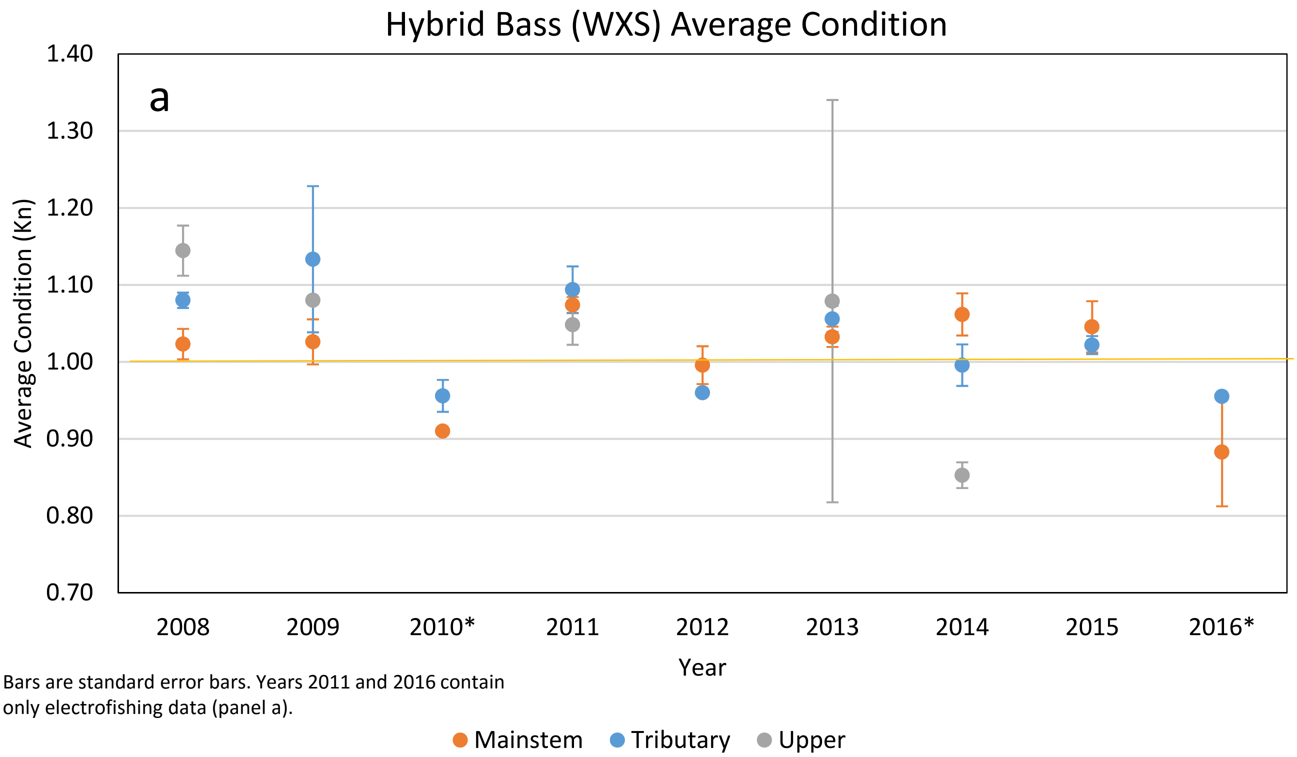
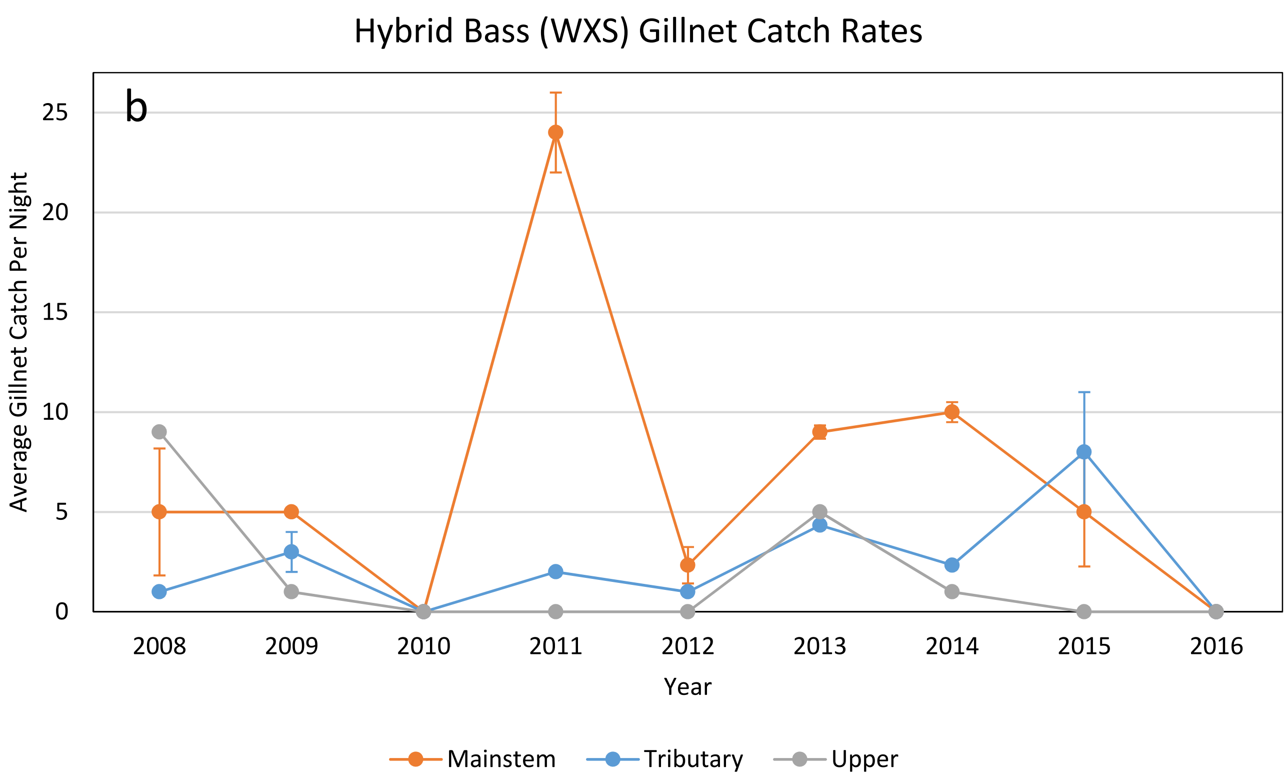
Figure 15
Length-frequency Distribution of Striped Bass
Wallace Dam Project (FERC No. 2413)



Bars are standard error bars. Years 2011 and 2016 contain only electrofishing data (panel a).



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Geosyntec
consultants

Figure 16
Hybrid Bass Average Condition and Catch Rates
Wallace Dam Project (FERC No. 2413)

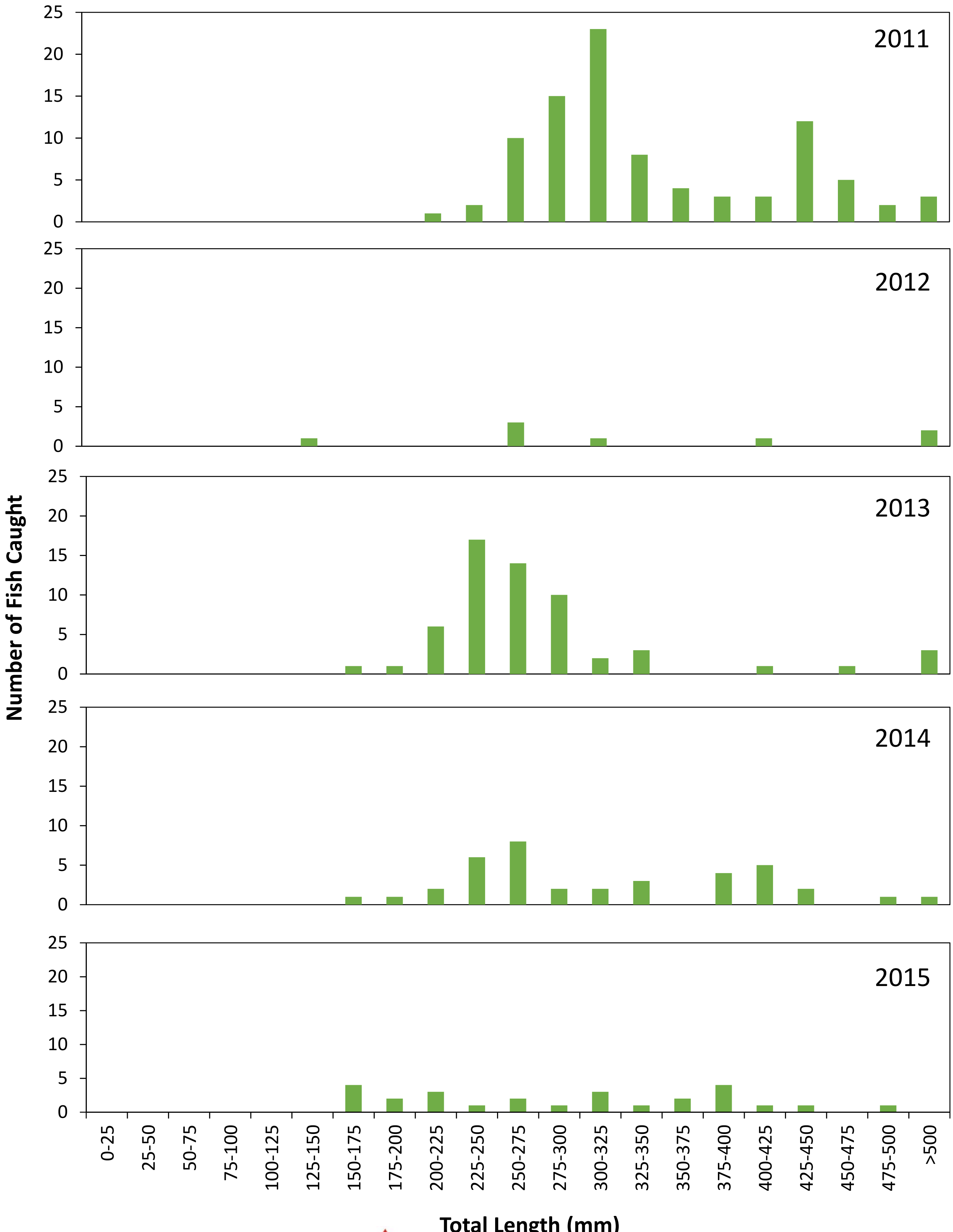


Figure 17
Length-frequency Distribution of Hybrid Bass
Wallace Dam Project (FERC No. 2413)

APPENDIX A

Freshwater Mussel Survey Reports for Lake Oconee and the Wallace Dam Tailrace

SURVEY FOR FRESHWATER MUSSELS IN LAKE OCONEE

Prepared for:

Georgia Power

Prepared by:

Gerald R. Dinkins
Dinkins Biological Consulting, LLC
PO Box 1851
Powell, TN 37849

October 2016

DBC Project 1308

SECTION 1
INTRODUCTION

1.0 INTRODUCTION

Georgia Power Company is conducting baseline characterization of natural resources, including freshwater mussel fauna at their Wallace Dam hydroelectric power generation project. The project is licensed by the Federal Energy Regulatory Commission (FERC) as Project No. 2413. Wallace Dam impounds Lake Oconee and is operated as a pumped storage system. Wallace Dam releases water downstream directly into the backwaters of Lake Sinclair during peak power demand hours and pumps water back up into Lake Oconee at night for reuse in the next day's generation cycle. The project boundary extends downstream of Wallace Dam about 4.0 river miles as thin strips of land along each side of the narrow upper reach of Lake Sinclair (Figure 1).

Most records of freshwater mussels in Lake Oconee are from the section upstream of U.S. Interstate Highway 20 (I-20). Searches conducted by Georgia Department of Natural Resources (GDNR) downstream of I-20 have not been extensive, and they have not yielded live native mussels (J. Wisniewski, personal communication to Georgia Power regarding mollusk survey design for Lake Oconee, 24 August 2015). The Inflated Floater (*Pyganodon gibbosa*) and Altamaha Arcmussel (*Alasmidonta arcula*) occur in stable but soft substrates of mud or fine sand, and GDNR has found both species in abundance in coves and backwater areas in Lake Jackson. These habitats also occur in Lake Oconee, indicating these species potentially occur in Lake Oconee. In 2010, the Center for Biological Diversity (CBD) petitioned the U.S. Fish and Wildlife Service (USFWS) to place both species on the federal list of threatened and endangered species. As part of the FERC relicensing effort for Wallace Dam, Georgia Power responded by designing a study plan incorporating the need to collect occurrence information on these two species in Lake Oconee. On 17 December 2015, the CBD withdrew those species from the petition. Although, removed from the petitioned list, information on the rarity and conservation status as well as occurrence of those species within the Oconee project boundary is lacking.

Little is known about the mussels in Lake Oconee, especially downstream of I-20. However, there have been surveys in Lake Oconee upstream of I-20 and in the free flowing reaches of the Oconee River downstream of Lake Sinclair area (Wisniewski et al. 2005, Dinkins 2007, Dinkins 2011). To provide information on the native freshwater mussels in the reach of the Oconee River impounded by Wallace Dam, Georgia Power contracted Dinkins Biological Consulting, LLC (DBC) to conduct mussel surveys in Lake Oconee. These surveys were conducted according to the methods described in a study plan prepared by DBC (Dinkins 2016) and approved by Georgia Power and the Georgia Department of Natural Resources on 11 March 2016.

2.0 METHODS

The study area included the main channel of Lake Oconee and the major tributary embayments of Richland Creek, Lick Creek, Sugar Creek, Apalachee River, and Greenbrier Creek (Figure 2). Fieldwork was conducted 26 to 29 July 2016 and sampling targeted representative habitats in these areas. The search for native mussels utilized using the occupancy-based sampling design (occupancy model) recommended by the GDNR's Wildlife Resources Division (WRD), Nongame Conservation Section. Twenty sites were within coves and tributaries to the reservoir, and ten sites were located along the margins of the main channel (Tables 1 and 2) (Figure 2).

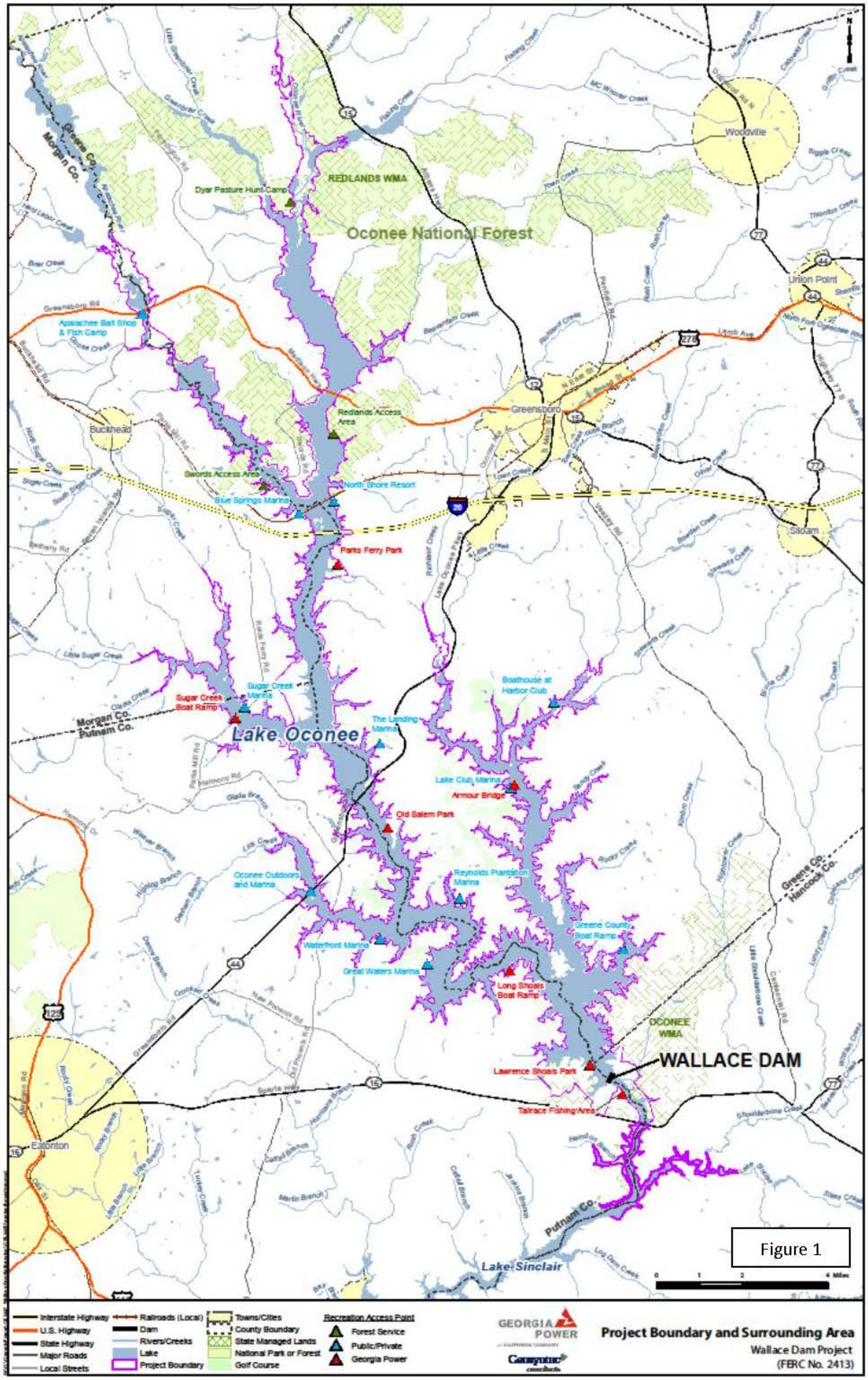
The survey effort was led by Gerald Dinkins. A copy of Mr. Dinkins Federal Endangered Species Permit (Section 10) from the U.S. Fish and Wildlife Service (USFWS) is provided in Appendix A. This permit authorizes him and his team to handle live and dead federally-listed species of mussels and to retain dead shells for a voucher collection.

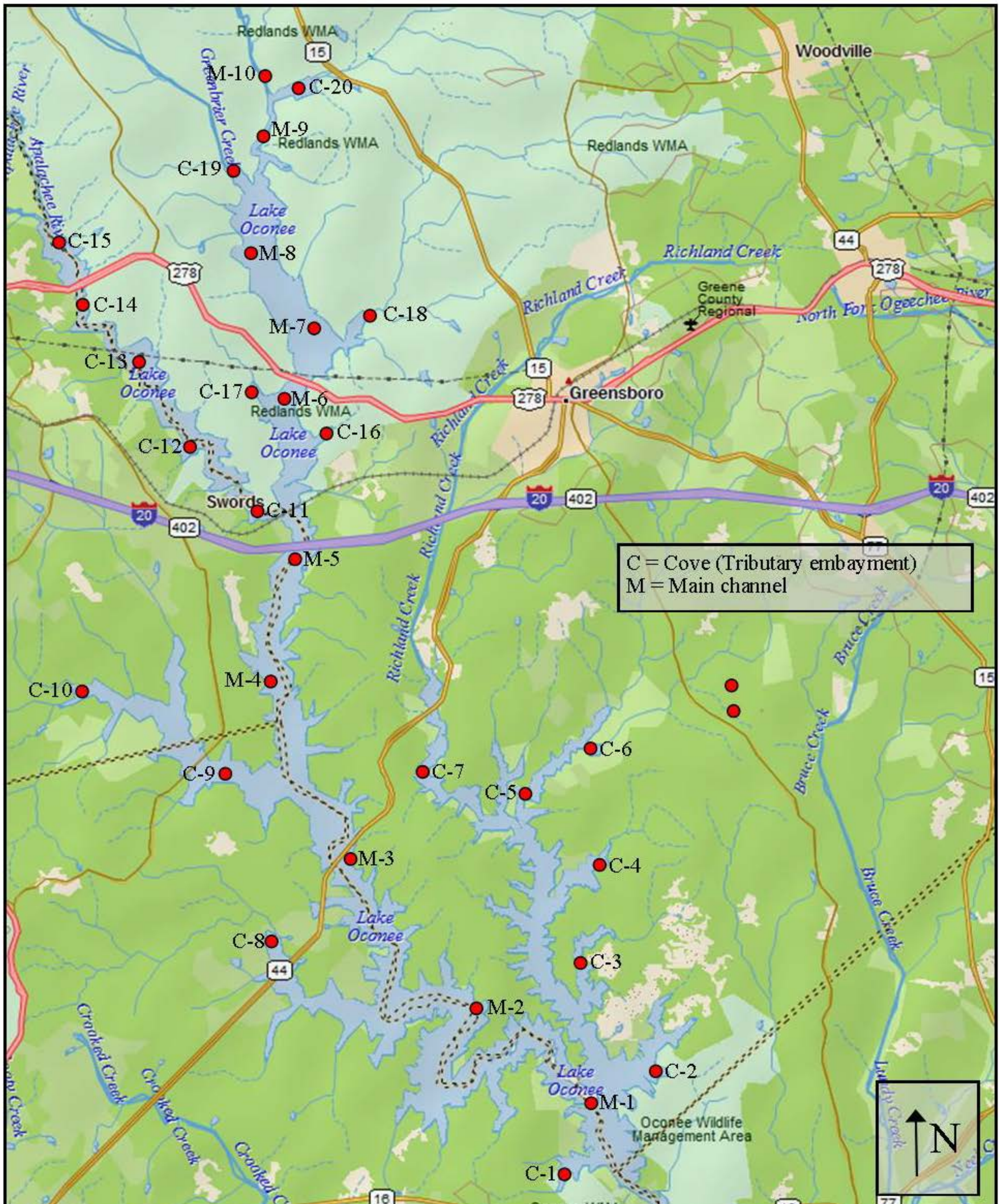
Prior to the initiation of fieldwork, a reconnaissance of benthic substrates in the study area was conducted to select suitable sites for study. In this initial reconnaissance, conducted 17 June 2016, sites were selected based to include representative habitats containing potentially suitable substrates for occupation by native mussels. Physical features examined during the survey included depth, substrate composition, position relative to the historic river channel, and current.

One person hour was spent underwater searching for native mussels at each location, for a total of 30 person hours (Table 3). Sites in which the water depth exceeded two feet were surveyed by two teams composed of two divers each. In shallow water habitat, one to two additional searchers were employed. All surveys were conducted during daylight hours under normal project operations during weekdays (to avoid increased surveyor safety risk due weekend boater traffic). Search effort and capture efficiency of each individual searcher was tracked separately. The field team used a variety of survey methods, tailored to site-specific conditions of depth, accessibility, and water clarity, to search for live mussels and dead shells where potentially suitable habitat was encountered. Survey methods included visual observations while wading, hand grubbing while on hands and knees, snorkeling, SCUBA, and surface-supplied air in deeper water. Divers followed all applicable safety regulations. The survey team recorded observations of live mussels and shells of dead mussels. The location of all survey areas was documented in the field using a hand-held GPS (Global Positioning System) unit. Digital photographs were taken of representative live specimens of each species. Most mussel specimens were measured (length in millimeters). At sites where a large number of live mussels were encountered, a representative subsample of shells was measured. Except for those mussels retained as necessary voucher specimens, all live mussels were returned unharmed to appropriate habitats in the area of collection. The surveyors recorded field notes and general information about the survey area to include such information as the date and time of survey; individual survey capture, flow and velocity conditions; water clarity; depth and substrate composition; and bank and riparian zone condition.

The survey began at the downstream end of Lake Oconee and proceeded in an upstream direction. Prior to the initiation of fieldwork, DBC submitted a dive plan to Georgia Power for safe diving coordination relative to dam operations, etc. Each survey team was equipped with a hand-held communication device and was in constant contact with the field coordinator.

Identification of mussels to the species level can be challenging even for experienced surveyors. Further, for certain genera (especially members of the Subfamily Anodontini, which includes *Anodonta*, *Pyganodon*, and *Alasmidonta*), there is some debate as to the validity of the currently recognized species. For this reason, a number of live mussels of this subfamily were preserved in 95% ETOH and retained as voucher specimens for DNA analysis. Ultimately, these samples may be analyzed and compared with molecular samples from other areas and drainages to resolve which species actually occur in not only the Wallace Dam project area, but in other project areas controlled by Georgia Power.


REDLANDS WMA
Dyar Pasture Hunt Camp
Oconee National Forest
Greene Co.
Morgan Co.
Apalachee Bait Shop & Fish Camp
Woodville
Union Point
Greensboro
Buckhead
Redlands Access Area
Swords Access Area
North Shore Resort
Blue Springs Marina
Siloam
Parks Ferry Park
Sugar Creek Boat Ramp
Sugar Creek Marina
Morgan Co.
Putnam Co.
Lake Oconee
The Landing Marina
Boathouse at Harbor Club
Lake Club Marina
Armour Bridge
Old Salem Park
Oconee Outdoors and Marina
Reynolds Plantation Marina
Waterfront Marina
Great Waters Marina
Greene County Boat Ramp
Long Shoals Boat Ramp
Greene Co.
Hancock Co.
OCONEE WMA
WALLACE DAM
Lawrence Shoals Park
Tailrace Fishing Area
Eatonton
Putnam Co.
Lake Sinclair
Figure 1
0
1
2
4 Miles
Interstate Highway
U.S. Highway
State Highway
Major Roads
Local Streets
Railroads (Local)
Dam
Rivers/Creeks
Lake
Project Boundary
Towns/Cities
County Boundary
State Managed Lands
National Park or Forest
Golf Course
Recreation Access Point
Forest Service
Public/Private
Georgia Power
GEORGIA POWER
Project Boundary and Surrounding Area
Wallace Dam Project
(FERC No. 2413)



USGS Quadrangles Penfield, Woodville, Buckhead, Greensboro, Harmony, Liberty, Meda, Rockville, GA	Figure 2 Mussel Survey Locations Lake Oconee, Georgia
Dinkins Biological Consulting PO Box 1851 Powell, TN 37849	km 0 2 4 6 8 10

Table 1. Description of mussel survey locations on main channel of Lake Oconee.

Site	Latitude	Longitude	Date	Location	Habitat Notes
M-1	N33.37610	W83.17885	26 July 2016	Island at confluence of main channel and Richland Creek embayment	Surveyed between island and main channel
M-2	N33.40136	W83.21698	27 July 2016	Main channel downstream of Lick Creek embayment	Large flat on edge of channel
M-3	N33.44650	W83.25572	27 July 2016	Main channel in back part of cove adjacent and downstream Hwy. 44	Silty quiet cove
M-4	N33.49462	W83.28584	27 July 2016	Main channel app. 1.8km upstream of Sugar Creek embayment in a slight right descending bank indentation	Shallow sandy area adjacent to a mud flat which averages 17 feet in depth
M-5	N33.53324	W83.27299	27 July 2016	Main channel downstream and west of I-20 bridge	Large expanse of open water with uniformly flat bottom
M-6	N33.57738	W83.27707	28 July 2016	Main channel app. 500m downstream of Hwy 278	Edge of and into channel
M-7	N33.59815	W83.26931	29 July 2016	Main channel app. 2km upstream of Hwy 278	Flat muddy plain along channel in large expanse of open water.
M-8	N33.61509	W83.29135	29 July 2016	Main channel app. 4km upstream of Hwy 278	Flat plain in open water, no discernible channel
M-9	N33.64919	W83.28725	29 July 2016	Main channel app. 8km upstream of Hwy 278	Slightly impounded, fairly narrow channel
M-10	N33.66861	W83.28531	29 July 2016	Main channel app. 1km upstream of confluence with Fishing Creek embayment	Slightly impounded channel

Table 2. Description of mussel survey locations on tributary embayments to Lake Oconee.

Site	Latitude	Longitude	Date	Location	Habitat Notes
C-1	N33.35167	W83.18406	26 July 2016	Unnamed cove on right descending bank of main channel	Many stumps/logs
C-2	N33.38262	W83.15095	26 July 2016	Double Creek embayment	Woody debris lines the channel
C-3	N33.40950	W83.17679	26 July 2016	Rocky Creek embayment	Soft flocculent silt in center of channel, transitions to coarse sand near shore
C-4	N33.44459	W83.16894	26 July 2016	Sandy Creek embayment	
C-5	N33.46288	W83.19615	26 July 2016	Richland Creek impoundment upstream of Sandy embayment	Sloping sandy submerged bank
C-6	N33.47604	W83.17044	26 July 2016	Beaverdam Creek embayment	Large open flat water
C-7	N33.46816	W83.23086	26 July 2016	End of Richland Creek embayment	Large open area/deep soft silt
C-8	N33.42826	W83.28683	27 July 2016	End of Lick Creek embayment	Vegetated island adjacent to site
C-9	N33.46810	W83.30198	27 July 2016	Halfway up the Sugar Creek embayment	Homes along shoreline
C-10	N33.48806	W83.33723	27 July 2016	End of Sugar Creek embayment	Deep, soft silt substrate
C-11	N33.54641	W83.28706	28 July 2016	Apalachee River impoundment just upstream of confluence with Oconee R. embayment.	Soft silt substrate
C-12	N33.56307	W83.31014	28 July 2016	Large cove on right descending bank of Apalachee River embayment	Soft silt substrate
C-13	N33.58685	W83.33343	28 July 2016	Near islands in marshy area of Apalachee River embayment	Substrate dominated by sand
C-14	N33.60662	W83.34782	28 July 2016	Small cove on left descending bank of Apalachee River embayment just downstream of Hwy 278	Substrate mixture of silt, sand, and detritus
C-15	N33.61585	W83.35175	28 July 2016	Near island in center of open shallow water at the end of Apalachee River embayment	Large expanse of open water
C-16	N33.56422	W83.26803	28 July 2016	Small cove on left descending bank of main channel about 6km above I-20	Revegetation plot adjacent to search area
C-17	N33.57684	W83.28745	28 July 2016	Cove off main channel just downstream of Swords Road	Silty sand substrate
C-18	N33.60034	W83.25077	29 July 2016	Town Creek embayment	Substrate mixture of silt and sand
C-19	N33.64011	W83.29571	29 July 2016	Greenbrier Creek embayment near CM Copeland Road	Large open cove
C-20	N33.65999	W83.28219	29 July 2016	End of Fishing Creek embayment	Back part of a large slough. Surveyed outer 2/3 of cove opening.

Table 3. Summary of timed searches.

Site No.	Date	Location	Effort (person hours)
Main Channel Sites			
M-1	26 July 2016	Main channel	1
M-2	27 July-2016	Main channel	1
M-3	27 July 2016	Main channel	1
M-4	27 July 2016	Main channel	1
M-5	27 July 2016	Main channel	1
M-6	28 July 2016	Main channel	1
M-7	29 July 2016	Main channel	1
M-8	29 July 2016	Main channel	1
M-9	29 July 2016	Main channel	1
M-10	29 July 2016	Main channel	1
Tributary Sites			
C-1	26 July 2016	Unnamed tributary to main Channel	1
C-2	26 July 2016	Double Creek	1
C-3	26 July 2016	Rocky Creek	1
C-4	26 July 2016	Sandy Creek	1
C-5	26 July 2016	Richland Creek	1
C-6	26 July 2016	Beaverdam Creek	1
C-7	26 July 2016	Richland Creek	1
C-8	27 July 2016	Lick Creek	1
C-9	27 July 2016	Sugar Creek	1
C-10	27 July 2016	Sugar Creek	1
C-11	28 July 2016	Apalachee River	1
C-12	28 July 2016	Apalachee River	1
C-13	28 July 2016	Apalachee River	1
C-14	28 July 2016	Apalachee River	1
C-15	28 July 2016	Apalachee River	1
C-16	28 July 2016	Unnamed tributary to Main Channel	1
C-17	28 July 2016	Unnamed tributary to Main Channel	1
C-18	29 July 2016	Town Creek	1
C-19	29 July 2016	Greenbrier Creek	1
C-20	29 July 2016	Fishing Creek	1
		Total Time (hours):	30

3.0 RESULTS

Substrate in most of the sites was dominated by silt and/or sand (Table 4). Depths in the survey areas on the main ranged from 0.9 to 10.5 meters (mean = 3.8 meters). In the tributary embayments, depths were not as deep as in the main channel, and ranged from 0.3 to 6.7 meters (mean = 2.3 meters).

A total of 355 live mussels representing four species were found in the main channel and tributary embayment sites in Lake Oconee: Altamaha Slabshell (*Elliptio hopetonensis*), Paper Pondshell (*Utterbackia imbecillis*), Inflated Floater (*Pyganodon gibbosa*), and a species that conchologically appeared to be Variable Spike (*Elliptio icterina*). All four species were present in both the main and the tributary embayments, although overall, native mussels were more common in the main channel. An average of 24.0 mussels was found in each main channel sites, compared to an average of 5.8 mussels in the tributary embayment sites. Overall, an average of 11.8 mussels was found at all main channel and tributary embayment sites combined.

In the main channel, the most common species was Altamaha Slabshell, comprising 86% of all specimens. Inflated Floater and Paper Pondshell were relatively equal in occurrence (7 and 6%, respectively). In general, the number of live mussels decreased with increasing distance from the dam. The greatest number of mussels was found at Site M-1, approximately two kilometers upstream of the dam. At this location, live mussels occurred at all depths. This was the only location where boulders were present in the survey area. Live mussels were found at all main channel sites except for Sites M-7 and M-8. These were the only two sites on the main channel in which the substrate composition was 100% silt. However, at Site M-7 two relic shells were found, suggesting live mussels may occur there, but are very rare. No relic shells were found at Site M-8.

In the tributary embayments, Inflated Floater and Altamaha Slabshell were relatively equal in occurrence (42.6 and 39.1%, respectively). There was no discernible trend in occurrence between the tributary embayments near the dam compared to those farther upstream. Live native mussels were found at all of the tributary embayment sites except for C-7. Site C-7 is in the upper part of the Richland Creek embayment, where the stream first becomes impounded by Lake Oconee. At this site, the substrate composition was 100% silt, but native mussels were found in other tributary embayment sites where the substrate similarly was dominated by silt.

Length frequency distributions for the three most common species (Altamaha Slabshell, Paper Pondshell, and Inflated Floater) indicated recruitment is occurring in the main channel and the tributary embayments (Appendix B). Because only a few individuals were found of the species tentatively assigned determined to be Variable Spike, no inference can be made as to this species' size distribution or recruitment. This species is uncommon in Lake Oconee, and represented less than 1% of all individuals found.

4.0 REFERENCES

Dinkins, G.R. 2007. Aquatic Protected Species Report. Survey of Fish, Mussels, and Snails in Oconee River at State Route 30/U.S. 280, Wheeler/Montgomery County, Georgia. Report to Georgia Department of Transportation.

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Dinkins, G.R. 2016. Study Plan and Cost Estimate for Survey of Native Mussels in Lake Oconee. Report to Georgia Power. 11 March 2016.

Wisniewski, J.M., Krakow, G. and Albanese, B. 2005. Current Status of Endemic Mussels in the Lower Ocmulgee and Altamaha Rivers. In: Hatcher, K.J (ed.), Proceedings of the 2005 Georgia Water Resources Conference. The University of Georgia, Athens, Georgia

Table 4. Characteristics of survey locations (% composition).

Site	Detritus	Clay	Silt	Sand	Gravel	Boulder	Depth Range (m)	Avg. Depth (m)
Main Channel								
M-1				60		40	1.2-10.5	5.9
M-2				100			1.2-7.6	4.4
M-3			50	50			6.4	6.4
M-4		100					1.0-1.2	1.1
M-5							5.5	5.5
M-6			50	50			3.4-6.1	4.8
M-7			100				3.4	3.4
M-8			100				2.1	2.1
M-9			20	80			2.7	2.7
M-10				100			0.9-3.4	2.2
							Mean	3.8
Tributary Embayments								
C-1	10		90				0.3-3.7	2.0
C-2				90	10		2.1-3.7	2.9
C-3			50	50			4.3-6.1	5.2
C-4			50	50			1.8-2.7	2.3
C-5				100			1.5-6.7	4.1
C-6			100				1.2	1.2
C-7			100				2.4	2.4
C-8			50	50			0.6-0.9	0.8
C-9			100				1.5-6.7	4.1
C-10			100				0.9	0.9
C-11			100				4.6	4.6
C-12			100				4.3	4.3
C-13				100			1.8-2.1	2.0
C-14	30		40	30			0.9-2.4	1.7
C-15	50		50				0.9-1.8	1.4
C-16			100				0.9	0.9
C-17			50	50			1.8	1.8
C-18			50	50			0.6	0.6
C-19			80	20			1.2-2.1	1.7
C-20			100				0.9	0.9
							Mean	2.3

Table 5. Individual species results.

Site No.	*Elliptio hopetonensis*	*Utterbackia imbecillis*	*Pyganodon gibbosa*	*Elliptio* sp. cf *icterina*	Total mussels/ one hour effort
Main Channel					
M-1	159	5	3	1	168
M-2	22	3	0	0	25
M-3	13	1	3	0	17
M-4	0	3	3	0	6
M-5	11	1	8	0	20
M-6	0	1	0	1	2
M-7	0	0	0	0	0
M-8	0	0	0	0	0
M-9	1	0	0	0	1
M-10	1	0	0	0	1
Subtotal	207	14	17	2	240
Mean	20.7	1.4	1.7	0.2	24.0
% occurrence	86.3	5.8	7.1	0.8	
Tributary Embayments					
C-1	4	2	3	0	9
C-2	3	4	5	0	12
C-3	1	0	2	0	3
C-4	2	3	3	0	8
C-5	0	0	1	0	1
C-6	0	0	1	0	1
C-7	0	0	0	0	0
C-8	0	0	1	0	1
C-9	0	0	2	0	2
C-10	0	0	2	0	2
C-11	4	1	9	0	14
C-12	0	0	3	0	3
C-13	5	0	4	1	10
C-14	16	2	4	0	22
C-15	3	0	0	0	3
C-16	3	6	1	0	10
C-17	0	1	4	0	5
C-18	0	1	3	0	4
C-19	0	0	1	0	1
C-20	4	0	0	0	4
Subtotal	45	20	49	1	115
Mean	2.3	1.0	2.5	0.1	5.8
% occurrence	39.1	17.4	42.6	0.9	
All Sites Combined					
Total	252	34	66	3	355
Mean	8.4	1.1	2.2	0.1	11.8
% occurrence	71.0	9.6	18.6	0.1	

Table 5. Surveyor results in main channel sites.

Site No.	Surveyor	*Elliptio hopetonensis*	*Pyganodon gibbosa*	*Utterbackia imbecillis*	*Elliptio* sp. cf *icterina*	Total
M-1	GRD	35	1	1	0	37
	RTE	36	0	3	0	39
	HDF	50	1	1	1	53
	BMM	38	1	0	0	39
	Total	159	3	5	1	168
M-2	GRD	1	0	0	0	1
	HDF	11	0	1	0	12
	BMM	10	0	2	0	12
	RTE	0	0	0	0	0
	Total	22	0	3	0	25
M-3	GRD	3	0	1	0	4
	RTE	4	3	0	0	7
	HDF	4	0	0	0	4
	BMM	2	0	0	0	2
	Total	13	3	1	0	17
M-4	GRD	0	0	0	0	0
	RTE	0	2	0	0	2
	HDF	0	0	0	0	0
	BMM	0	1	0	0	1
	BJD	0	0	2	0	2
	JMW	0	0	1	0	1
	Total	0	3	3	0	6
M-5	GRD	3	1	0	0	4
	RTE	2	0	0	0	2
	HDF	3	3	0	0	6
	BMM	3	4	1	0	8
	Total	11	8	1	0	20
M-6	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	0	0	1	1
	BMM	0	0	1	0	1
	Total	0	0	1	1	2
M-7	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	Total	0	0	0	0	0
M-8	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	Total	0	0	0	0	0
M-9	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	1	0	0	0	1
	Total	1	0	0	0	1
M-10	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	1	0	0	0	1
	JMW	0	0	0	0	0
	BJD	0	0	0	0	0
	Total	1	0	0	0	1

Table 6. Surveyor results in tributary sites.

Site No.	Surveyor	*Elliptio hopetonensis*	*Pyganodon gibbosa*	*Utterbackia imbecillis*	*Elliptio* sp. cf *icterina*	Total
C-1	HDF	4	1	0	0	5
	BMM	0	2	2	0	4
	Total	4	3	2	0	9
C-2	GRD	0	1	0	0	1
	RTE	0	1	2	0	3
	HDF	1	2	2	0	5
	BMM	2	1	0	0	3
	Total	3	5	4	0	12
C-3	GRD	0	1	0	0	1
	RTE	0	1	0	0	1
	HDF	0	0	0	0	0
	BMM	1	0	0	0	1
	Total	1	2	0	0	3
C-4	GRD	0	0	1	0	1
	RTE	0	2	0	0	2
	HDF	0	1	1	0	2
	BMM	2	0	1	0	3
	Total	2	3	3	0	8
C-5	GRD	0	1	0	0	1
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	Total	0	1	0	0	1
C-6	GRD	0	1	0	0	1
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	Total	0	1	0	0	1
C-7	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	Total	0	0	0	0	0
C-8	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	1	0	0	1
	BMM	0	0	0	0	0
	JMW	0	0	0	0	0
	ARD	0	0	0	0	0
	Total	0	1	0	0	1
C-9	GRD	0	2	0	0	2
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	Total	0	2	0	0	2
C-10	GRD	0	1	0	0	1
	RTE	0	1	0	0	1
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	JMW	0	0	0	0	0
	BJD	0	0	0	0	0
	Total	0	2	0	0	2

Table 6 (continued).

Site No.	Surveyor	*Elliptio hopetonensis*	*Pyganodon gibbosa*	*Utterbackia imbecillis*	*Elliptio* sp. cf *icterina*	Total
C-11	GRD	0	3	1	0	4
	RTE	0	0	0	0	0
	HDF	2	4	0	0	6
	BMM	2	2	0	0	4
	Total	4	9	1	0	14
C-12	GRD	0	1	0	0	1
	RTE	0	1	0	0	1
	HDF	0	0	0	0	0
	BMM	0	1	0	0	1
	Total	0	3	0	0	3
C-13	GRD	3	0	0	1	4
	RTE	2	2	0	0	4
	HDF	0	0	0	0	0
	BMM	0	2	0	0	2
	Total	5	4	0	1	10
C-14	GRD	1	0	1	0	2
	RTE	3	1	0	0	4
	HDF	1	0	0	0	1
	BMM	10	3	0	0	13
	JMW	1	0	0	0	1
	BJD	0	0	1	0	1
	Total	16	4	2	0	22
C-15	GRD	0	0	0	0	0
	RTE	2	0	0	0	2
	HDF	0	0	0	0	0
	BMM	1	0	0	0	1
	JMW	0	0	0	0	0
	BJD	0	0	0	0	0
	Total	3	0	0	0	3
C-16	GRD	2	0	1	0	3
	RTE	0	0	3	0	3
	HDF	1	0	1	0	2
	BMM	0	0	1	0	1
	BJD	0	1	0	0	1
	Total	3	1	6	0	7
C-17	GRD	0	1	0	0	1
	RTE	0	1	1	0	2
	HDF	0	0	0	0	0
	BMM	0	2	0	0	2
	Total	0	4	1	0	5
C-18	GRD	0	0	0	0	0
	RTE	0	2	1	0	3
	HDF	0	0	0	0	0
	BJD	0	1	0	0	1
	JMW	0	0	0	0	0
	BJD	0	0	0	0	0
	Total	0	3	1	0	4

Table 6 (continued).

Site No.	Surveyor	*Elliptio hopetonensis*	*Pyganodon gibbosa*	*Utterbackia imbecillis*	*Elliptio* sp. cf *icterina*	Total
C-19	GRD	0	0	0	0	0
	RTE	0	0	0	0	0
	HDF	0	1	0	0	1
	BMM	0	0	0	0	0
	Total	0	1	0	0	1
C-20	GRD	1	0	0	0	1
	RTE	0	0	0	0	0
	HDF	0	0	0	0	0
	BMM	0	0	0	0	0
	JMW	2	0	0	0	2
	BJD	1	0	0	0	1
	Total	4	0	0	0	4

APPENDIX A

COLLECTING PERMITS

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
WILDLIFE RESOURCES DIVISION

SCIENTIFIC COLLECTING PERMIT

(29-WJH-16-73) **FEE: $50**

Permittee: **DINKINS BIOLOGICAL CONSULTING, G. DINKINS**
PO BOX 1851
POWELL, TN 37849 5103
CN: 8947

Species: NATIVE LISTED & NON-LISTED FRESHWATER MUSSELS/SNAILS & FISHES
Numbers(if applicable):
Expiration date: **March 31, 2017**

Above named is hereby permitted, in accordance with O.C.GA 27-2-12 and the regulations of the Georgia Department of Natural resources subject to the terms, exceptions, and restrictions expressed on the attached "General Conditions" and subject to any other applicable State or federal regulations, to take for scientific and educational purposes only in the State of Georgia, wildlife which is listed above.

This permit is conditional and confers NO priviledges whatsoever to take, possess, exchange, or transport migratory birds or their parts, nests, or eggs unless the permittee has in his possession, while exercising the priviledge granted herein a valid subsisting permit to take Migratory Birds and their parts, nests, or eggs for scientific purposes in the State of Georgia issued to him by the U.S. Fish and Wildlife Service, and unless or until that condition is fulfilled, the taking of Migratory Birds, their parts, nests, or eggs is a violation of the regulations as set forth by the State.

Unless otherwise specified, permittee must submit a complete report of all specimens collected under the authority of this permit upon expiration date of permit. This permit (copy and letter of authorization for subpermittees) must be in possession while collecting.

CONDITIONS: LOCATION: Statewide
1.Fish species shall be collected by seine or electroshocker. State & federally listed fishes may be collected by hand seining or netting, & observed via wading, snorkeling, scuba diving, or backpack electrofishing. Federally-listed fish species may be temporarily retained for identification purposes, & shall be released near their original point of capture immediately after identification.
2.Freshwater unionids shall be collected using visual searches (SCUBA, snorkeling, viewbuckets), tactile searches, raking, & ponar dredge. Specimens may be retained for further identification & voucher collections providing that the specimens are not state or federally listed as unusual, rare, threatened, or endangered. All state & federally listed species should be immediately identified, counted, photographed, or measured & returned to the substrate from which they were collected.
3.WRD has determined, pursuant to O.C.G.A. 27-2-12, that this permit will provide valuable information regarding the species & population proposed for study. WRD has determined that this project is of sound design, does not duplicate previous research, & will not be detrimental to the species or populations proposed for study. O.C.G.A. 27-2-12(e) requires that the permittee submit to DNR, reports detailing the information or data obtained from such collections & in carrying out this permittee is therefore acting as an agent of DNR in furthering the conservation & protection of this state's natural resources.
** This permit is subject to general provisions numbered 1-15, General Permit Conditions for State Protected Fishes NonGame conservation section- updated March 2015,and General conditions for freshwater mollusks January 2013 version, as attached. All pages pages shall be attached hereto. (4 pages, including permit)

Permit is 4 pages total.

Signature of Permittee

Date Issued: 02-MAR-16
Expiration date: March 31, 2017

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

FEDERAL FISH AND WILDLIFE PERMIT

1. PERMITTEE

GERALD R DINKINS
DINKINS BIOLOGICAL CONSULTING
3716 W. BEAVER CREEK DRIVE
POWELL, TN 37849
U.S.A.

2. AUTHORITY-STATUTES
16 USC 1539(a)
16 USC 1533(d)

REGULATIONS
50 CFR 17.22
50 CFR 17.32

50 CFR 13

3. NUMBER
TE069794-4 | AMENDMENT

4. RENEWABLE
☒ YES
☐ NO

5. MAY COPY
☒ YES
☐ NO

6. EFFECTIVE
07/12/2013

7. EXPIRES
07/31/2015

8. NAME AND TITLE OF PRINCIPAL OFFICER (If #1 is a business)

9. TYPE OF PERMIT
NATIVE ENDANGERED & THREATENED SP. RECOVERY - E & T WILDLIFE

10. LOCATION WHERE AUTHORIZED ACTIVITY MAY BE CONDUCTED
FLORIDA, MISSISSIPPI, LOUISIANA, GEORGIA, TENNESSEE, ALABAMA, KENTUCKY, VIRGINIA, WEST VIRGINIA, NORTH CAROLINA, INDIANA, ILLINOIS, MISSOURI, OHIO, IOWA, MINNESOTA, WISCONSIN, MICHIGAN

11. CONDITIONS AND AUTHORIZATIONS:

A. GENERAL CONDITIONS SET OUT IN SUBPART D OF 50 CFR 13, AND SPECIFIC CONDITIONS CONTAINED IN FEDERAL REGULATIONS CITED IN BLOCK #2 ABOVE, ARE HEREBY MADE A PART OF THIS PERMIT. ALL ACTIVITIES AUTHORIZED HEREIN MUST BE CARRIED OUT IN ACCORD WITH AND FOR THE PURPOSES DESCRIBED IN THE APPLICATION SUBMITTED. CONTINUED VALIDITY, OR RENEWAL, OF THIS PERMIT IS SUBJECT TO COMPLETE AND TIMELY COMPLIANCE WITH ALL APPLICABLE CONDITIONS, INCLUDING THE FILING OF ALL REQUIRED INFORMATION AND REPORTS.

B. THE VALIDITY OF THIS PERMIT IS ALSO CONDITIONED UPON STRICT OBSERVANCE OF ALL APPLICABLE FOREIGN, STATE, LOCAL, TRIBAL, OR OTHER FEDERAL LAW.

C. VALID FOR USE BY PERMITTEE NAMED ABOVE.

D. PERMITTEE IS AUTHORIZED TO TAKE (HARASS, CAPTURE, HANDLE, IDENTIFY, RELEASE, TRANSLOCATE LIVE SPECIMENS, AND COLLECT RELICT SHELLS) THE ENDANGERED AND THREATENED AQUATIC SPECIES LISTED ON THE ATTACHED LIST WHILE CONDUCTING PRESENCE AND ABSENCE SURVEYS, AS CONDITIONED BELOW:

1. FEDERALLY-LISTED FISH SPECIES MAY BE CAPTURED BY HAND SEINING OR NETTING, AND OBSERVED VIA WADING, SNORKELING, SCUBA DIVING, OR BACKPACK ELECTROFISHING. FEDERALLY-LISTED FISH SPECIES MAY BE TEMPORARILY RETAINED FOR IDENTIFICATION PURPOSES, AND SHALL BE RELEASED AT THEIR ORIGINAL POINT OF CAPTURE IMMEDIATELY AFTER IDENTIFICATION.

2. HAND COLLECTING IS THE ONLY COLLECTION METHOD AUTHORIZED FOR MOLLUSKS. COLLECTION OF LIVE MUSSELS IS LIMITED TO A BRIEF PERIOD OF TIME USED TO IDENTIFY AND PHOTOGRAPH THEM. RETAINING LIVE SPECIMENS IS **NOT** AUTHORIZED. ALL LIVE MOLLUSKS WHICH ARE CAPTURED MUST BE RETURNED TO, AND POSITIONED PROPERLY ON THE SUBSTRATE AT THE APPROXIMATE POINT OF CAPTURE.

A. ELECTROSHOCKING SHALL BE ONLY USED DURING PRESENCE/ABSENCE SURVEYS FOR CHEROKEE DARTERS IN SMALLER ETOWAH BASIN TRIBUTARIES.

B. COLLECTIONS IN THE MAINSTEM OF ETOWAH RIVER AND IN OTHER UPPER COOSA BASINS (CONASAUGA,

☒ ADDITIONAL CONDITIONS AND AUTHORIZATIONS ALSO APPLY

12. REPORTING REQUIREMENTS
REPORTS WILL BE PROVIDED TO THE U.S. FISH AND WILDLIFE SERVICE OFFICES APPEARING IN CONDITIONS L AND M OF THIS PERMIT. REPORTING CONTENT, FORMAT, SUFFICIENCY AND FREQUENCY ARE OUTLINED IN CONDITION K OF THIS PERMIT.

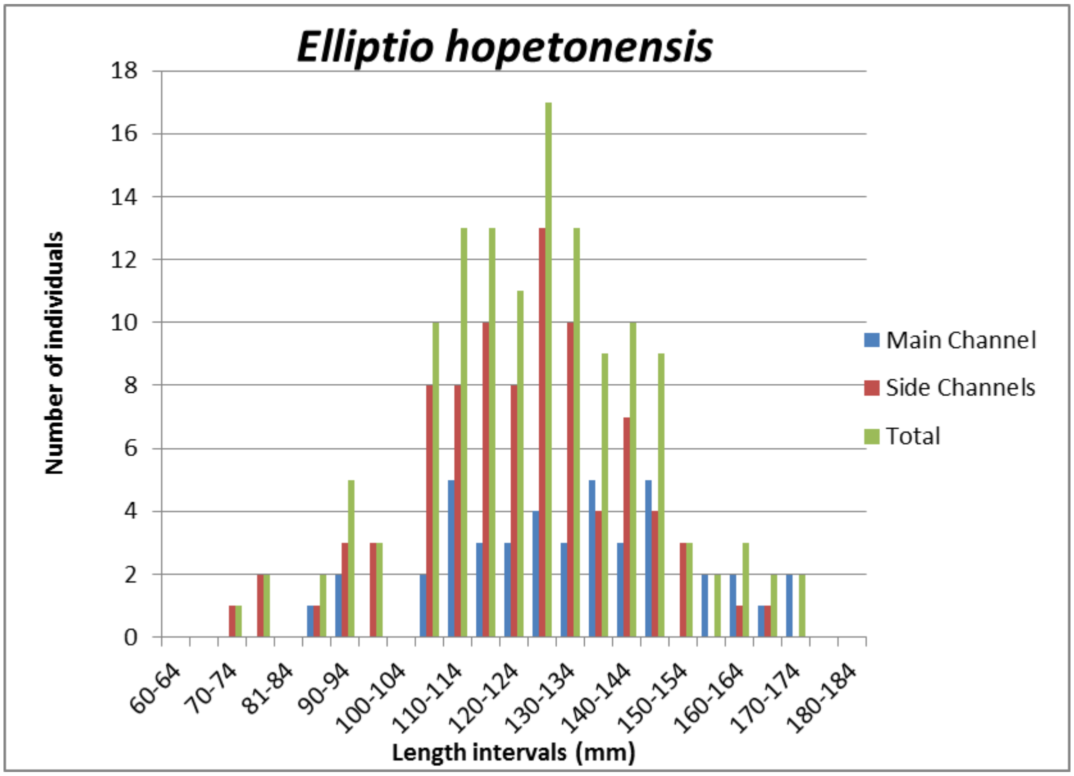
ISSUED BY

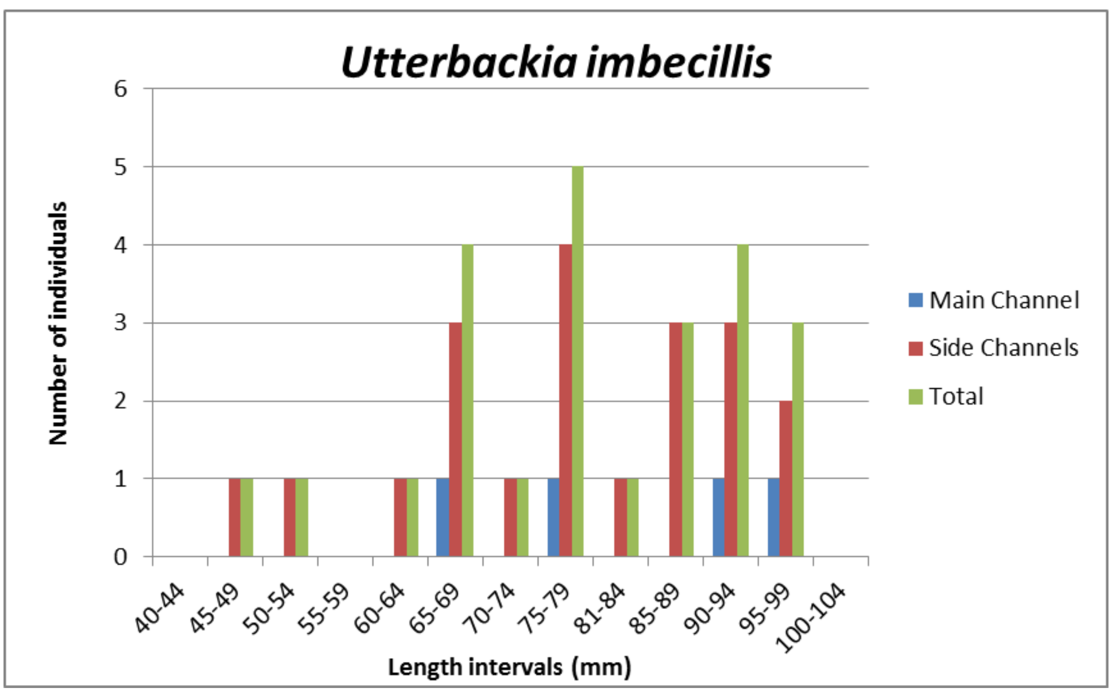
TITLE
CHIEF, DIVISION OF ENDANGERED SPECIES

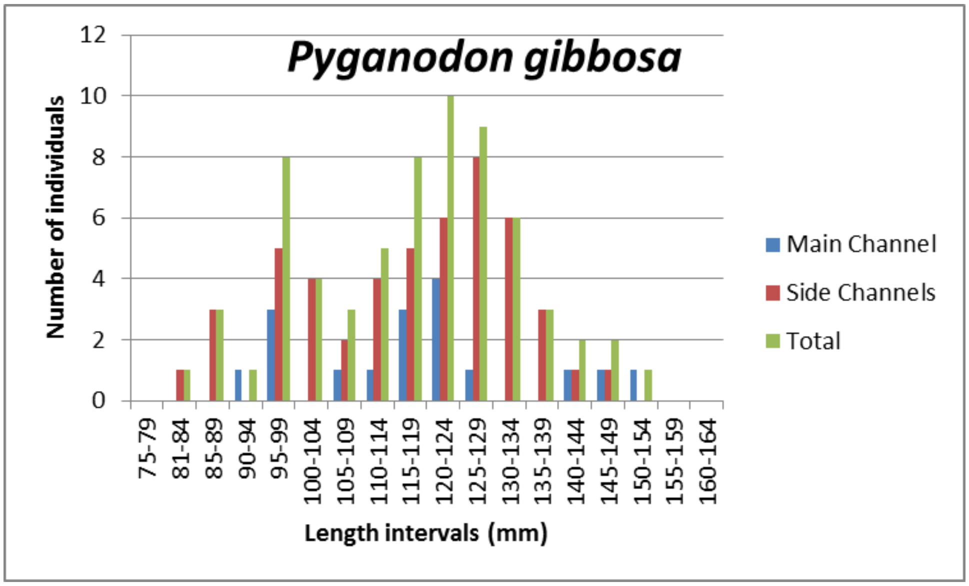
DATE
07/12/2013

APPENDIX B

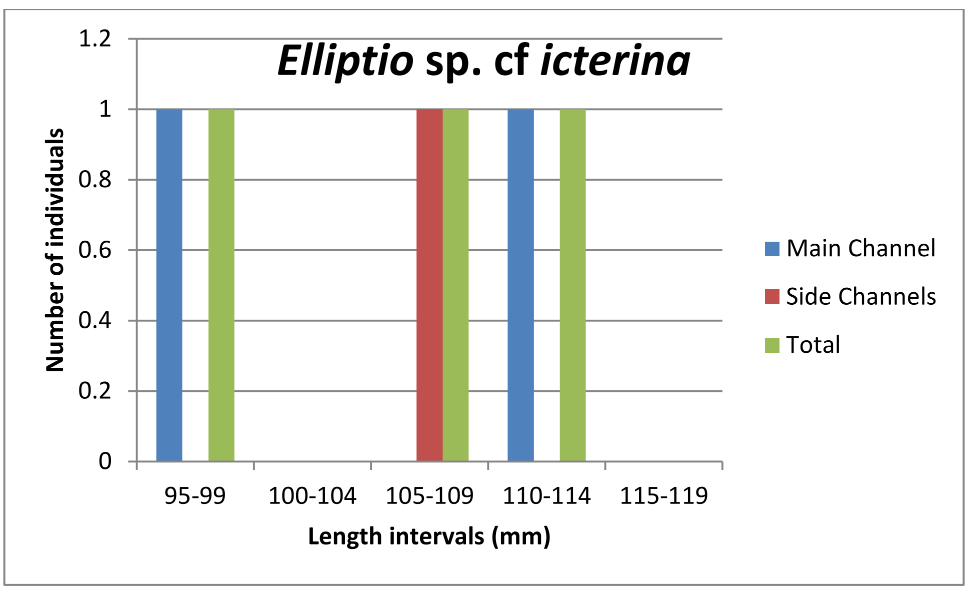
LENGTH FREQUENCIES


Elliptio hopetonensis
Number of individuals
Length intervals (mm)
Main Channel
Side Channels
Total
0
2
4
6
8
10
12
14
16
18
60-64
70-74
81-84
90-94
100-104
110-114
120-124
130-134
140-144
150-154
160-164
170-174
180-184


Utterbackia imbecillis
Number of individuals
Length intervals (mm)
Main Channel
Side Channels
Total
0
1
2
3
4
5
6
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
81-84
85-89
90-94
95-99
100-104



Pyganodon gibbosa
Number of individuals
Length intervals (mm)
Main Channel
Side Channels
Total
0
2
4
6
8
10
12
75-79
81-84
85-89
90-94
95-99
100-104
105-109
110-114
115-119
120-124
125-129
130-134
135-139
140-144
145-149
150-154
155-159
160-164



Elliptio sp. cf icterina
Number of individuals
Length intervals (mm)
Main Channel
Side Channels
Total
0
0.2
0.4
0.6
0.8
1
1.2
95-99
100-104
105-109
110-114
115-119

SURVEY FOR FRESHWATER MUSSELS IN TAILRACE BELOW WALLACE DAM

Prepared for:

Georgia Power

Prepared by:

Gerald R. Dinkins
Dinkins Biological Consulting, LLC
PO Box 1851
Powell, TN 37849

October 2016

DBC Project 1296

SECTION 1
INTRODUCTION

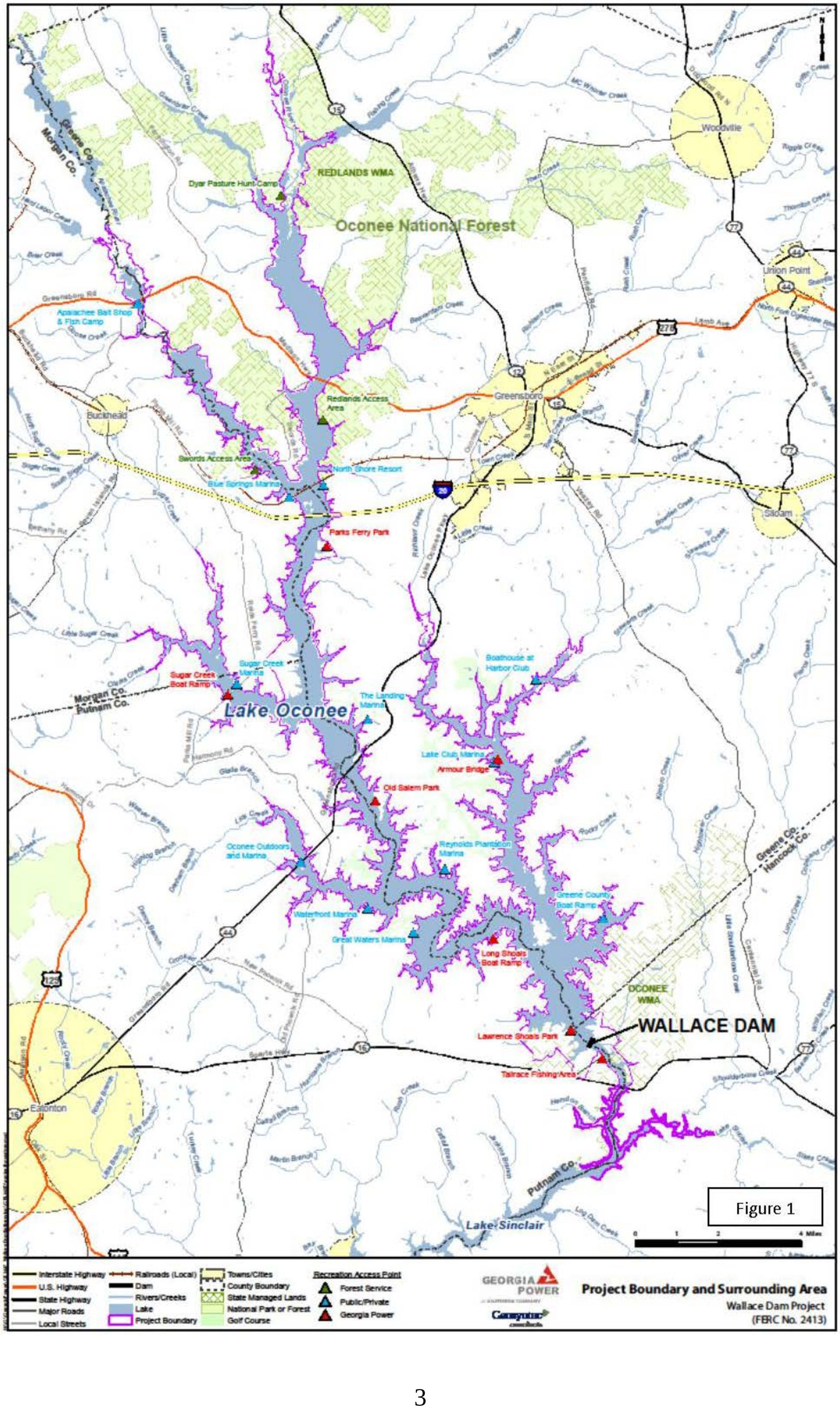
1.0 INTRODUCTION

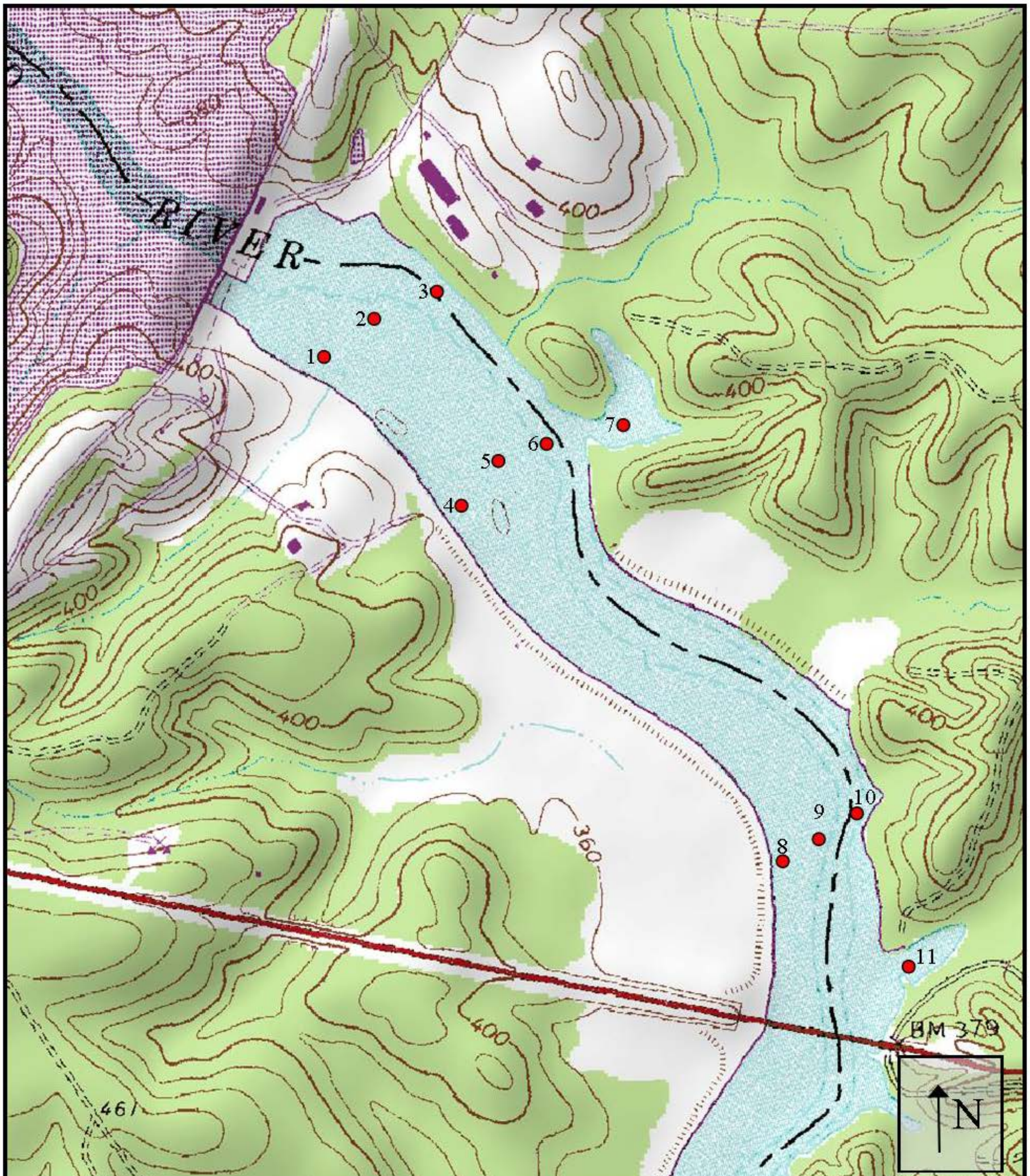
Georgia Power Company is conducting baseline characterization of natural resources, including freshwater mussel fauna, at their Wallace Dam hydroelectric power generation project. The project is licensed by the Federal Energy Regulatory Commission (FERC) as Project No. 2413. Wallace Dam impounds Lake Oconee and is operated as a pumped storage system. Wallace Dam releases water downstream directly into the backwaters of Lake Sinclair during peak power demand hours and pumps water back up into Lake Oconee at night for reuse in the next day's generation cycle. The project boundary extends downstream of Wallace Dam about 1.5 river miles to State Route 16 as thin strips of land along each side of the narrow upper reach of Lake Sinclair (Figure 1). This downstream section (tailwater) is the subject of this mussel survey report. Little is known about the mussels in the area, although there have been recent surveys in Lake Oconee (Dinkins 2016) and in the Oconee River downstream of Lake Sinclair (Dinkins 2011, Wisniewski et al. 2005).

2.0 METHODS

The study area below Wallace Dam began at the dam and extended downstream approximately 1.5 miles to the State Route 16 bridge. The survey was conducted 23-25 August 2016 between sunrise and 1130 during a period of managed flow reduction to maximize the ability of the survey team to adequately search selected habitats. The survey focused on both sides of the channel, and included two backwater areas (Figure 2, Table 1). The study team was led by Gerald Dinkins (GRD), assisted by Robert Eldridge (RTE), Hugh Faust (HDF), and Brian Mize (BMM). A copy of Mr. Dinkins Federal Endangered Species Permit and Georgia Department of Natural Resources Permit is provided in Appendix A. During the survey period, the habitat below Wallace Dam consisted of wadeable (coves) and non-wadeable habitats (main channel). All of the main channel sites required SCUBA, while the coves were shallow and could be sampled with mask and snorkel. The first day of the survey began with a reconnaissance of benthic substrates in the study area. In this initial reconnaissance, best professional judgment was applied in identifying representative habitats containing potentially suitable substrates for native mussels. Nine areas in the river channel and two backwater areas were investigated for the presence of native freshwater mussels. The nine areas in the river channel were arranged in groups of three each across the span of the channel. The two backwater areas occurred along the left descending bank, and were where small, unnamed tributaries were impounded by backwaters of the tailrace. The field surveys were conducted consistent with the effort required to provide data for the occupancy model developed by Jason Wisniewski (Georgia Wildlife Resources Division) and others for streams in the Altamaha River basin. To that end, one person-hour was spent searching for native mussels at each location. The amount of time spent at each location was closely monitored to ensure the resulting data closely conforms to the needs of the model. In addition, the search effort and capture efficiency of each individual searcher was tracked separately. In the river channel, the field team used SCUBA. In the two backwater areas, the field team snorkeled, waded, and grubbed the substrate while on hands and knees.

Each survey location was documented in the field using a hand-held GPS unit. Digital photographs were taken of representative live specimens of each species collected. All live mussels were returned unharmed to appropriate habitats in the area of collection. The surveyors recorded field notes and general information about the survey area including date and time of survey; individual survey capture, water clarity; and depth and substrate composition. A representative number of each species was measured to the nearest millimeter (length) to produce a length frequency histogram.


Lake Oconee
WALLACE DAM
Oconee National Forest
REDLANDS WMA
OCONEE WMA
Lake Sinclair
Greensboro
Eatonton
Buckhead
Woodville
Union Point
Siloam
Morgan Co.
Putnam Co.
Greene Co.
Hancock Co.
Dyar Pasture Hunt Camp
Apalachee Bait Shop & Fish Camp
Redlands Access Area
Swords Access Area
North Shore Resort
Blue Springs Marina
Parks Ferry Park
Sugar Creek Boat Ramp
Sugar Creek Marina
The Landing Marina
Boathouse at Harbor Club
Lake Club Marina
Armour Bridge
Old Salem Park
Oconee Outdoors and Marina
Reynolds Plantation Marina
Waterfront Marina
Great Waters Marina
Long Shoals Boat Ramp
Greene County Boat Ramp
Lawrence Shoals Park
Tailrace Fishing Area
Interstate Highway
U.S. Highway
State Highway
Major Roads
Local Streets
Railroads (Local)
Dam
Rivers/Creeks
Lake
Project Boundary
Towns/Cities
County Boundary
State Managed Lands
National Park or Forest
Golf Course
Recreation Access Point
Forest Service
Public/Private
Georgia Power
GEORGIA POWER
Project Boundary and Surrounding Area
Wallace Dam Project
(FERC No. 2413)
Figure 1



USGS Quadrangle Rockville, GA	Figure 2 Mussel Survey Locations Wallace Dam Tailrace, Georgia
Dinkins Biological Consulting PO Box 1851 Powell, TN 37849	0 100 200 300 400 500 m

Table 1. Description of mussel survey locations below Wallace Dam.

Site	Latitude	Longitude	Date	Location	Habitat Notes	Effort (person hours)
1	N33.34778	W83.15574	23 Aug 2016	Main channel, right descending side	Rip-rap bank on right side of channel; depth 5	1
2	N33.34867	W83.15412	23 Aug 2016	Main channel, middle	Directly below dam	1
3	N33.34972	W83.15322	23 Aug 2016	Main channel, left descending side	None	1
4	N33.34507	W83.15219	24 Aug 2016	Main channel, right descending side	Directly out from opening of small cove on left descending bank	1
5	N33.34590	W83.15141	24 Aug 2016	Main channel, middle	None	1
6	N33.34613	W83.15013	24 Aug 2016	Main channel, left descending side	Cold water detected emanating from substrate at one location (spring?)	1
7	N33.34628	W83.14899	25 Aug 2016	Cove on left descending side	None	1
8	N33.33816	W83.14480	25 Aug 2016	Main channel, right descending side	Current flowing back upstream along bottom	1
9	N33.33804	W83.14422	25 Aug 2016	Main channel, middle	Occasional logs stuck into substrate, some large bedrock outcrops; mussels deeply inserted.	1
10	N33.33893	W83.14314	25 Aug 2016	Main channel, left descending side	Vertical bedrock shelves with mussels in troughs	1
11	N33.33592	W83.14247	25 Aug 2016	Cove on left descending side	Submerged aquatic vegetation abundant	1
					Total Effort	11 person hours

3.0 RESULTS

At most of the sites in the main channel, the substrate was relatively evenly represented by sand, gravel and cobble. Boulders and bedrock were present at most of the sites (Table 2). In the two coves, the substrate was dominated by silt. Depths in the main channel varied, and ranged between 1.5 and 9.1 meters. In general, the depth of the main channel between the dam and the SR 16 bridge averaged seven meters. In the two coves, depths were shallow and averaged between 0.6 and 0.7 meters.

A total of 1479 live mussels representing four species were found in the main channel and two coves: Altamaha Slabshell (*Elliptio hopetonensis*), Paper Pondshell (*Utterbackia imbecillis*), Inflated Floater (*Pyganodon gibbosa*), and a species that conchologically appeared to be Variable Spike (*Elliptio icterina*). All four species were present in both the main, but the Variable Spike was absent from the two coves. An average of 161.4 mussels was found in each main channel sites, compared to an average of 13.0 mussels in the two coves.

In the main channel, the most common species was Altamaha Slabshell, comprising 98.1% of all specimens. Variable Spike, Inflated Floater, and Paper Pondshell were relatively equal in occurrence (1% or less) (Table 3). In general, the number of live mussels decreased with increasing distance from the dam (Table 4). The greatest number of mussels was found at Site 3, approximately 300 meters downstream of the dam near the left descending bank. Within the channel, mussels were more common on the sides of the channel compared to the center (Table 5). Overall, mussels were considerably more common on the left side compared to right side of the channel. Most of the difference was attributable to the Altamaha Slabshell.

The number of specimens of each species collected by site for each person on the survey team is provided in Table 6.

Length frequency distributions for the most common species (*Elliptio hopetonensis*) in the main channel downstream of Wallace Dam indicated a normal distribution with recruitment (Appendix B). Recruitment was also observed in the other three species, but no inference can be made as to their size distributions because relatively few individuals were encountered.

4.0 REFERENCES

Dinkins, G.R. 2007. Aquatic Protected Species Report. Survey of Fish, Mussels, and Snails in Oconee River at State Route 30/U.S. 280, Wheeler/Montgomery County, Georgia. Report to Georgia Department of Transportation.

Dinkins, G.R. 2011. Aquatic Protected Species Report. Survey of Fish, Mussels, and Snails in Oconee River at State Route 30/U.S. 280, Wheeler/Montgomery County, Georgia. Report to Georgia Department of Transportation.

Dinkins, G.R. 2016. Survey for Freshwater Mussels in Lake Oconee. Report to Georgia Power. October 2016.

Wisniewski, J.M., Krakow, G. and Albanese, B. 2005. Current Status of Endemic Mussels in the Lower Ocmulgee and Altamaha Rivers. In: Hatcher, K.J (ed.), Proceedings of the 2005 Georgia Water Resources Conference. The University of Georgia, Athens, Georgia

Table 2. Characteristics of survey locations (% composition).

Site	Detritus	Clay	Silt	Sand	Gravel	Cobble	Boulder	Bedrock	Depth Range (m)	Avg. Depth (m)
Main Channel										
1					10	30		60	1.5	1.5
2					40	50	10		4.6	4.6
3				10	30	30	30		6.1	6.1
4				20	30	50			6.4-7.3	7.3
5				40	50		10		5.8	5.8
6	10			20	40	20	10		4.6	4.6
8				30	60			10	5.5-6.7	6.1
9			20	80					6.7-9.1	7.6
10					10	30		60	6.1	6.1
Coves										
7			80	20					0.3-1.2	0.8
11			100						0.3-0.9	0.6

Table 3. Individual species results.

Site	*E. hopetonensis*	*P. gibbosa*	*U. imbecillis*	*E. icterina*	TOTAL
Main Channel					
1	303	0	0	3	306
2	32	0	0	0	32
3	493	4	1	3	501
4	81	0	0	3	84
5	84	0	1	6	91
6	149	2	1	0	152
8	3	0	0	0	3
9	13	0	0	0	13
10	267	2	0	2	271
Subtotal	1425	8	3	17	1453
Mean	158.3	0.9	0.3	1.8	161.4
% occurrence	98.1	<1.0	<1.0	1.0	
Coves					
7	7	1	3	0	11
11	10	1	4	0	15
Subtotal	17	2	7	0	26
Mean	8.5	1.0	3.5	0.0	13.0
% occurrence	65.4	7.7	26.9	0.0	

Table 4. Individual species results based on distance from dam.

Sites	Distance from Dam (m)	*E. hopetonensis*	*P. gibbosa*	*U. imbecillis*	*E. icterina*	TOTAL
1,2,3	300	828	4	1	6	839
4,5,6	980	314	2	2	9	327
8,9,10	1870	283	2	0	2	287
	Subtotal	1425	8	3	7	1453

Table 5. Individual species results based on location in channel.

Sites	Channel Location	*E. hopetonensis*	*P. gibbosa*	*U. imbecillis*	*E. icterina*	TOTAL
1,4,8	Right	387	0	0	6	393
2,5,9	Center	129	0	1	6	136
3,6,10	Left	909	8	2	5	924
	Subtotal	1425	8	3	17	1453

Table 6. Individual surveyor results.

Site	Surveyor	Species				Total
		E. hopetonensis	*P. gibbosa*	*U. imbecillis*	*E. icterina*	
1	GRD	159			2	161
	BMM	144			1	145
	Total	303			3	306
2	GRD	7				7
	BMM	25				25
	Total	32				32
3	GRD	134	2		2	138
	BMM	359	2	1	1	363
	Total	493	4	1	3	501
4	RTE	37			1	38
	HDF	44			2	46
	Total	81			3	84
5	RTE	38		1	4	43
	HDF	46			2	48
	Total	84		1	6	91
6	RTE	83	1	1		85
	HDF	66	1			67
	Total	149	2	1		152
7	GRD	3		2		5
	RTE	4	1			5
	HDF			1		1
	Total	7	1	3		11
8	BMM	3				3
	GRD	0				0
	Total	3				3
9	BMM	7				7
	GRD	6				6
	Total	13				13
10	BMM	127	2			129
	GRD	140	2			142
	Total	267	4			271
11	HDF	1				1
	BMM	7		2		9
	GRD	2	1	2		5
	Total	10	1	4		15

APPENDIX A

COLLECTING PERMITS

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
WILDLIFE RESOURCES DIVISION

SCIENTIFIC COLLECTING PERMIT

(29-WJH-16-73) **FEE: $50**

Permittee: **DINKINS BIOLOGICAL CONSULTING, G. DINKINS**
PO BOX 1851
POWELL, TN 37849 5103
CN: 8947

Species: NATIVE LISTED & NON-LISTED FRESHWATER MUSSELS/SNAILS & FISHES
Numbers(if applicable):
Expiration date: **March 31, 2017**

Above named is hereby permitted, in accordance with O.C.GA 27-2-12 and the regulations of the Georgia Department of Natural resources subject to the terms, exceptions, and restrictions expressed on the attached "General Conditions" and subject to any other applicable State or federal regulations, to take for scientific and educational purposes only in the State of Georgia, wildlife which is listed above.

This permit is conditional and confers NO priviledges whatsoever to take, possess, exchange, or transport migratory birds or their parts, nests, or eggs unless the permittee has in his possession, while exercising the priviledge granted herein a valid subsisting permit to take Migratory Birds and their parts, nests, or eggs for scientific purposes in the State of Georgia issued to him by the U.S. Fish and Wildlife Service, and unless or until that condition is fulfilled, the taking of Migratory Birds, their parts, nests, or eggs is a violation of the regulations as set forth by the State.

Unless otherwise specified, permittee must submit a complete report of all specimens collected under the authority of this permit upon expiration date of permit. This permit (copy and letter of authorization for subpermittees) must be in possession while collecting.

CONDITIONS: LOCATION: Statewide
1.Fish species shall be collected by seine or electroshocker. State & federally listed fishes may be collected by hand seining or netting, & observed via wading, snorkeling, scuba diving, or backpack electrofishing. Federally-listed fish species may be temporarily retained for identification purposes, & shall be released near their original point of capture immediately after identification.
2.Freshwater unionids shall be collected using visual searches (SCUBA, snorkeling, viewbuckets), tactile searches, raking, & ponar dredge. Specimens may be retained for further identification & voucher collections providing that the specimens are not state or federally listed as unusual, rare, threatened, or endangered. All state & federally listed species should be immediately identified, counted, photographed, or measured & returned to the substrate from which they were collected.
3.WRD has determined, pursuant to O.C.G.A. 27-2-12, that this permit will provide valuable information regarding the species & population proposed for study. WRD has determined that this project is of sound design, does not duplicate previous research, & will not be detrimental to the species or populations proposed for study. O.C.G.A. 27-2-12(e) requires that the permittee submit to DNR, reports detailing the information or data obtained from such collections & in carrying out this permittee is therefore acting as an agent of DNR in furthering the conservation & protection of this state's natural resources.
** This permit is subject to general provisions numbered 1-15, General Permit Conditions for State Protected Fishes NonGame conservation section- updated March 2015,and General conditions for freshwater mollusks January 2013 version, as attached. All pages pages shall be attached hereto. (4 pages, including permit)

Permit is 4 pages total.

Signature of Permittee

Date Issued: 02-MAR-16
Expiration date: March 31, 2017

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

FEDERAL FISH AND WILDLIFE PERMIT

1. PERMITTEE

GERALD R DINKINS
DINKINS BIOLOGICAL CONSULTING
3716 W. BEAVER CREEK DRIVE
POWELL, TN 37849
U.S.A.

2. AUTHORITY-STATUTES
16 USC 1539(a)
16 USC 1533(d)

REGULATIONS
50 CFR 17.22
50 CFR 17.32

50 CFR 13

3. NUMBER
TE069754-4 AMENDMENT

4. RENEWABLE
☒ YES
☐ NO

5. MAY COPY
☒ YES
☐ NO

6. EFFECTIVE
07/12/2013

7. EXPIRES
07/31/2015

8. NAME AND TITLE OF PRINCIPAL OFFICER (if #1 is a business)

9. TYPE OF PERMIT
NATIVE ENDANGERED & THREATENED SP. RECOVERY - E & T WILDLIFE

10. LOCATION WHERE AUTHORIZED ACTIVITY MAY BE CONDUCTED
FLORIDA, MISSISSIPPI, LOUISIANA, GEORGIA, TENNESSEE, ALABAMA, KENTUCKY, VIRGINIA, WEST VIRGINIA, NORTH CAROLINA, INDIANA, ILLINOIS, MISSOURI, OHIO, IOWA, MINNESOTA, WISCONSIN, MICHIGAN

11. CONDITIONS AND AUTHORIZATIONS:

A. GENERAL CONDITIONS SET OUT IN SUBPART D OF 50 CFR 13, AND SPECIFIC CONDITIONS CONTAINED IN FEDERAL REGULATIONS CITED IN BLOCK #2 ABOVE, ARE HEREBY MADE A PART OF THIS PERMIT. ALL ACTIVITIES AUTHORIZED HEREIN MUST BE CARRIED OUT IN ACCORD WITH AND FOR THE PURPOSES DESCRIBED IN THE APPLICATION SUBMITTED. CONTINUED VALIDITY, OR RENEWAL, OF THIS PERMIT IS SUBJECT TO COMPLETE AND TIMELY COMPLIANCE WITH ALL APPLICABLE CONDITIONS, INCLUDING THE FILING OF ALL REQUIRED INFORMATION AND REPORTS.

B. THE VALIDITY OF THIS PERMIT IS ALSO CONDITIONED UPON STRICT OBSERVANCE OF ALL APPLICABLE FOREIGN, STATE, LOCAL, TRIBAL, OR OTHER FEDERAL LAW.

C. VALID FOR USE BY PERMITTEE NAMED ABOVE.

D. PERMITTEE IS AUTHORIZED TO TAKE (HARASS, CAPTURE, HANDLE, IDENTIFY, RELEASE, TRANSLOCATE LIVE SPECIMENS, AND COLLECT RELICT SHELLS) THE ENDANGERED AND THREATENED AQUATIC SPECIES LISTED ON THE ATTACHED LIST WHILE CONDUCTING PRESENCE AND ABSENCE SURVEYS, AS CONDITIONED BELOW:

1. FEDERALLY-LISTED FISH SPECIES MAY BE CAPTURED BY HAND SEINING OR NETTING, AND OBSERVED VIA WADING, SNORKELING, SCUBA DIVING, OR BACKPACK ELECTROFISHING. FEDERALLY-LISTED FISH SPECIES MAY BE TEMPORARILY RETAINED FOR IDENTIFICATION PURPOSES, AND SHALL BE RELEASED AT THEIR ORIGINAL POINT OF CAPTURE IMMEDIATELY AFTER IDENTIFICATION.

2. HAND COLLECTING IS THE ONLY COLLECTION METHOD AUTHORIZED FOR MOLLUSKS. COLLECTION OF LIVE MUSSELS IS LIMITED TO A BRIEF PERIOD OF TIME USED TO IDENTIFY AND PHOTOGRAPH THEM. RETAINING LIVE SPECIMENS IS **NOT** AUTHORIZED. ALL LIVE MOLLUSKS WHICH ARE CAPTURED MUST BE RETURNED TO, AND POSITIONED PROPERLY ON THE SUBSTRATE AT THE APPROXIMATE POINT OF CAPTURE.

A. ELECTROSHOCKING SHALL BE ONLY USED DURING PRESENCE/ABSENCE SURVEYS FOR CHEROKEE DARTERS IN SMALLER ETOWAH BASIN TRIBUTARIES.

B. COLLECTIONS IN THE MAINSTEM OF ETOWAH RIVER AND IN OTHER UPPER COOSA BASINS (CONASAUGA,

☒ ADDITIONAL CONDITIONS AND AUTHORIZATIONS ALSO APPLY

12. REPORTING REQUIREMENTS
REPORTS WILL BE PROVIDED TO THE U.S. FISH AND WILDLIFE SERVICE OFFICES APPEARING IN CONDITIONS L AND M OF THIS PERMIT. REPORTING CONTENT, FORMAT, SUFFICIENCY AND FREQUENCY ARE OUTLINED IN CONDITION K OF THIS PERMIT.

ISSUED BY [signature] Acting

TITLE
CHIEF, DIVISION OF ENDANGERED SPECIES

DATE
07/12/2013

APPENDIX B

LENGTH FREQUENCIES

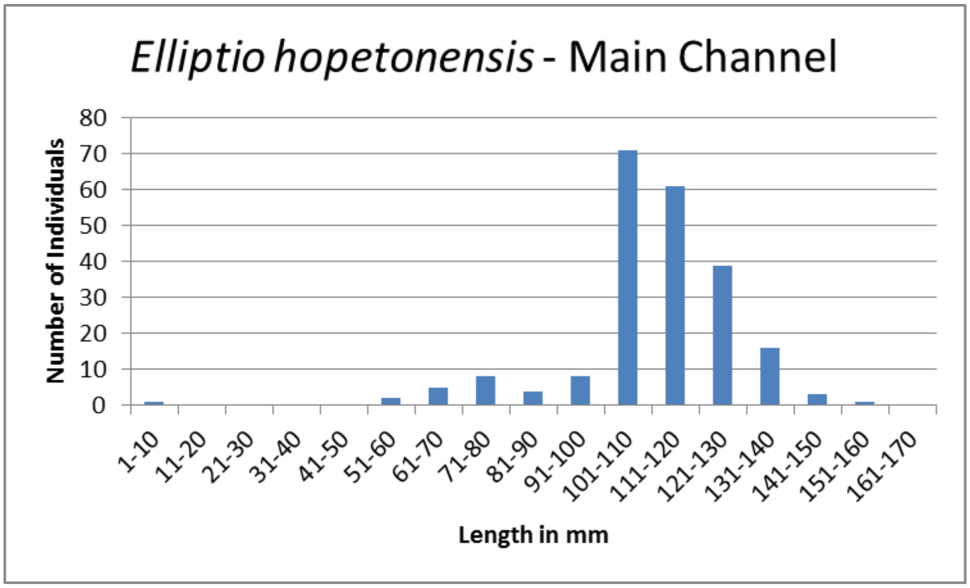


Figure B-1. Length frequency of a representative sample of *Elliptio hopetonensis* (N = 229) from the main channel of Oconee River in the tailrace below Wallace Dam (23-25 August 2016).

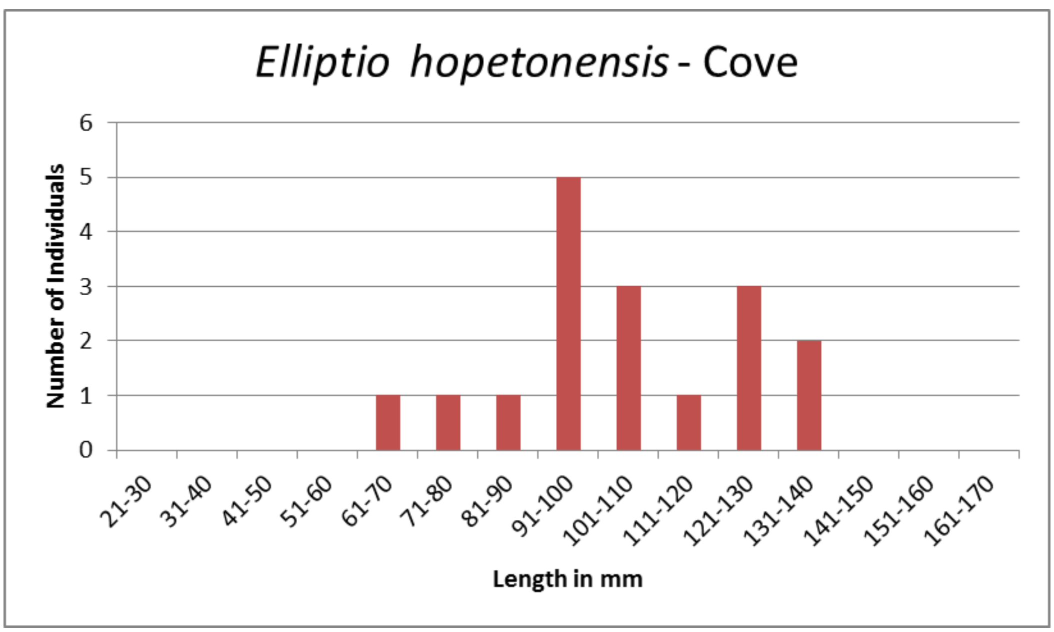


Figure B-2. Length frequency of *Elliptio hopetonensis* (N = 17) from the two coves on the left descending side of the channel of Oconee River in the tailrace below Wallace Dam (23-25 August 2016).

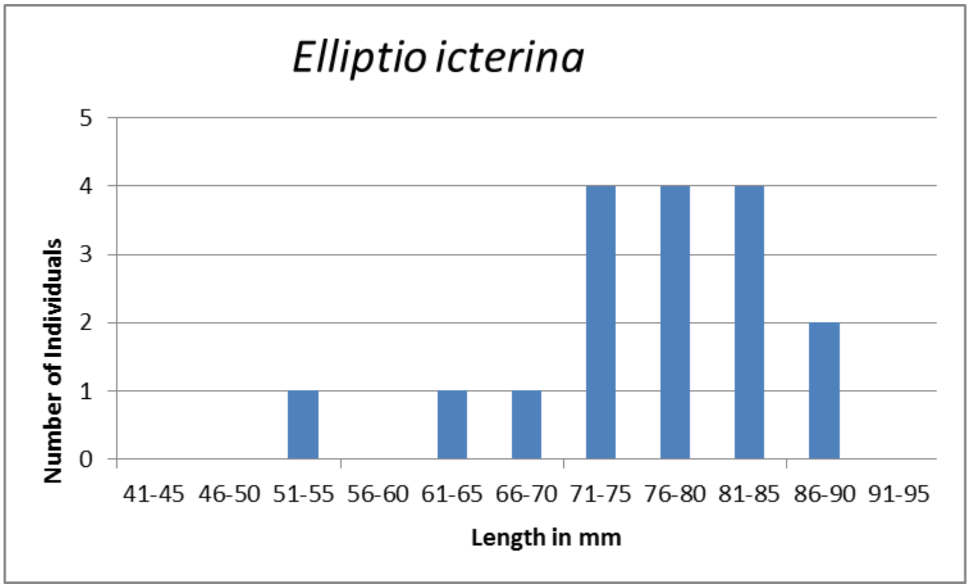


Figure B-3. Length frequency of *Elliptio icterina* from the main channel (N = 17) of Oconee River in the tailrace below Wallace Dam (23-25 August 2016).

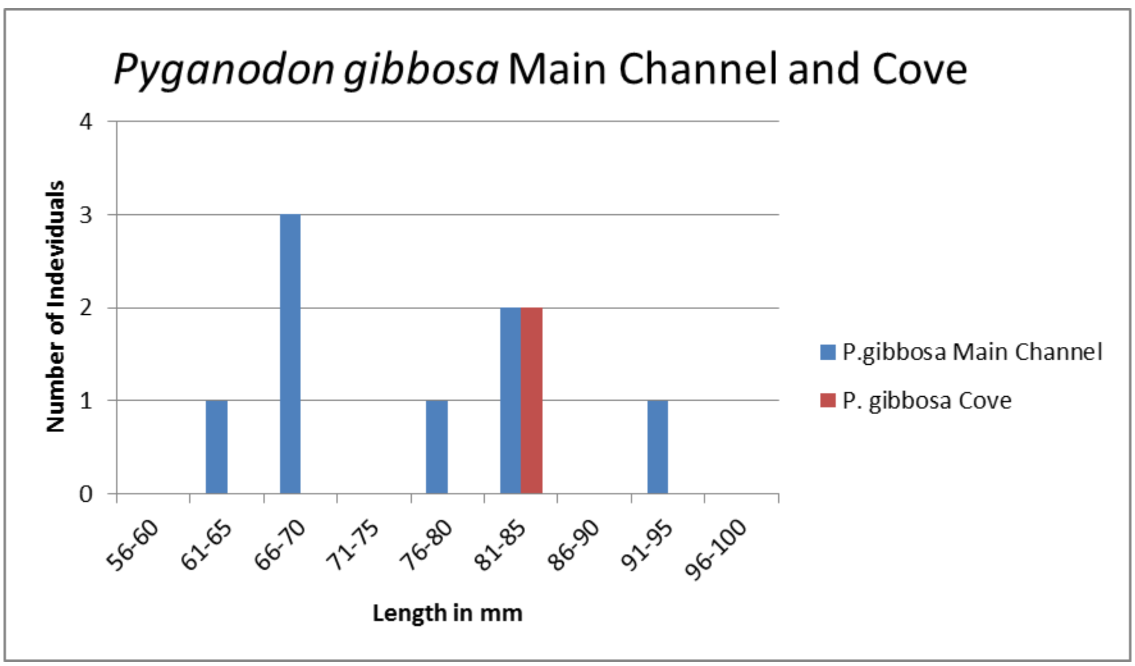


Figure B-4. Length frequency of *Pyganodon gibbosa* (N = 10) from the main channel and two coves of Oconee River in the tailrace below Wallace Dam (23-25 August 2016).

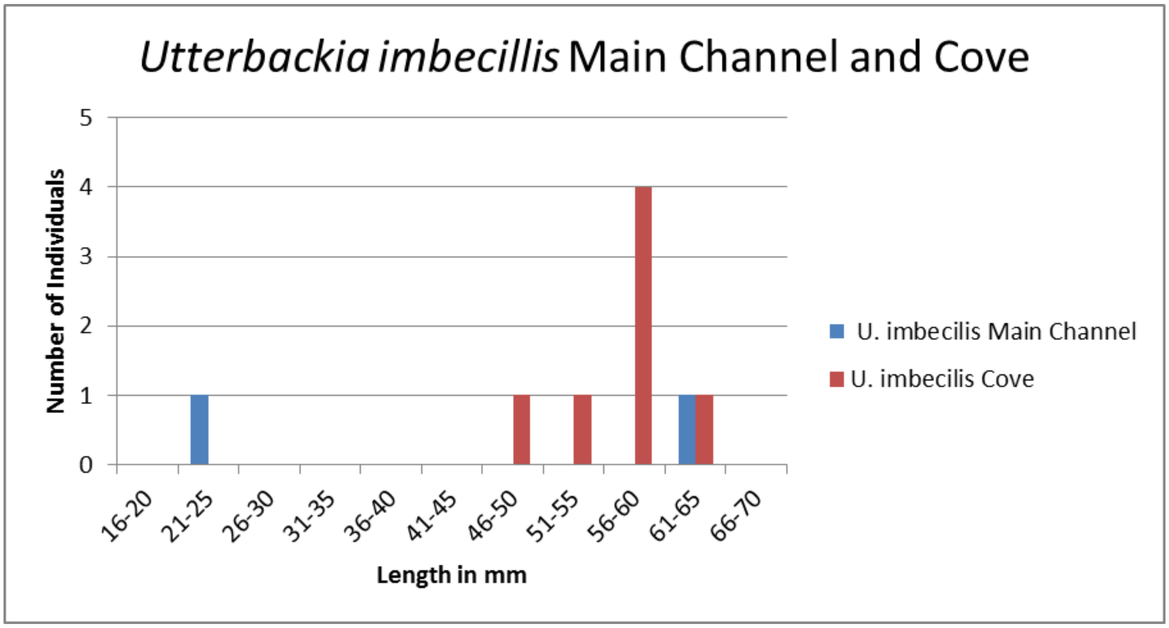


Figure B-5. Length frequency of *Utterbackia imbecillis* (N = 9) from the main channel and two coves of Oconee River in the tailrace below Wallace Dam (23-25 August 2016).

APPENDIX B

Lake Oconee Vertical Profile Data from the Water Resources Study

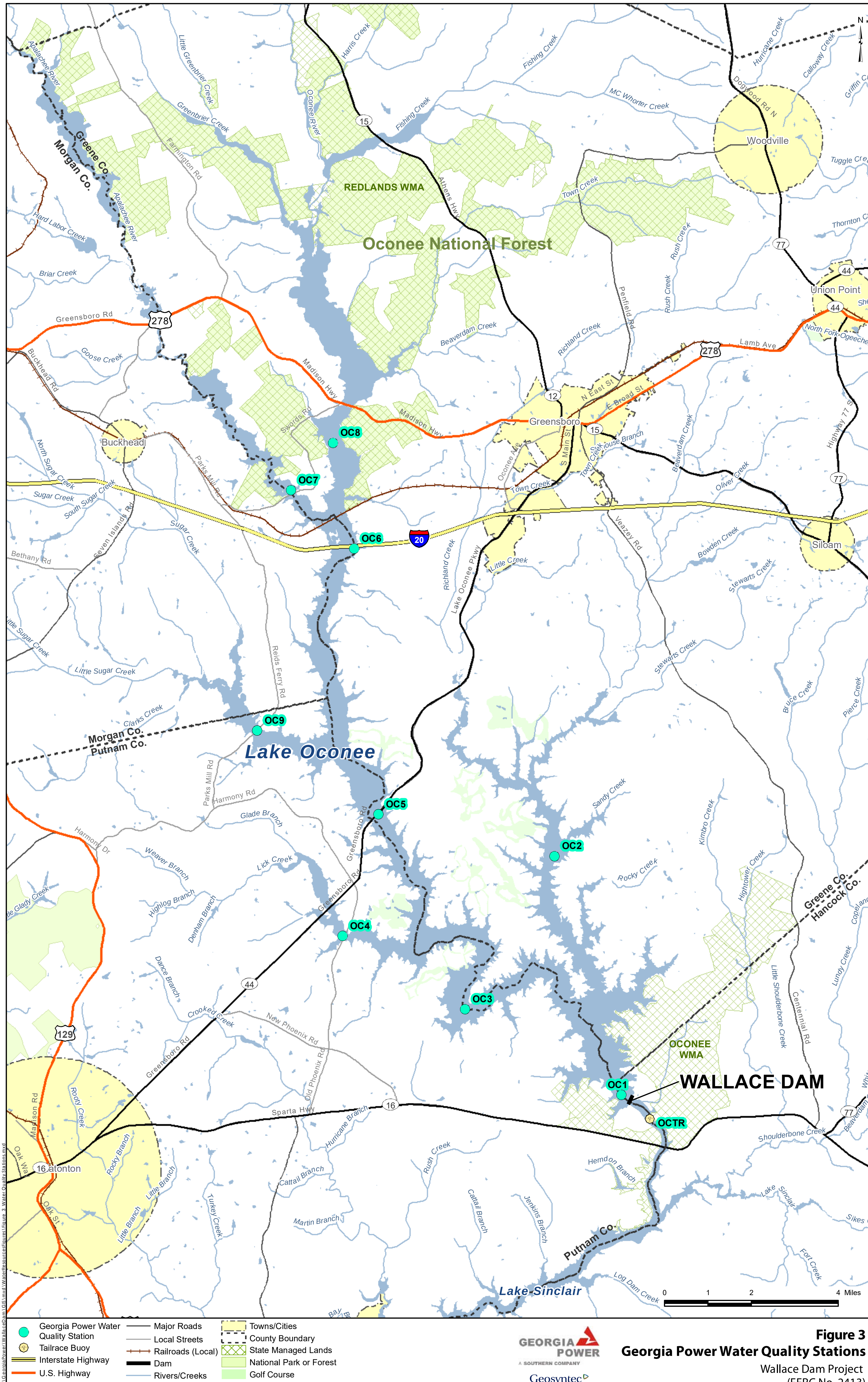


Figure 3
Georgia Power Water Quality Stations
Wallace Dam Project
(FERC No. 2413)

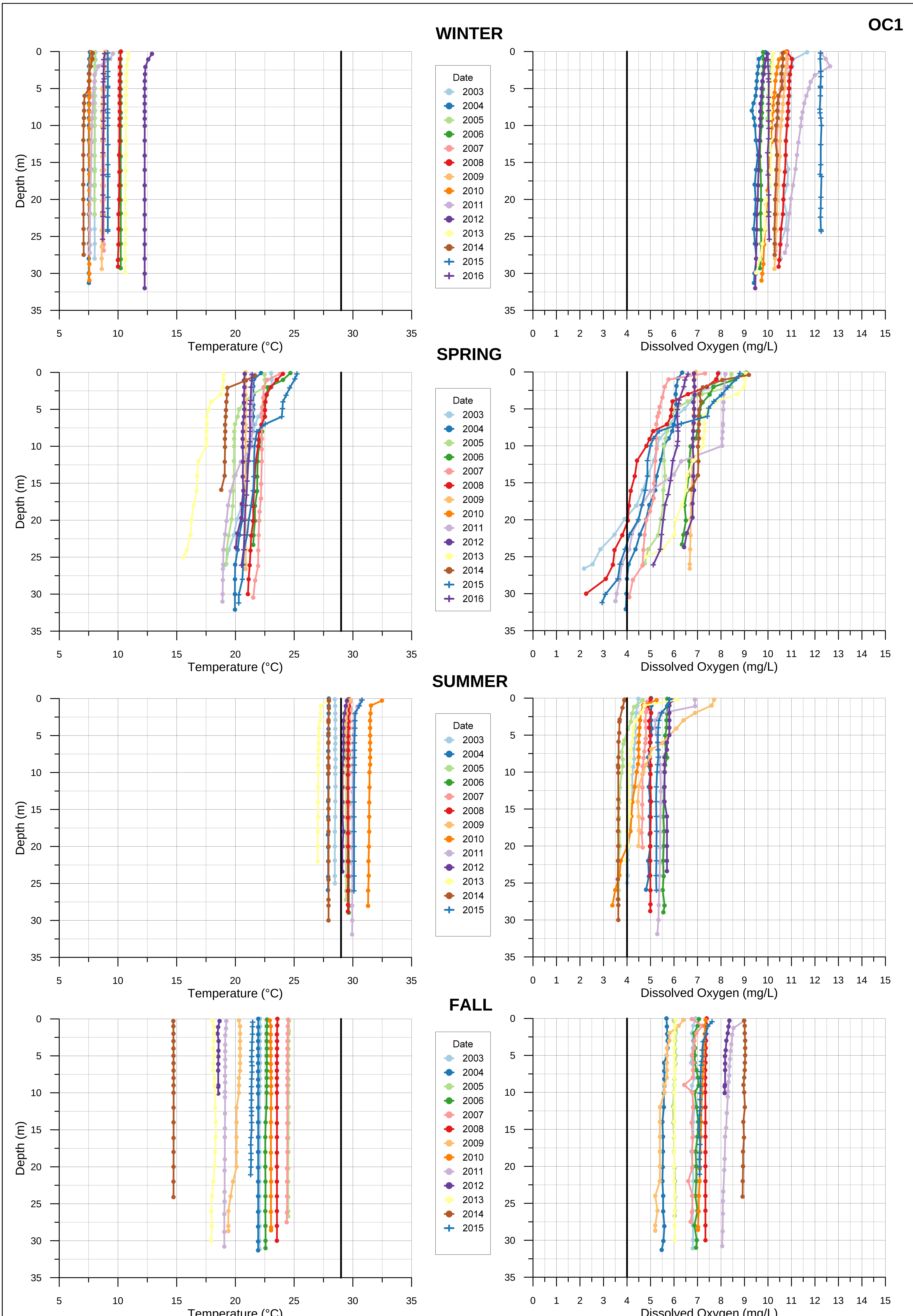


Figure 5a
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC1 2003-2016
Wallace Dam Project
(FERC No. 2413)

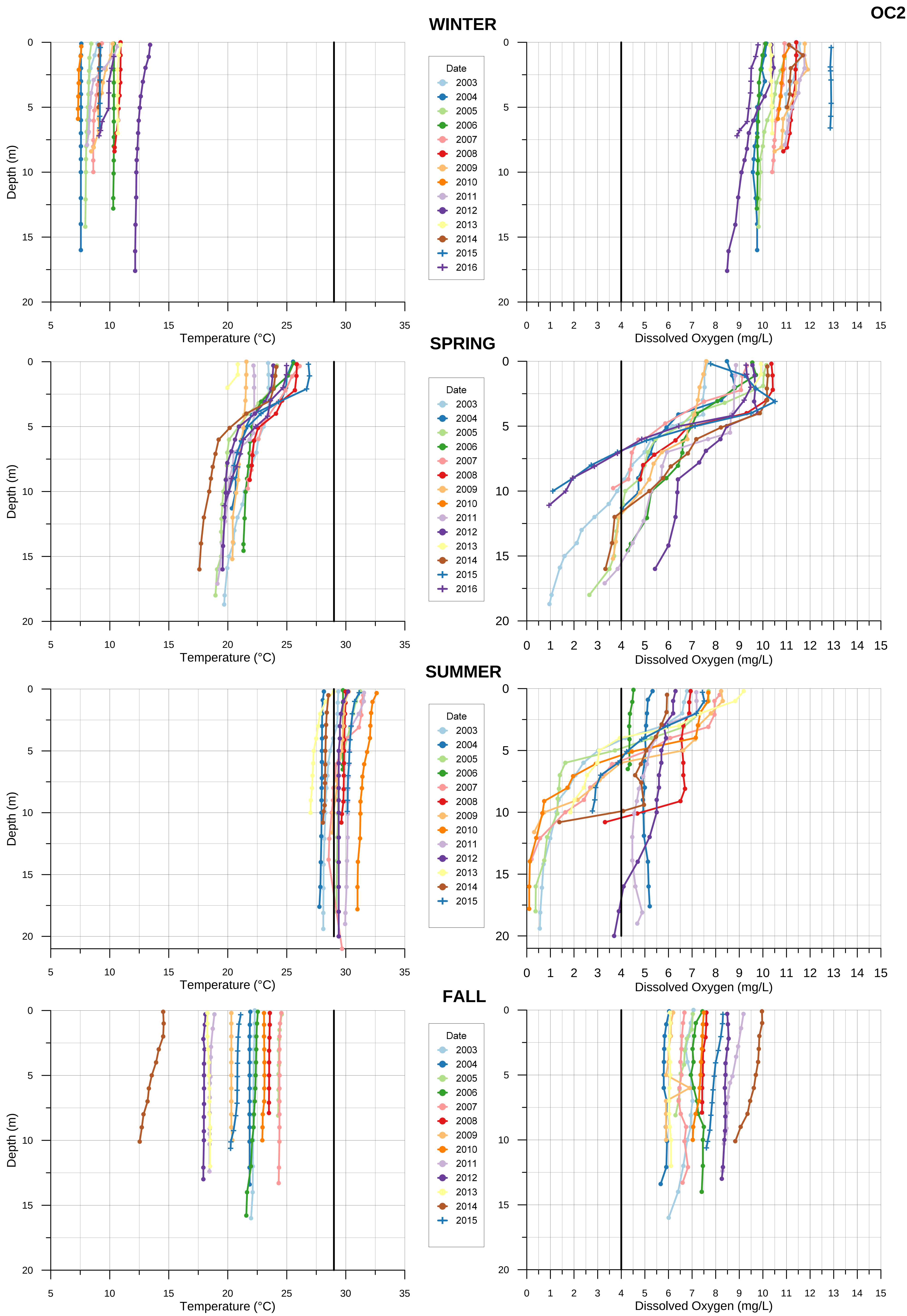


Figure 5b

Seasonal Vertical Temperature and DO Profiles at Lake Oconee

OC2 2003-2016

Wallace Dam Project

(FERC No. 2413)

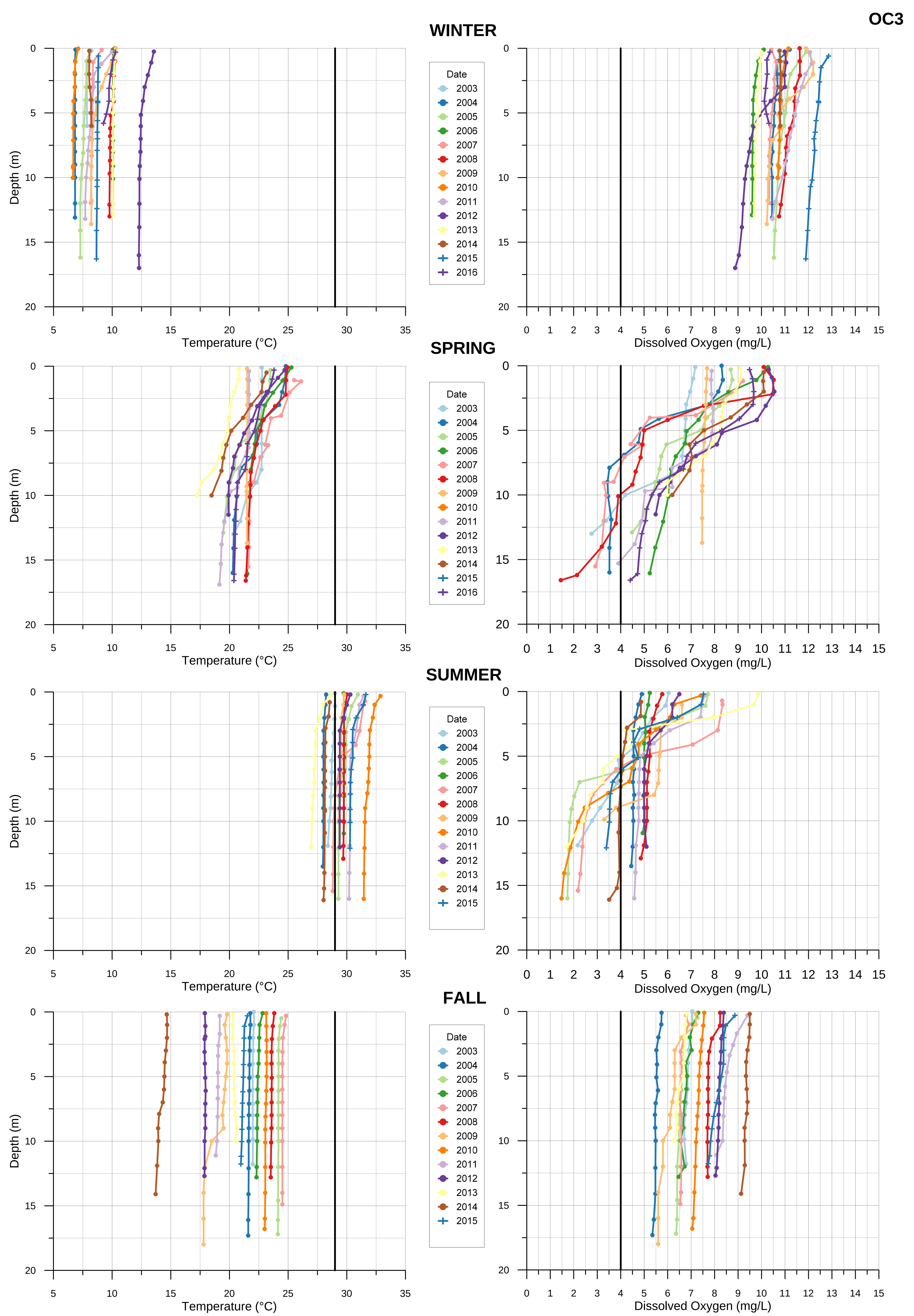
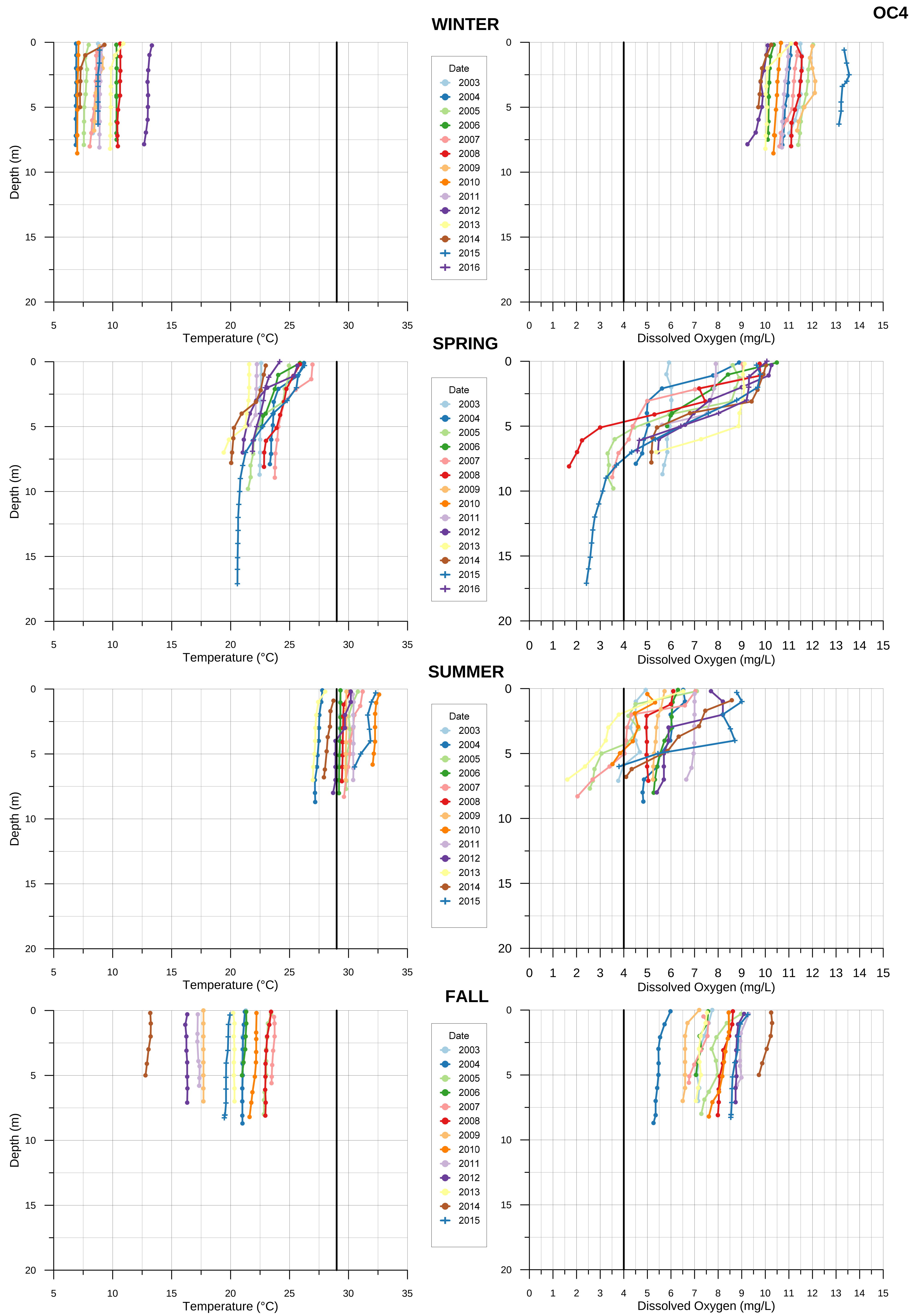


Figure 5c
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC3 2003-2016
Wallace Dam Project
(FERC No. 2413)



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A SOUTHERN COMPANY

Geosyntec consultants

Figure 5d
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC4 2003-2016
Wallace Dam Project
(FERC No. 2413)

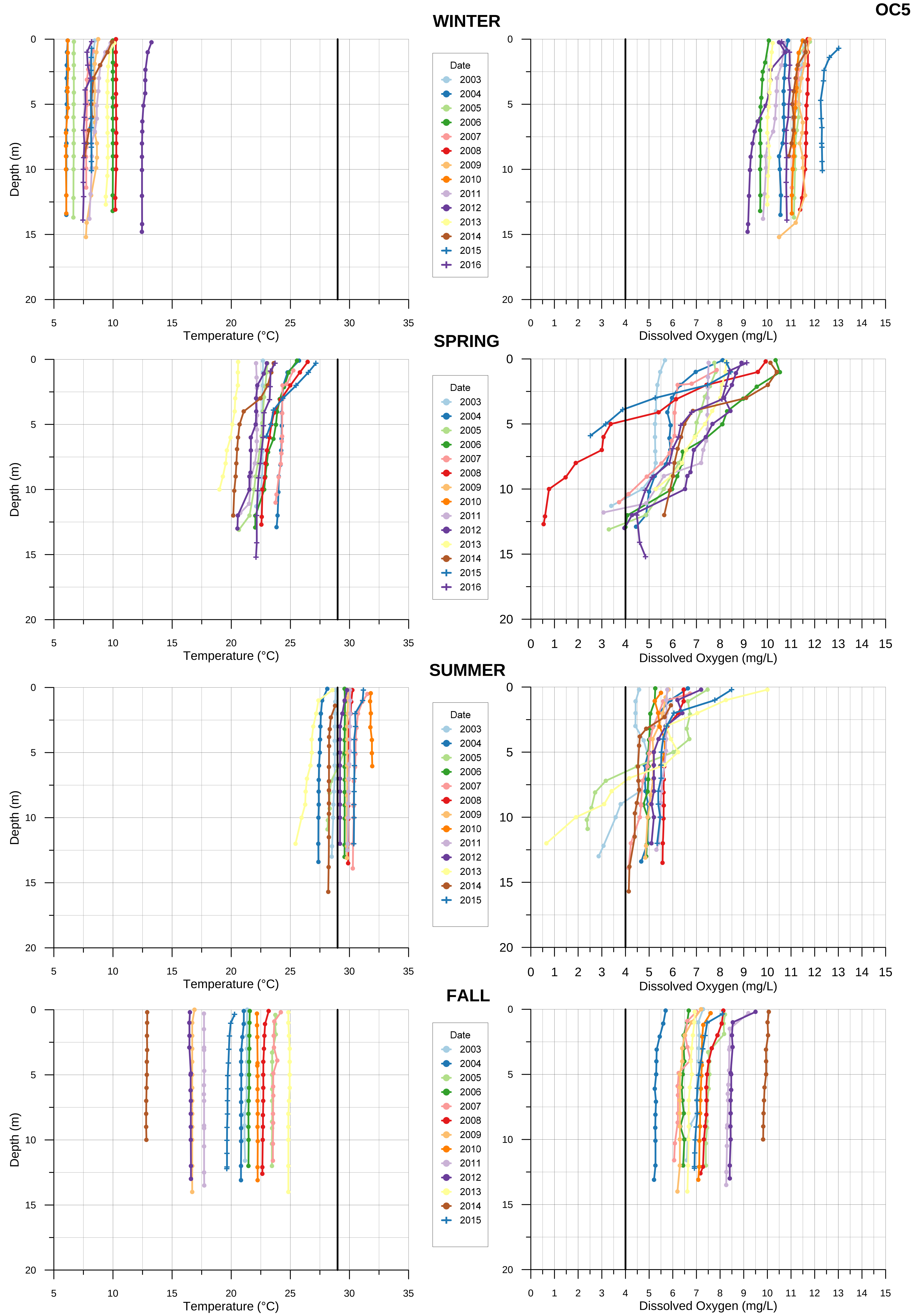

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Figure 5e
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC5 2003-2016
Wallace Dam Project
(FERC No. 2413)

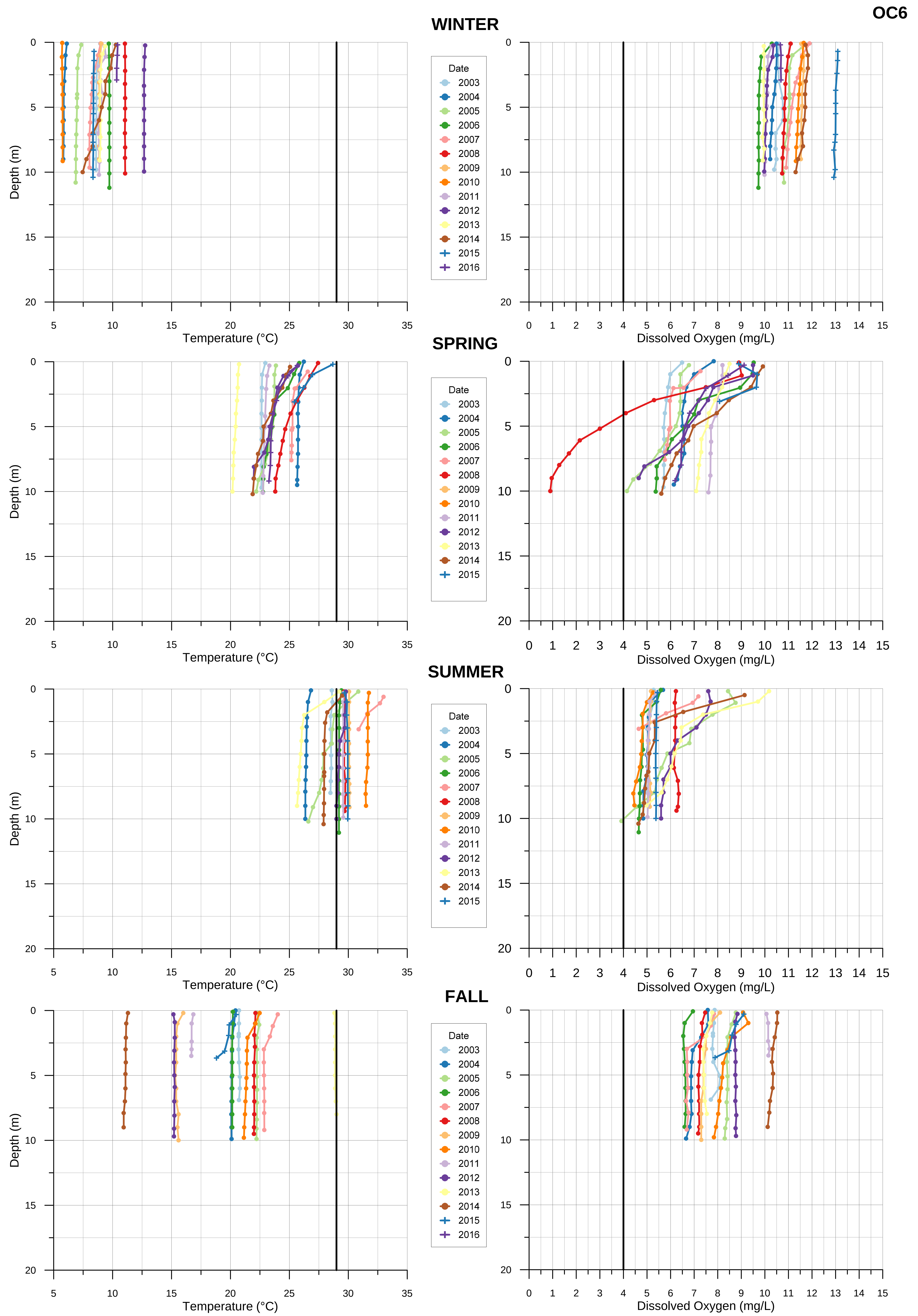

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Figure 5f
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC6 2003-2016
Wallace Dam Project
(FERC No. 2413)

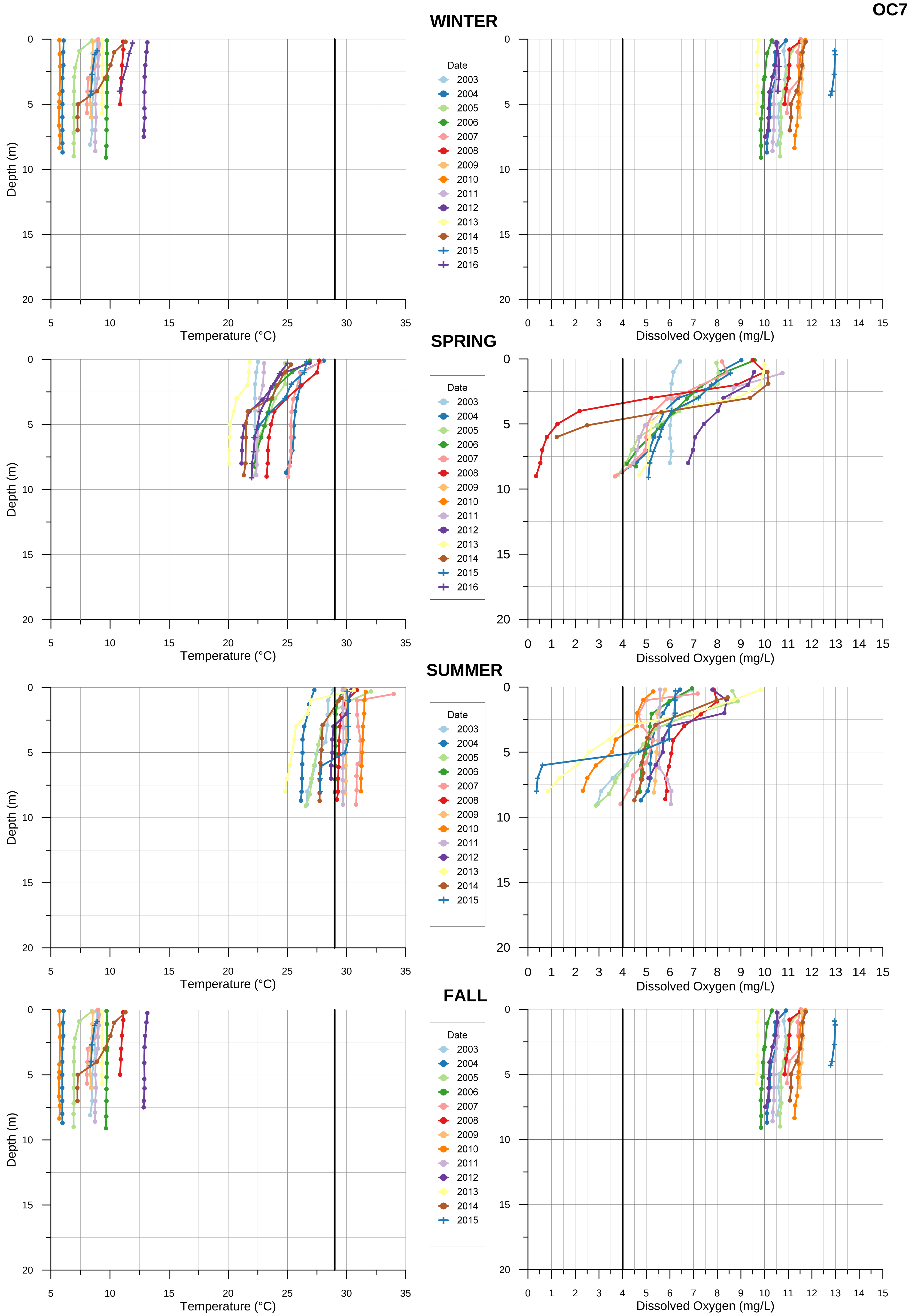

Figure 5g
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC7 2003-2016
Wallace Dam Project
(FERC No. 2413)

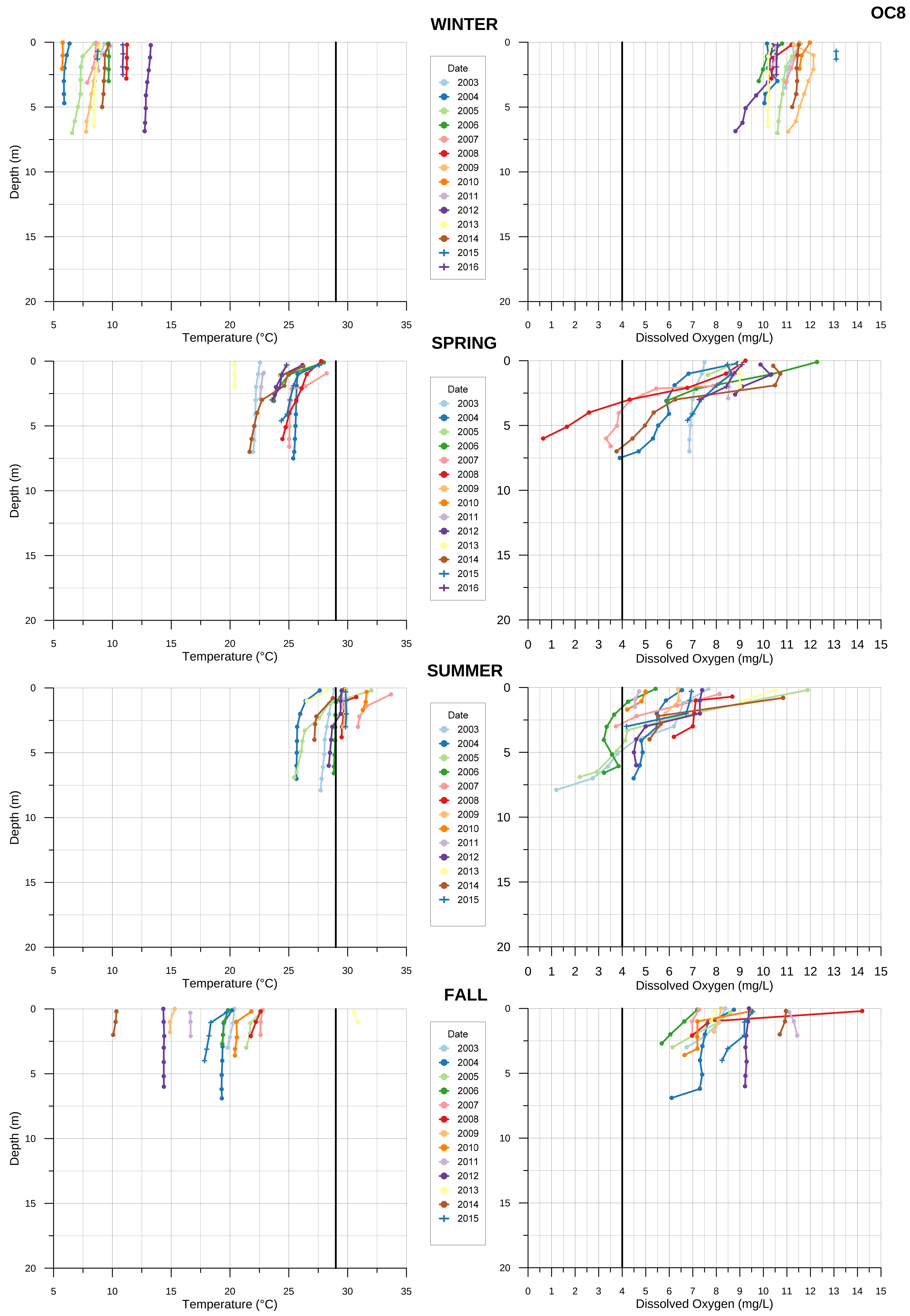

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Figure 5h
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC8 2003-2016
Wallace Dam Project
(FERC No. 2413)

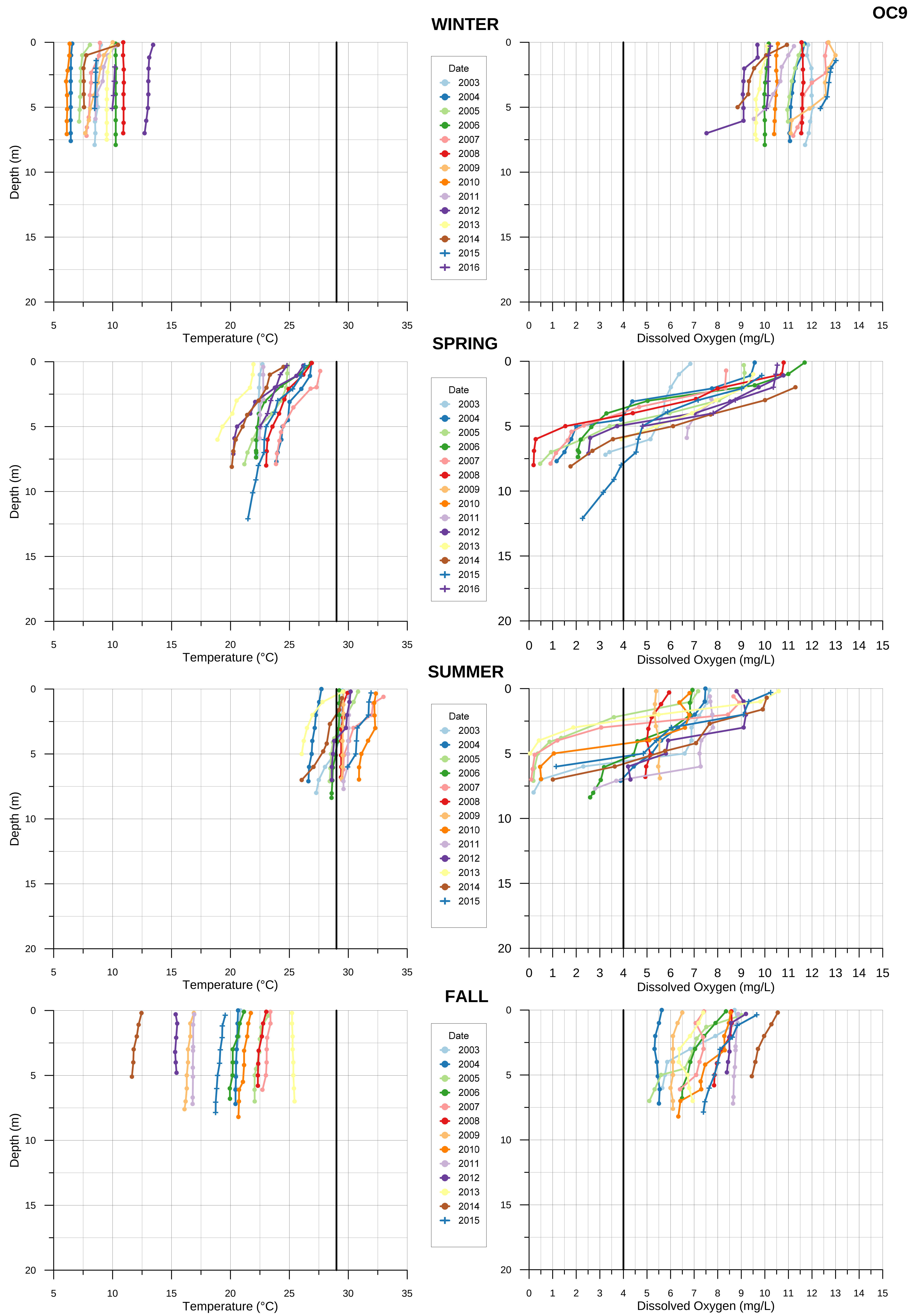

Figure 5i
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC9 2003-2016
Wallace Dam Project
(FERC No. 2413)

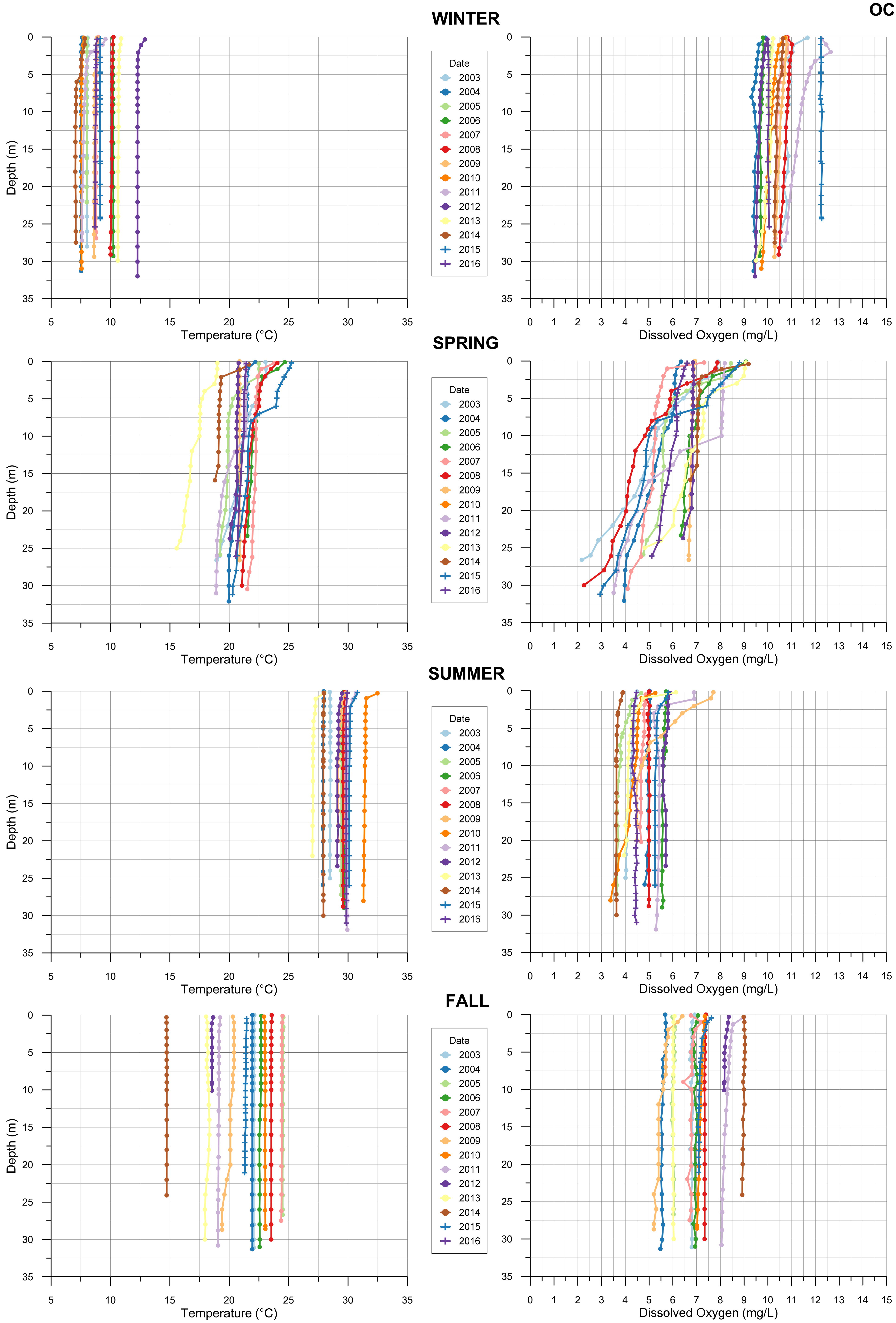

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Figure 6a
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC1 2003-2016
Wallace Dam Project
(FERC No. 2413)

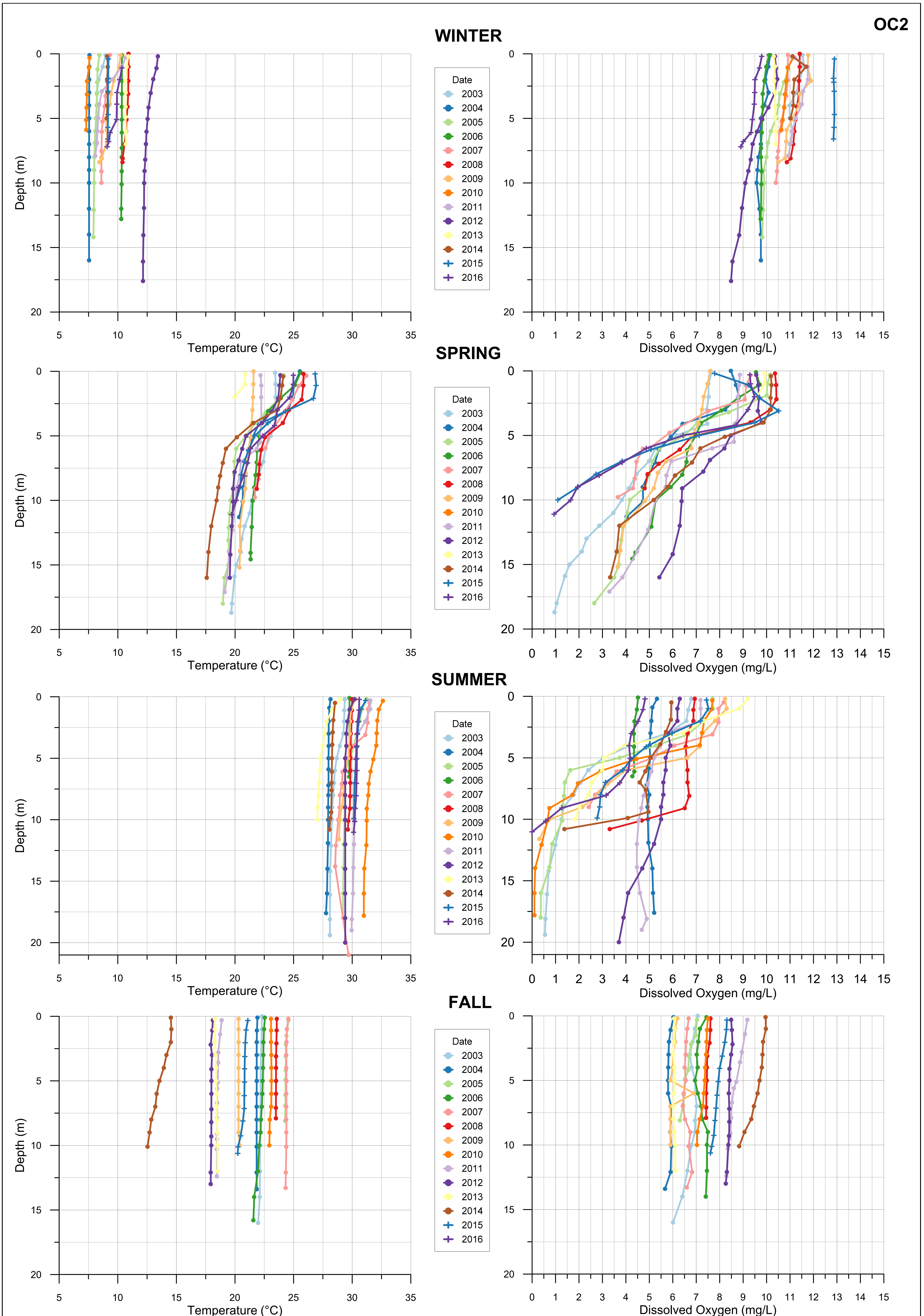

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Figure 6b
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC2 2003-2016
Wallace Dam Project
(FERC No. 2413)

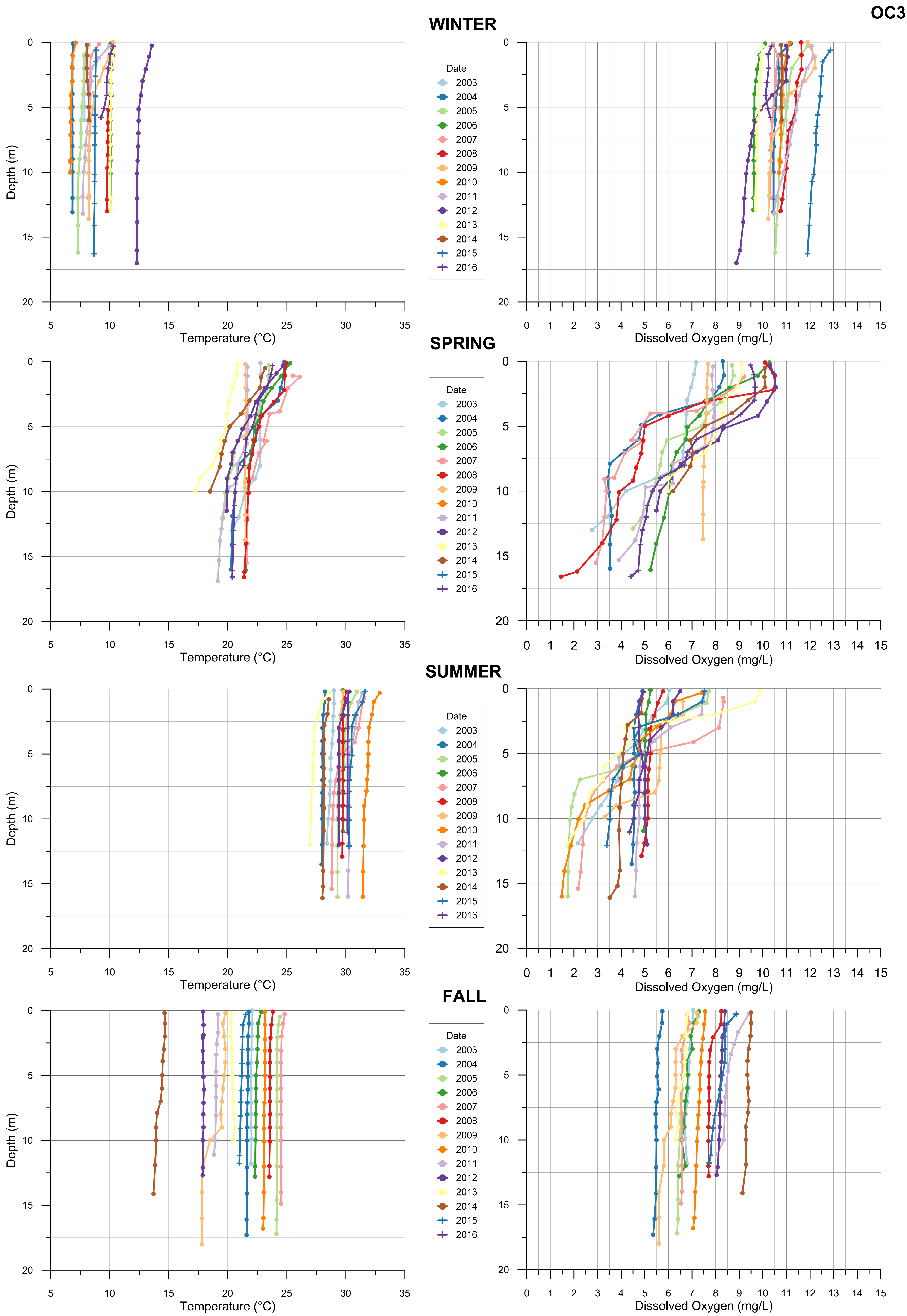

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Figure 6c
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC3 2003-2016
Wallace Dam Project
(FERC No. 2413)

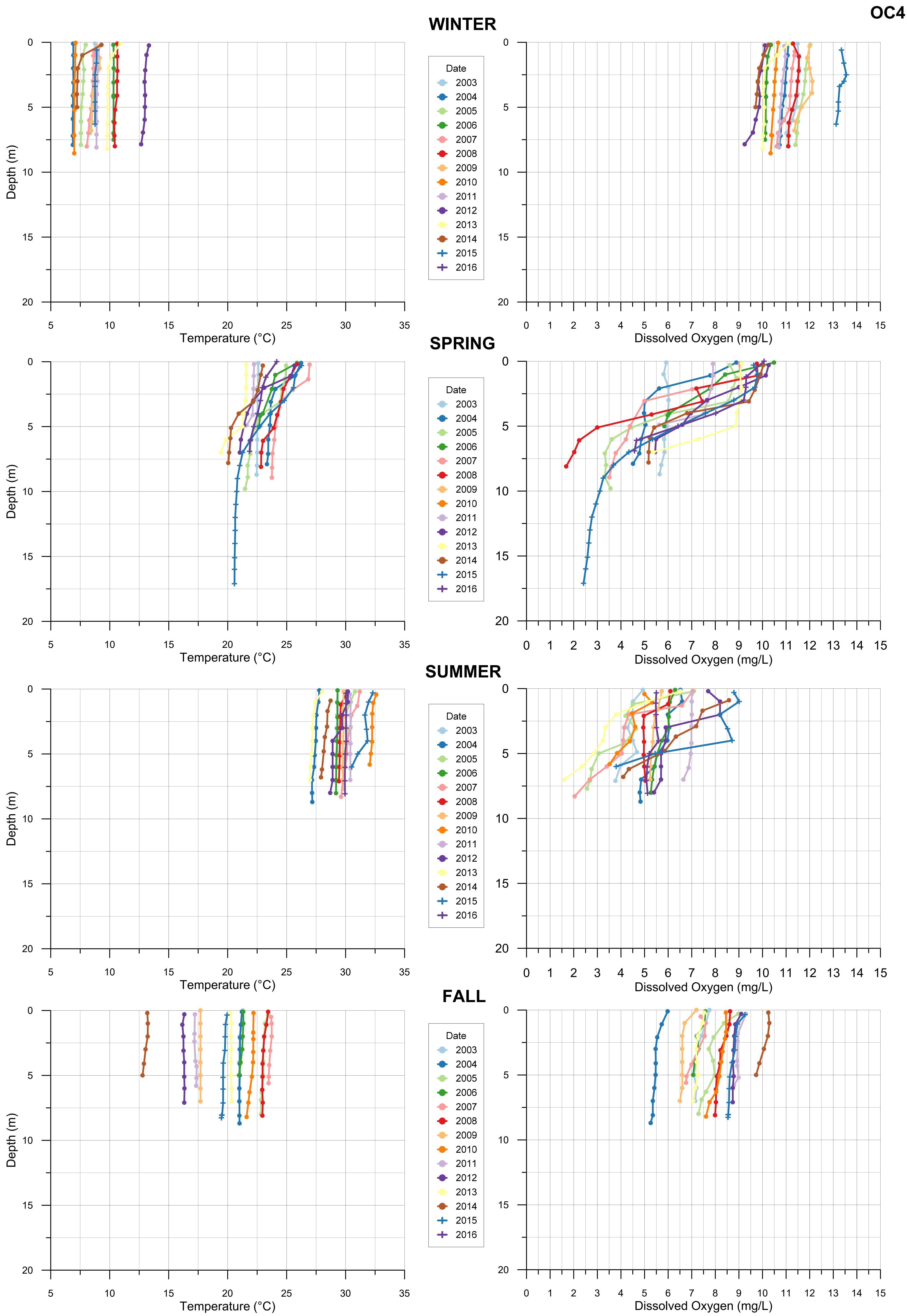

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Figure 6d
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC4 2003-2016
Wallace Dam Project
(FERC No. 2413)

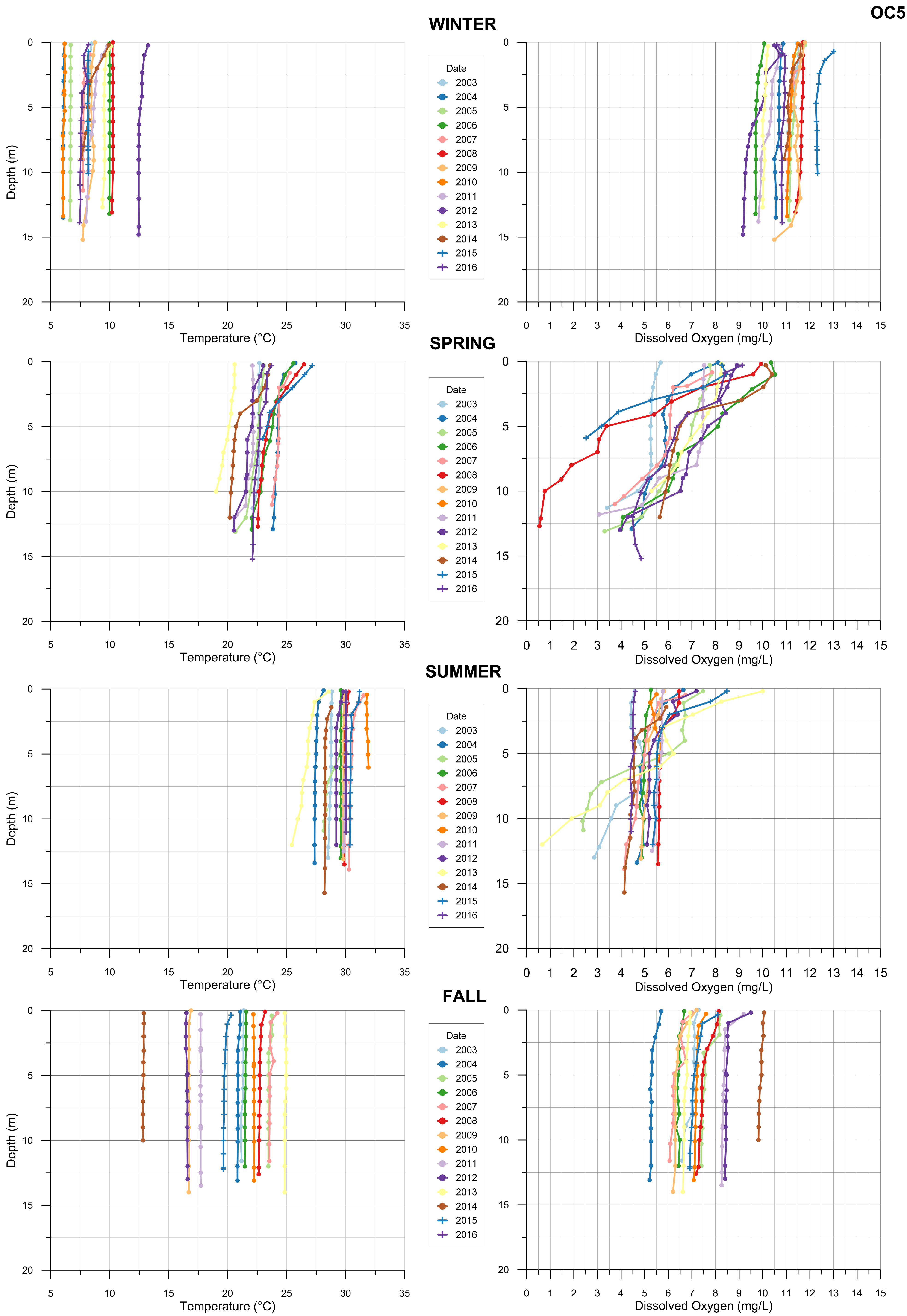

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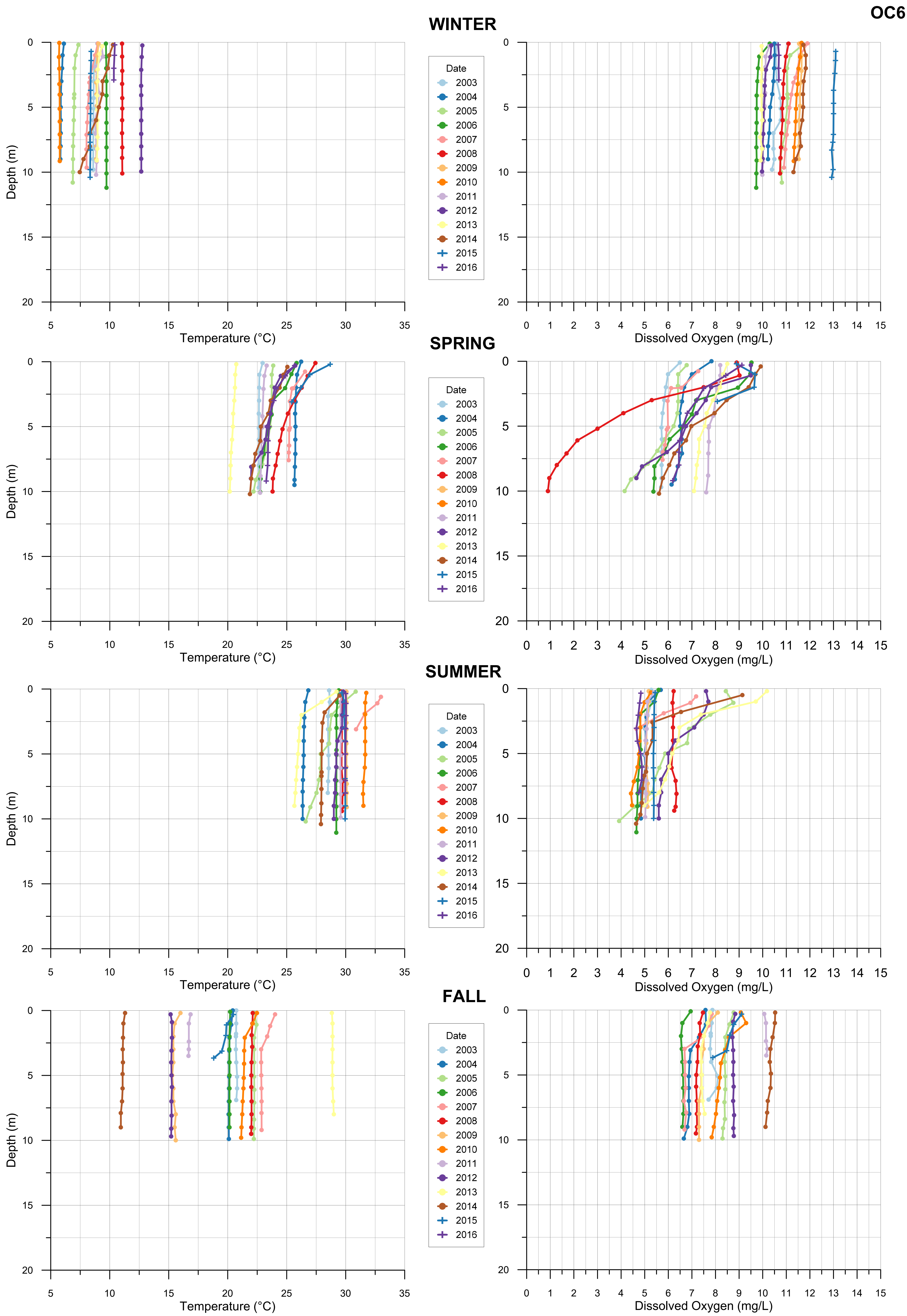
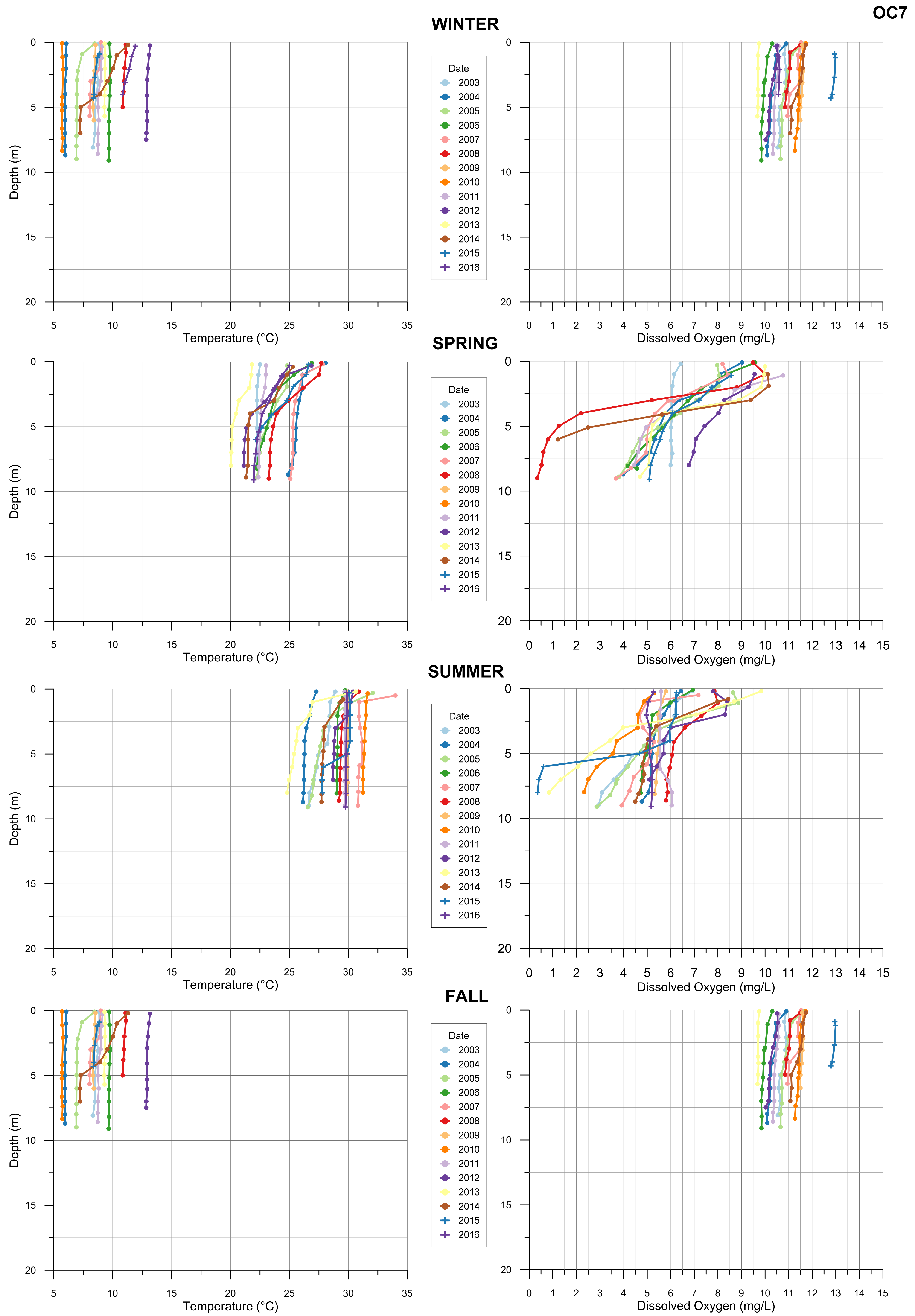
Figure 6e
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC5 2003-2016
Wallace Dam Project
(FERC No. 2413)



GEORGIA POWER
A SOUTHERN COMPANY

Geosyntec consultants

Figure 6f
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC6 2003-2016
Wallace Dam Project
(FERC No. 2413)



GEORGIA POWER
A SOUTHERN COMPANY

Geosyntec consultants

Figure 6g
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC7 2003-2016
Wallace Dam Project
(FERC No. 2413)

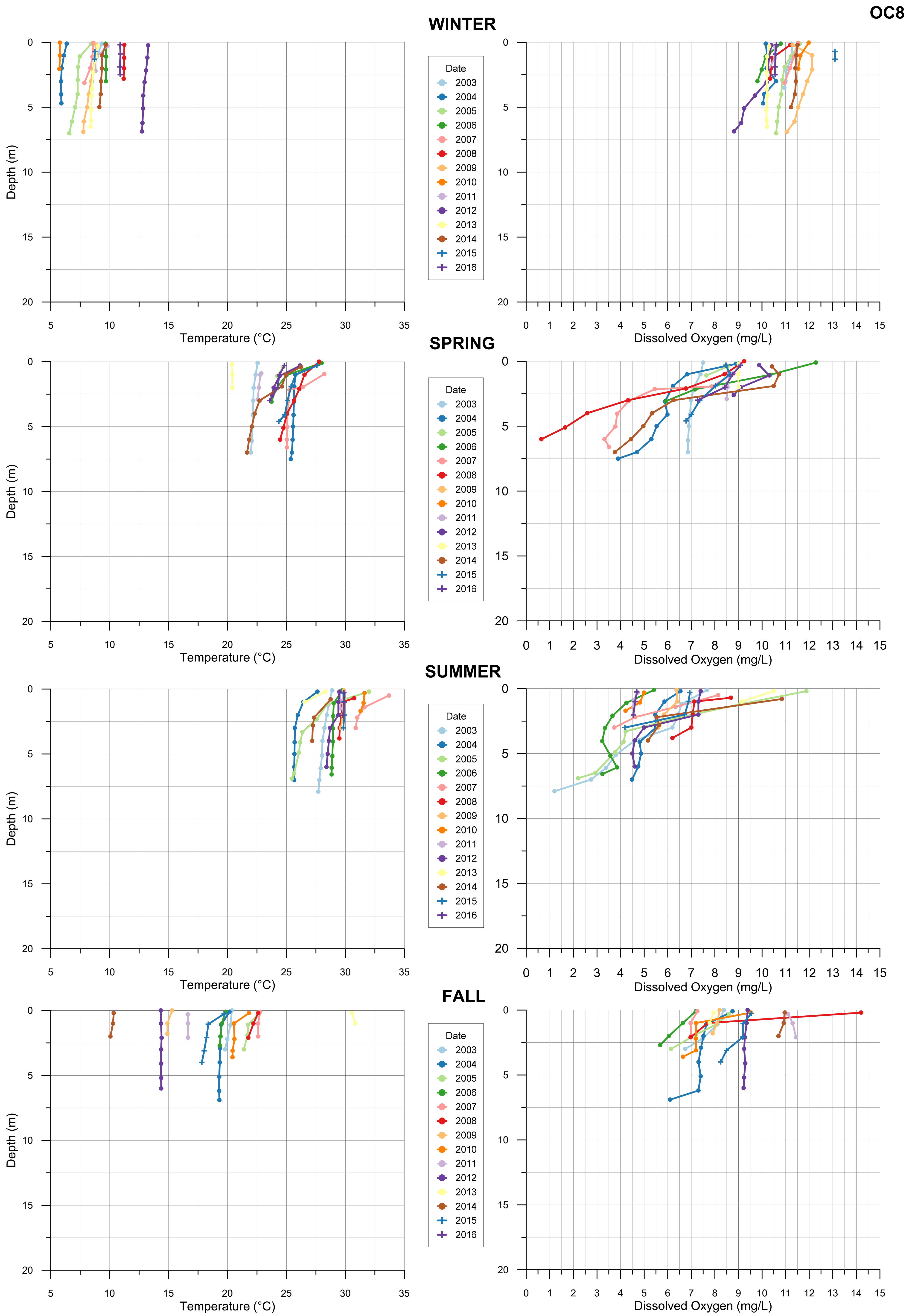


Figure 6h
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC8 2003-2016
Wallace Dam Project
(FERC No. 2413)

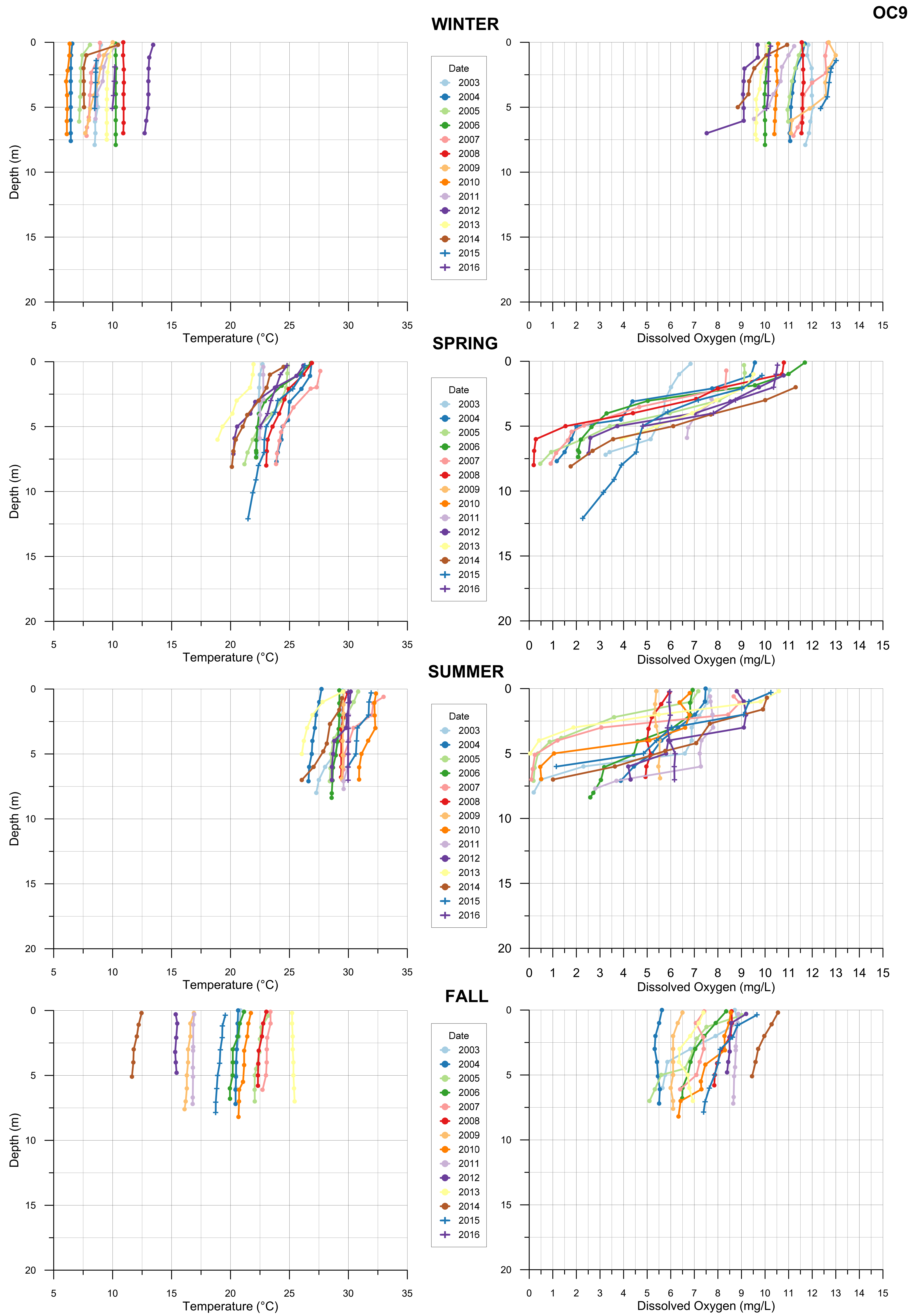
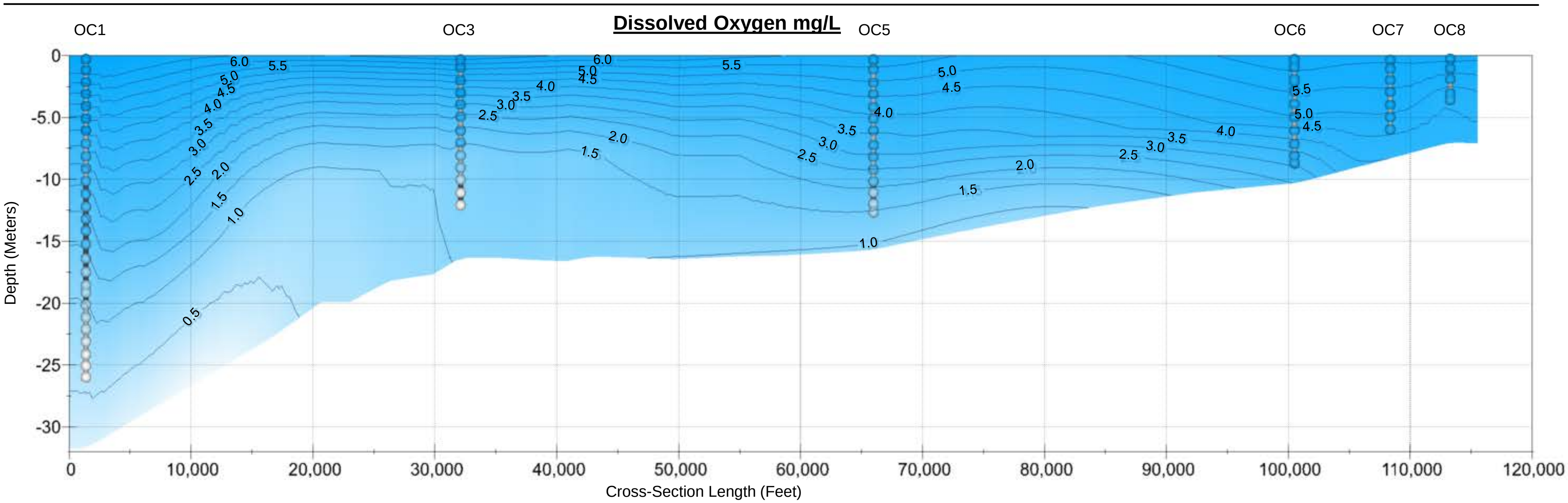


Figure 6i
Seasonal Vertical Temperature and DO Profiles at Lake Oconee
OC9 2003-2016
Wallace Dam Project
(FERC No. 2413)



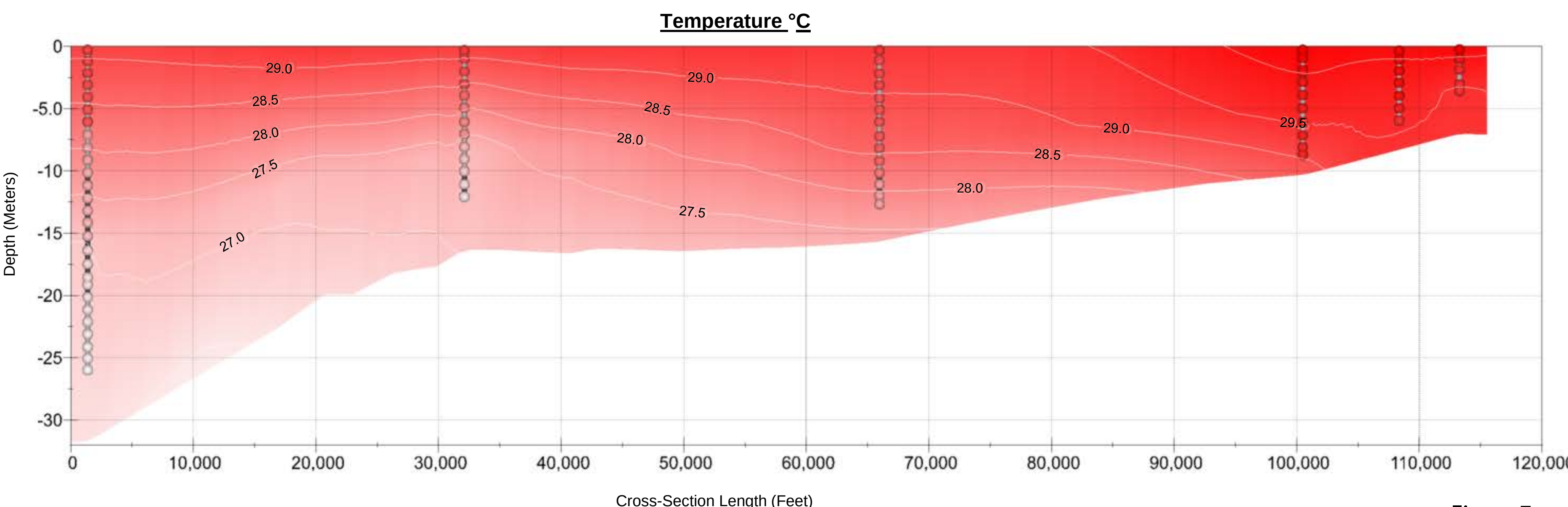


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Figure 7a
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - June 2015
Wallace Dam Project
(FERC No. 2413)

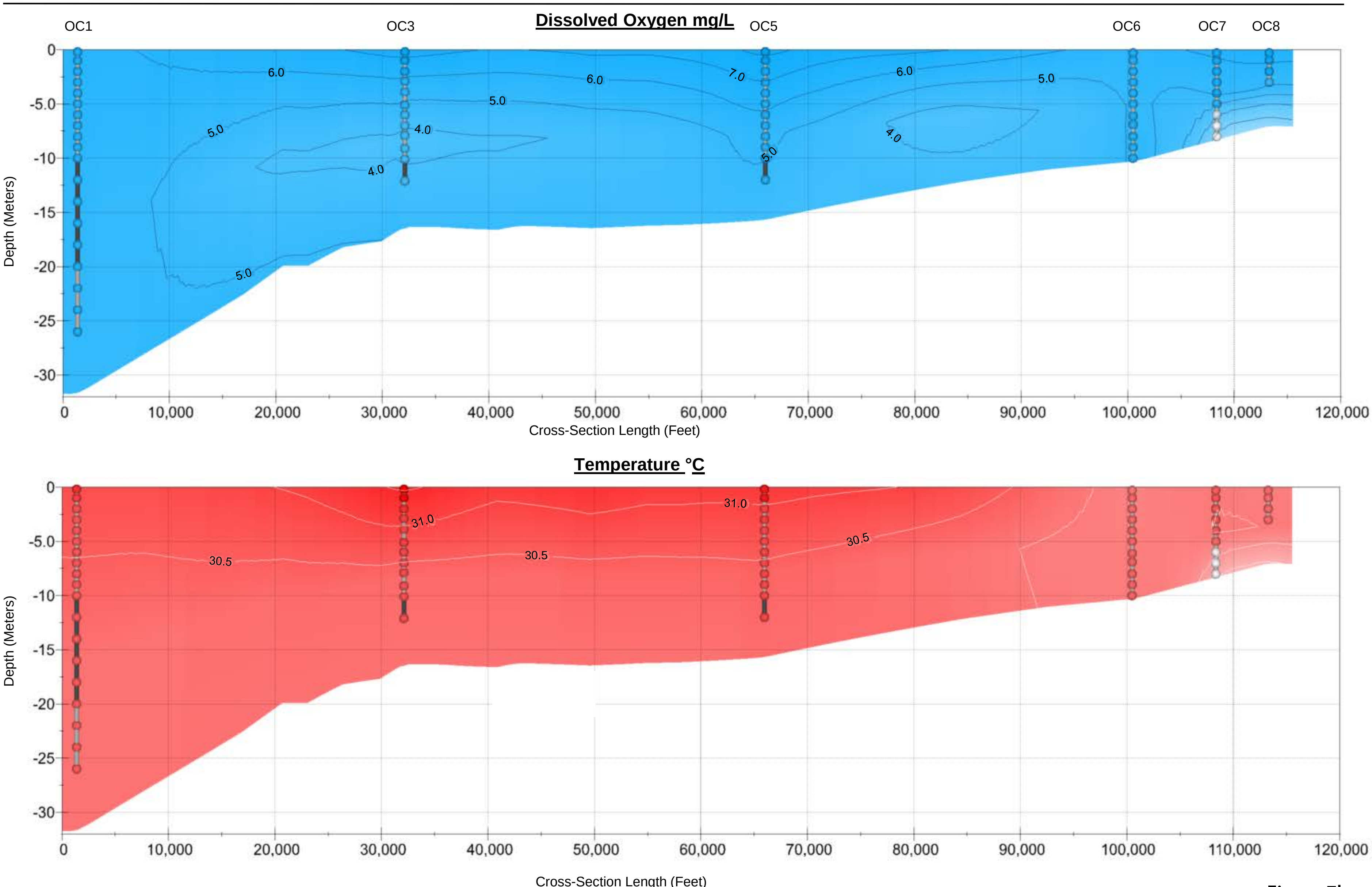

Figure 7b
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - August 2015
Wallace Dam Project
(FERC No. 2413)

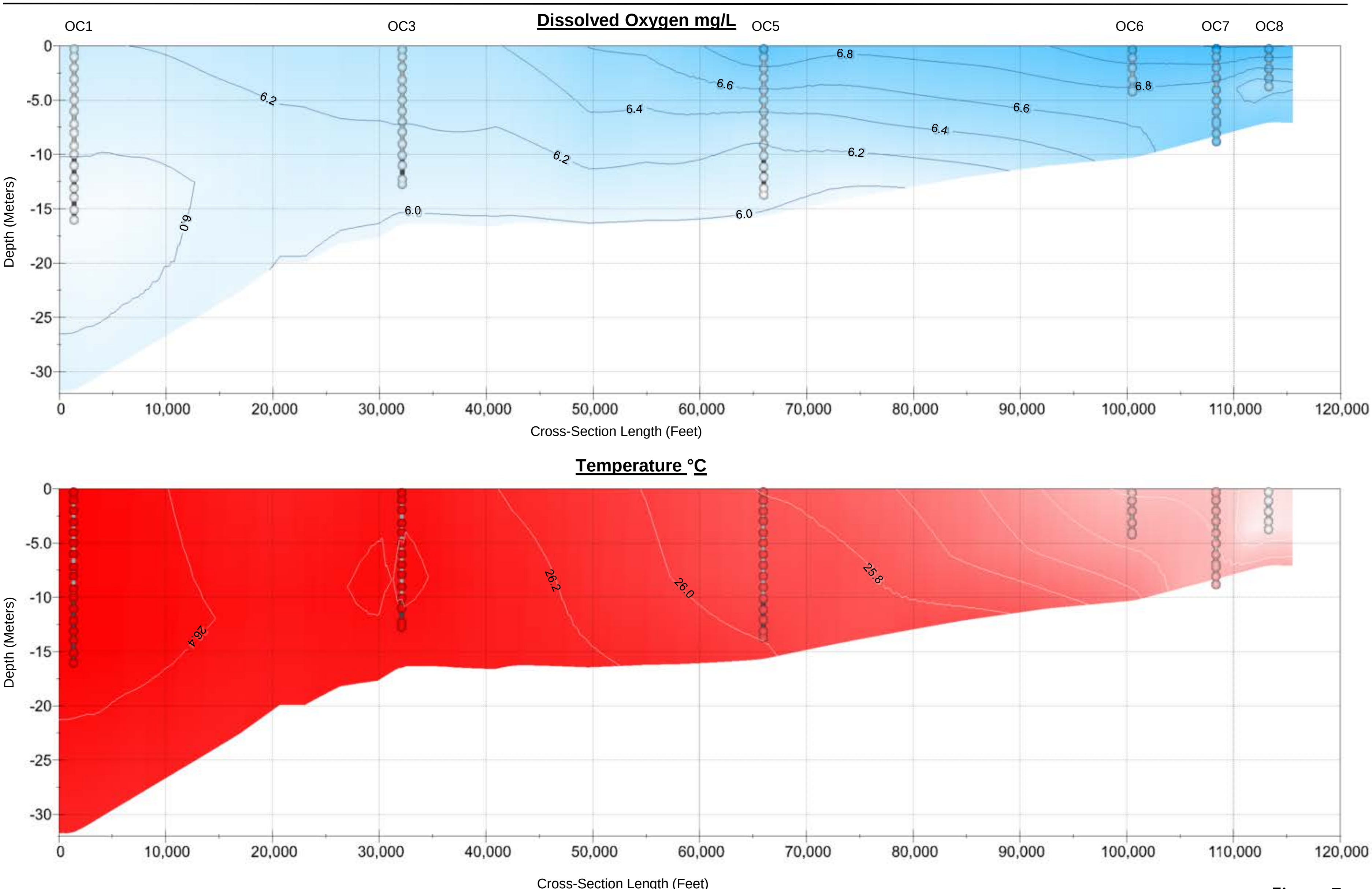

Figure 7c
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - September 2015
Wallace Dam Project
(FERC No. 2413)

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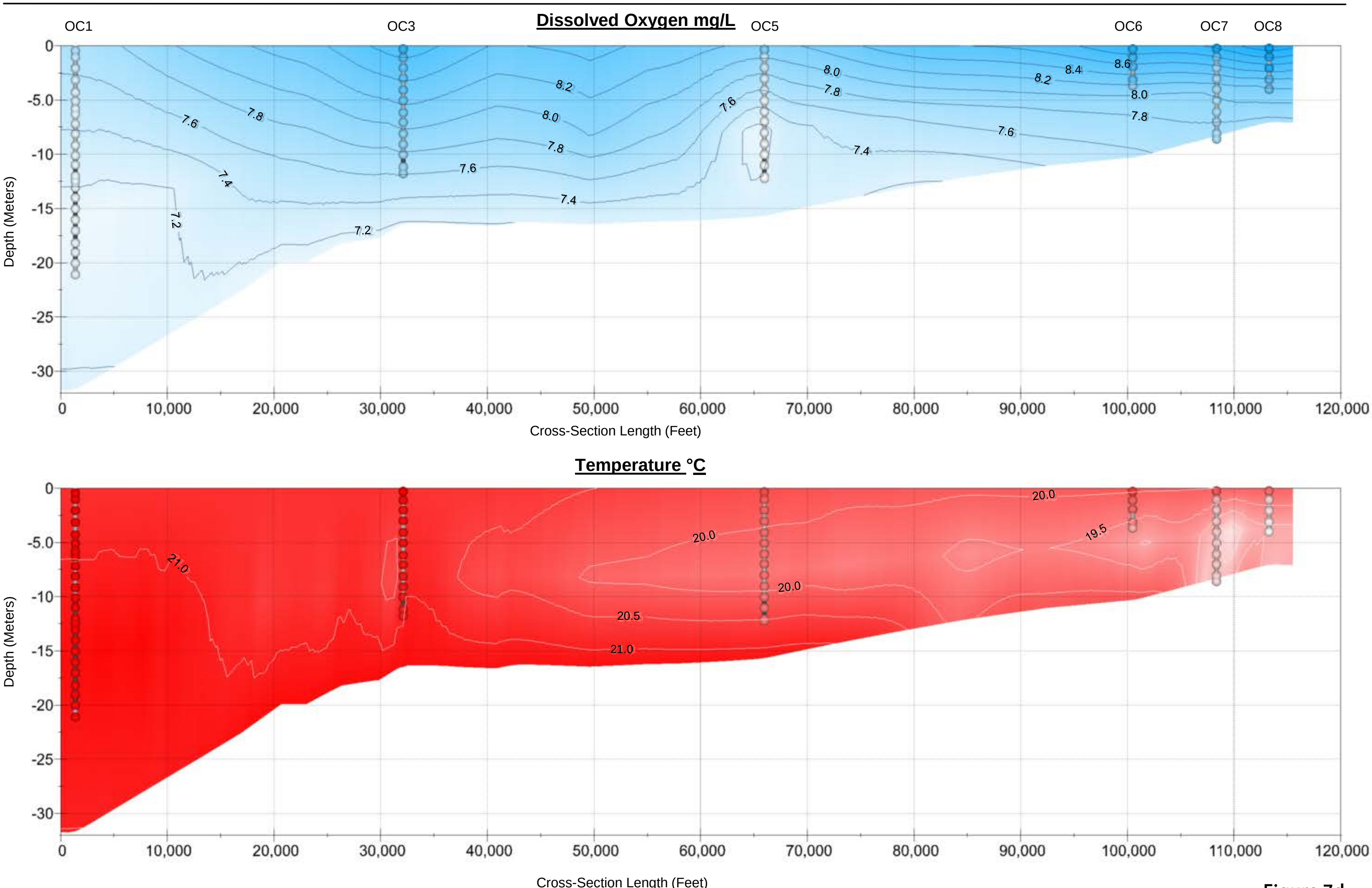

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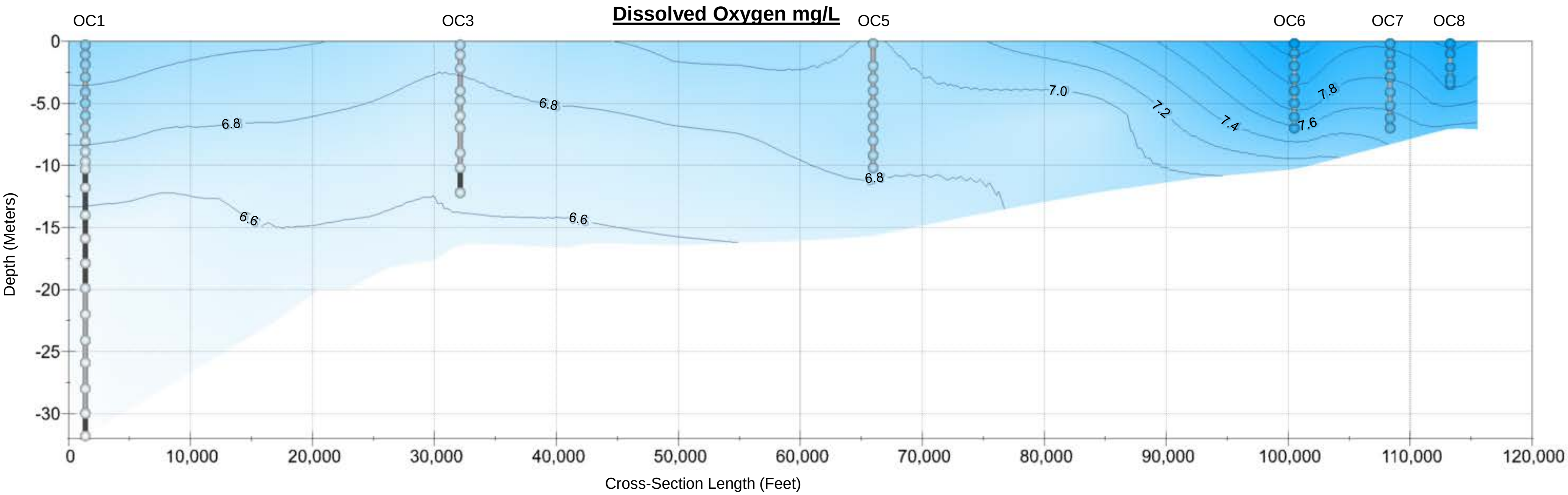
Figure 7d
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - October 2015
Wallace Dam Project
(FERC No. 2413)



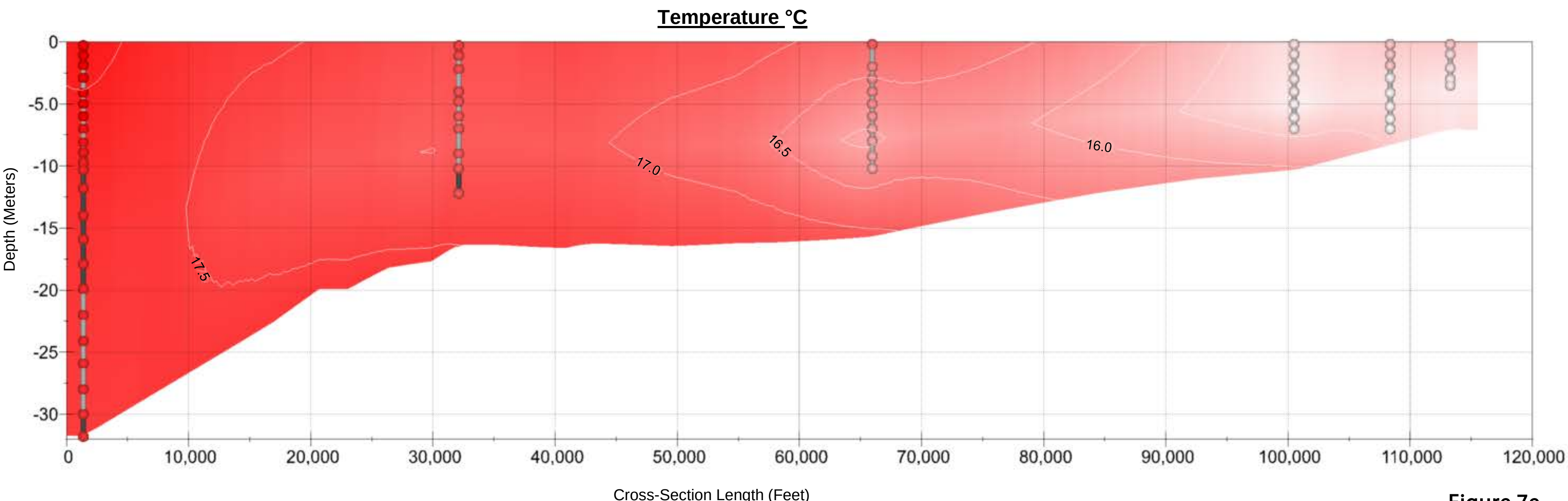


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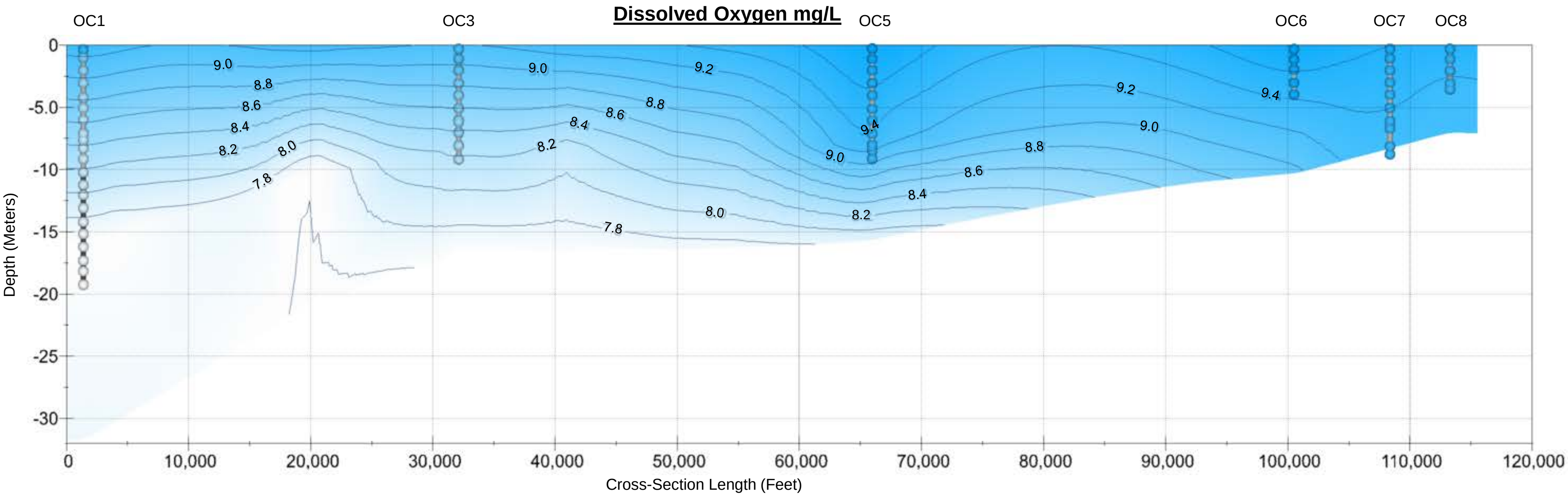
Figure 7e
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - November 2015
Wallace Dam Project
(FERC No. 2413)



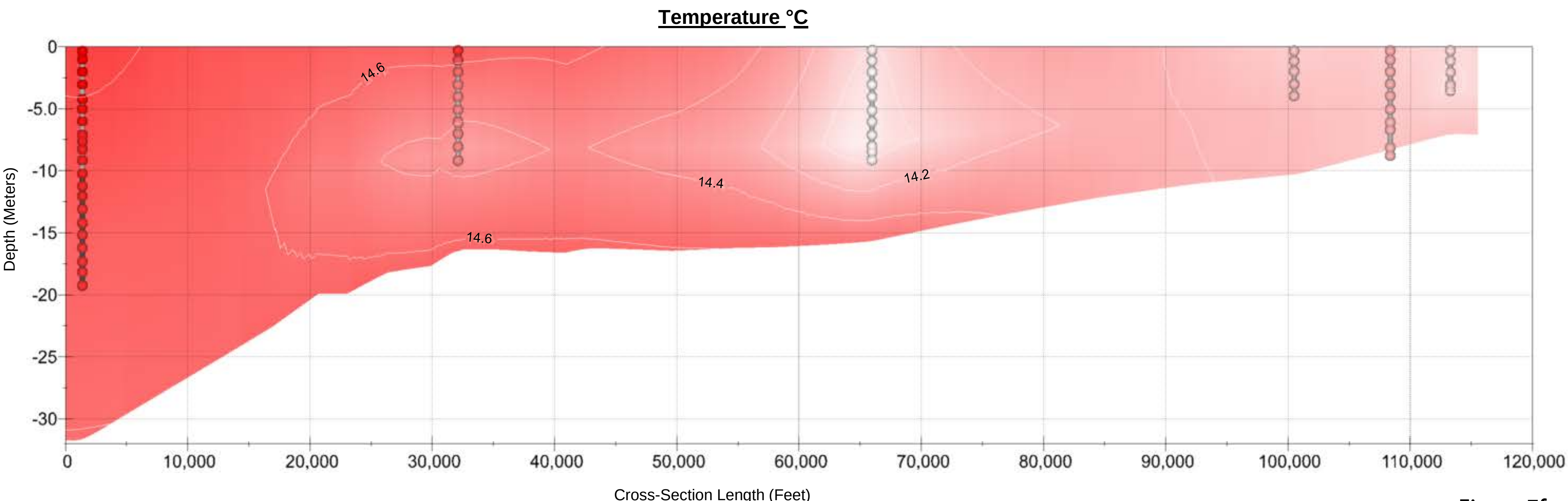


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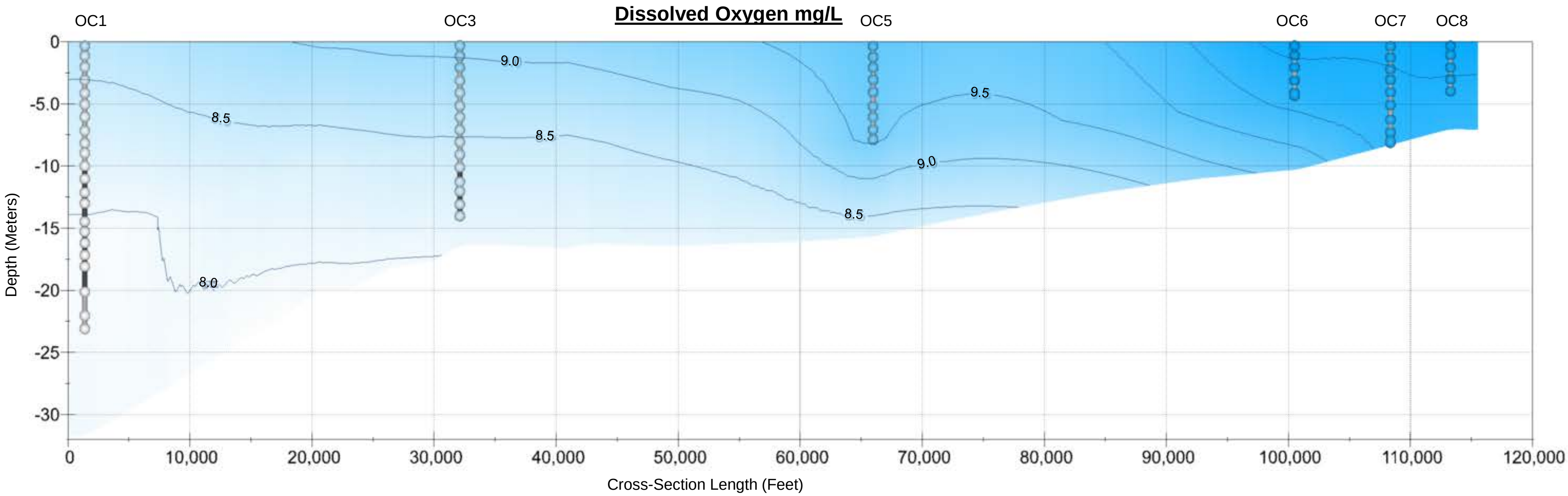
Figure 7f

Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - December 2015

Wallace Dam Project

(FERC No. 2413)



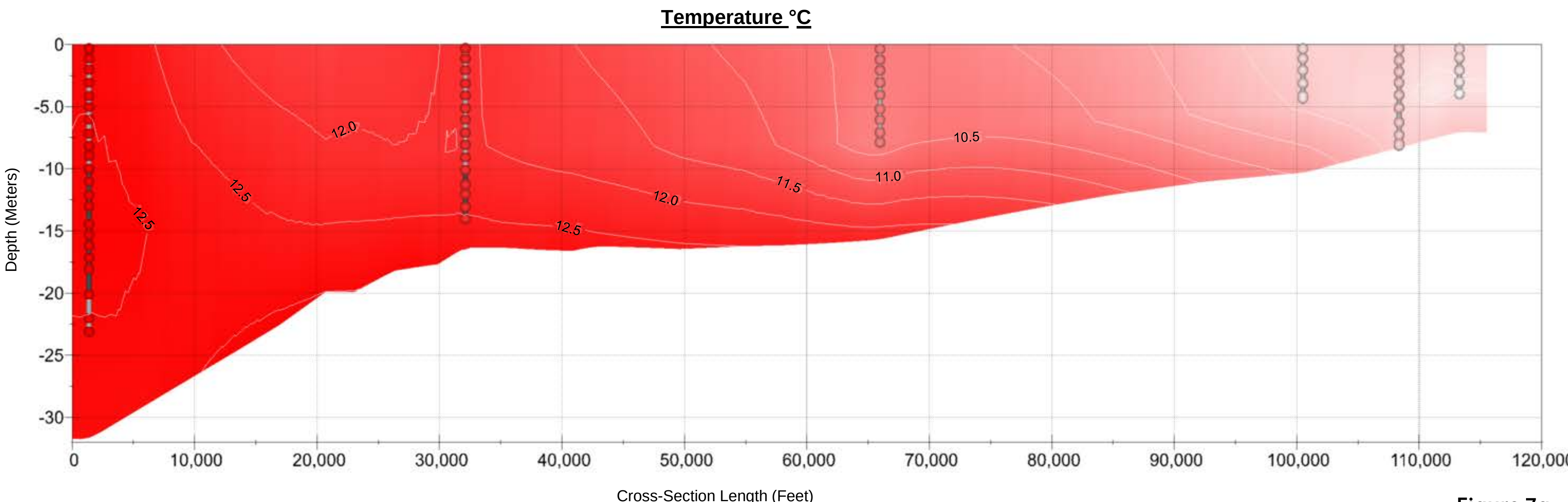


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Figure 7g
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - January 2016
Wallace Dam Project
(FERC No. 2413)

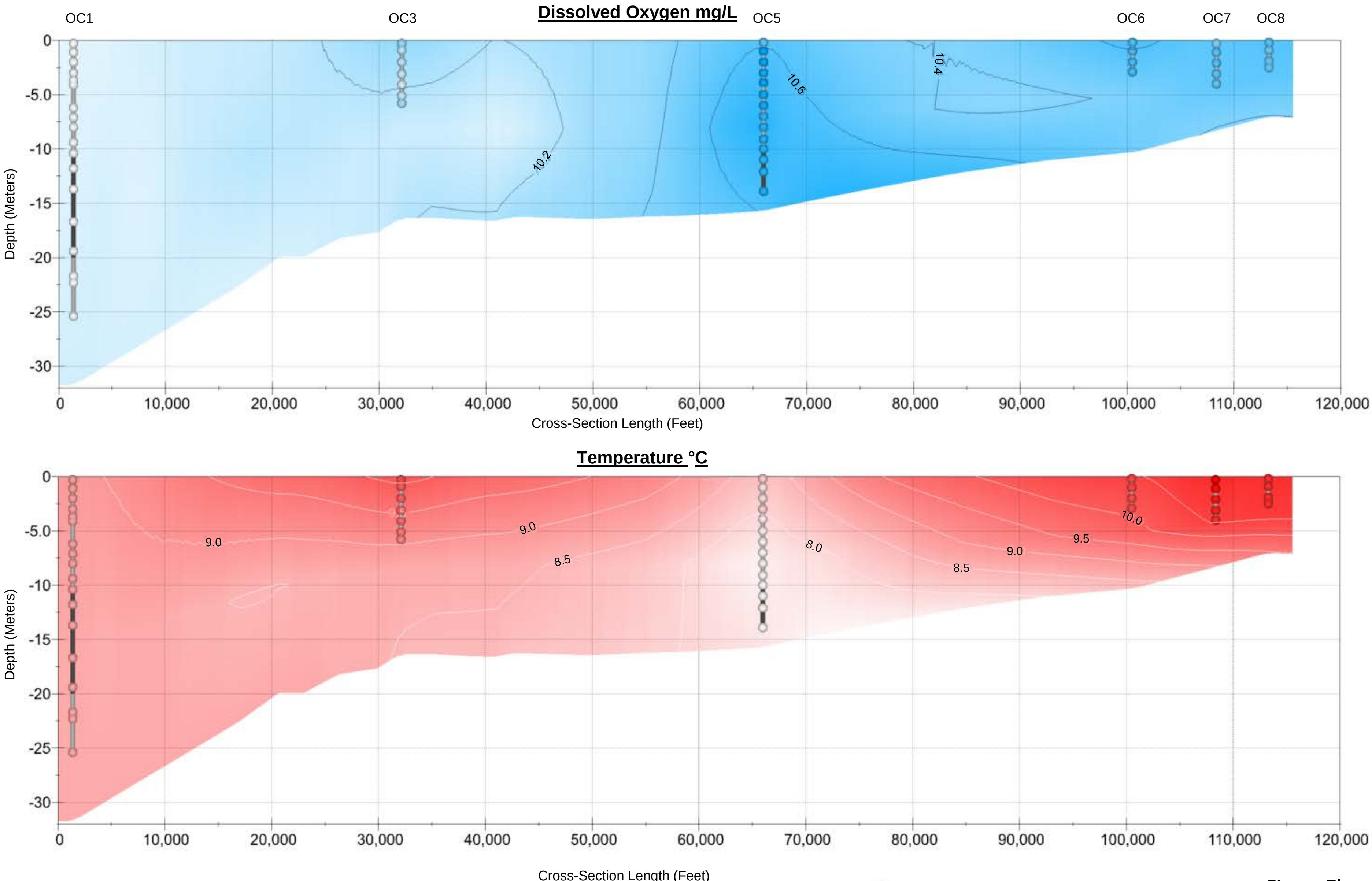

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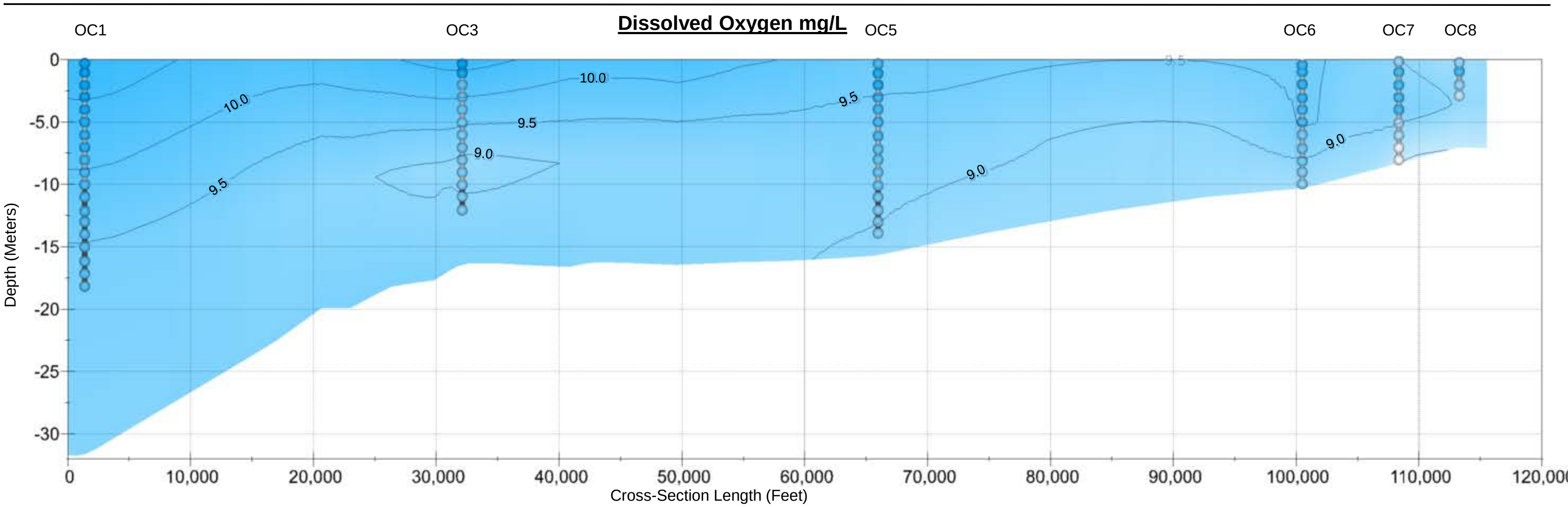
Figure 7h
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - February 2016
Wallace Dam Project
(FERC No. 2413)



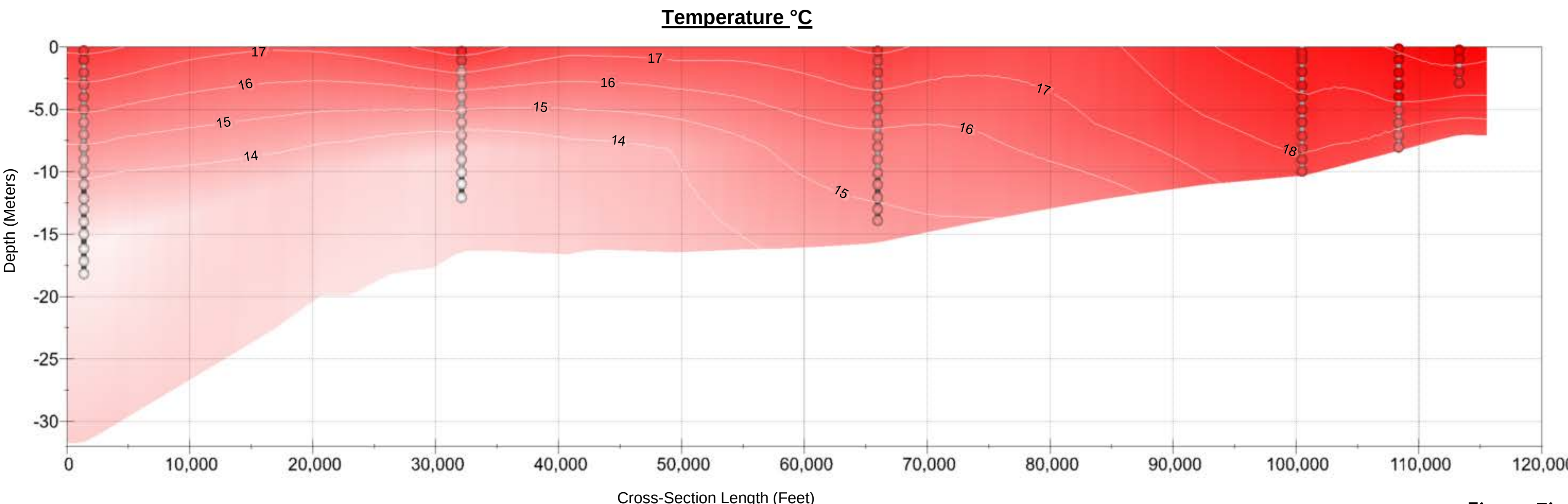
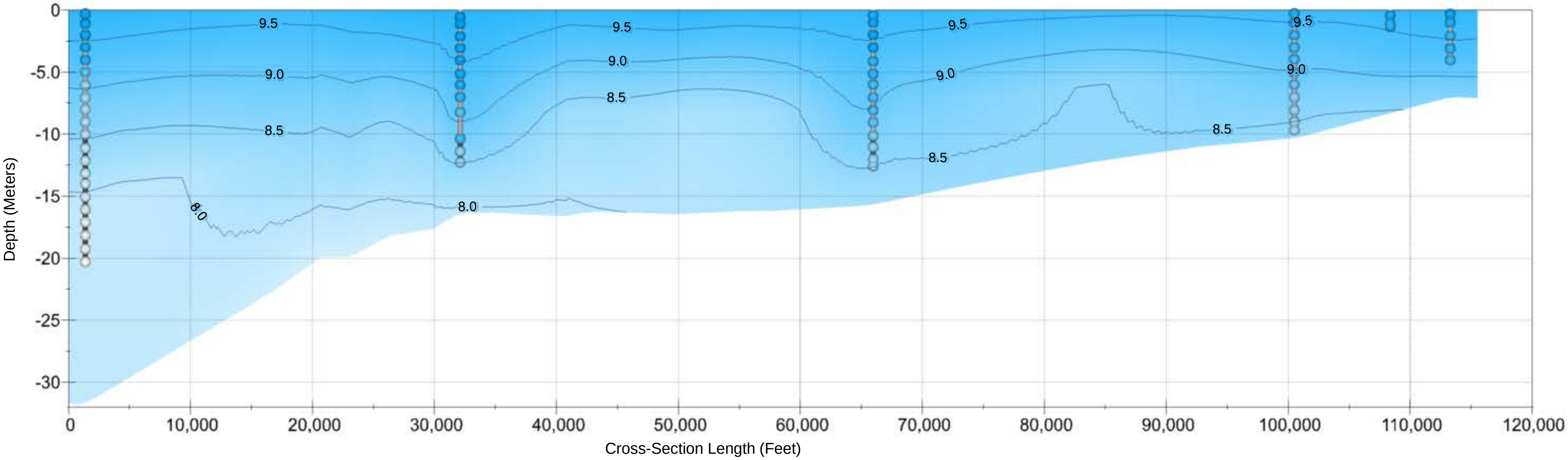


Figure 7i
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - March 2016
Wallace Dam Project
(FERC No. 2413)

Dissolved Oxygen mg/L



Temperature °C

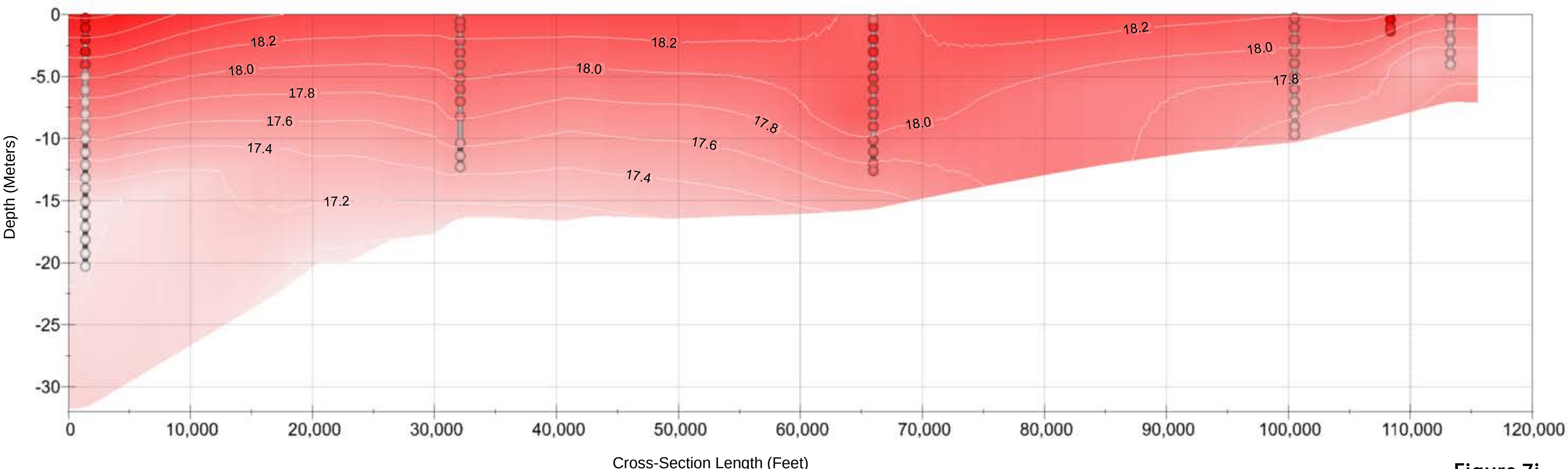


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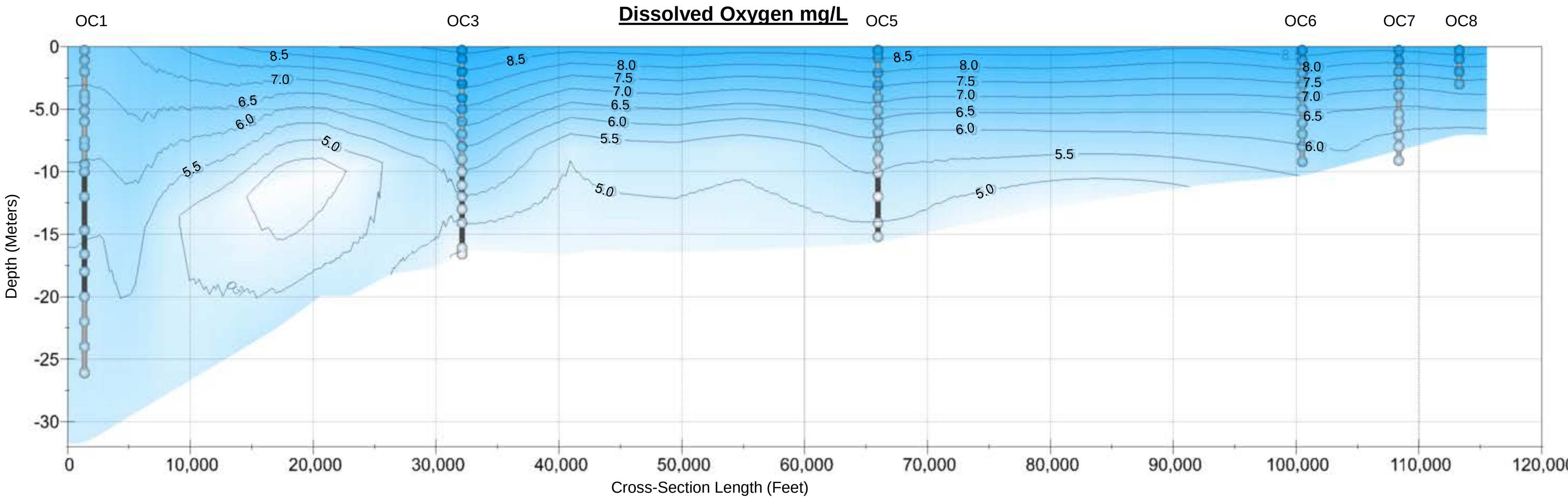
Figure 7j
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - April 2016
Wallace Dam Project
(FERC No. 2413)



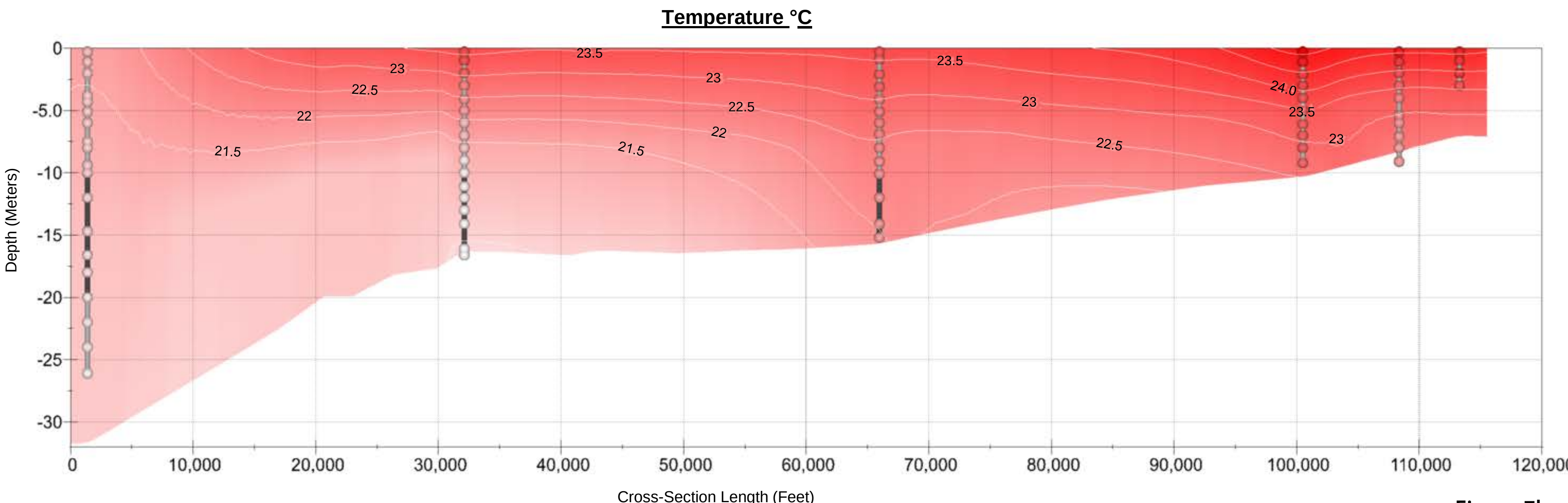
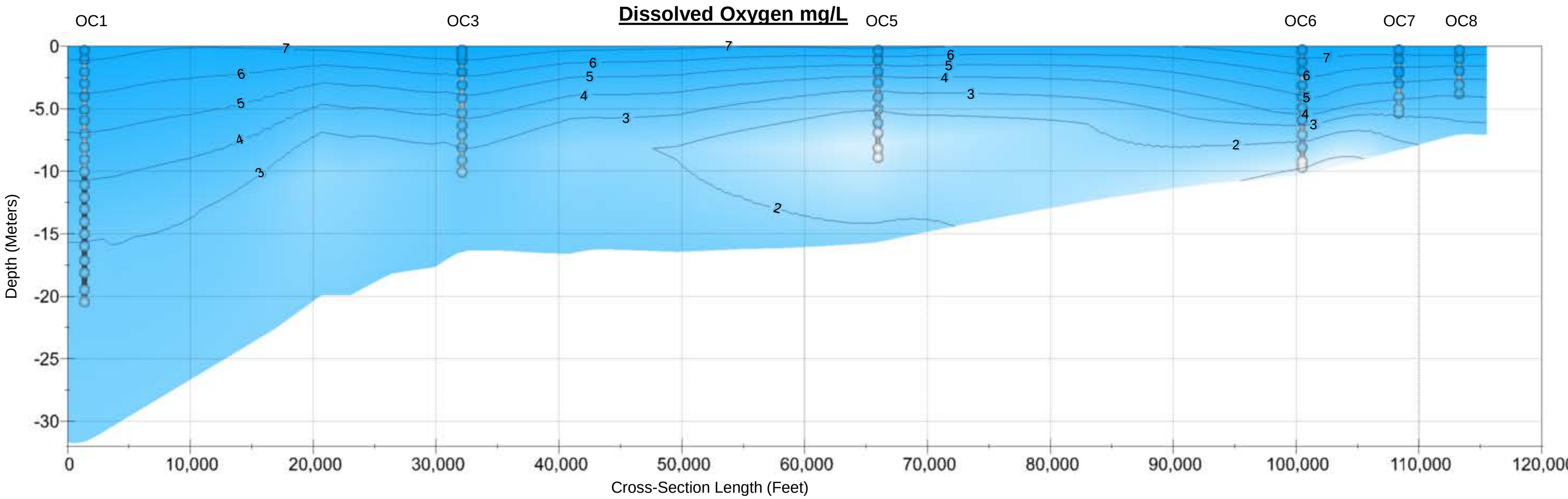


Figure 7k

Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - May 2016

Wallace Dam Project

(FERC No. 2413)



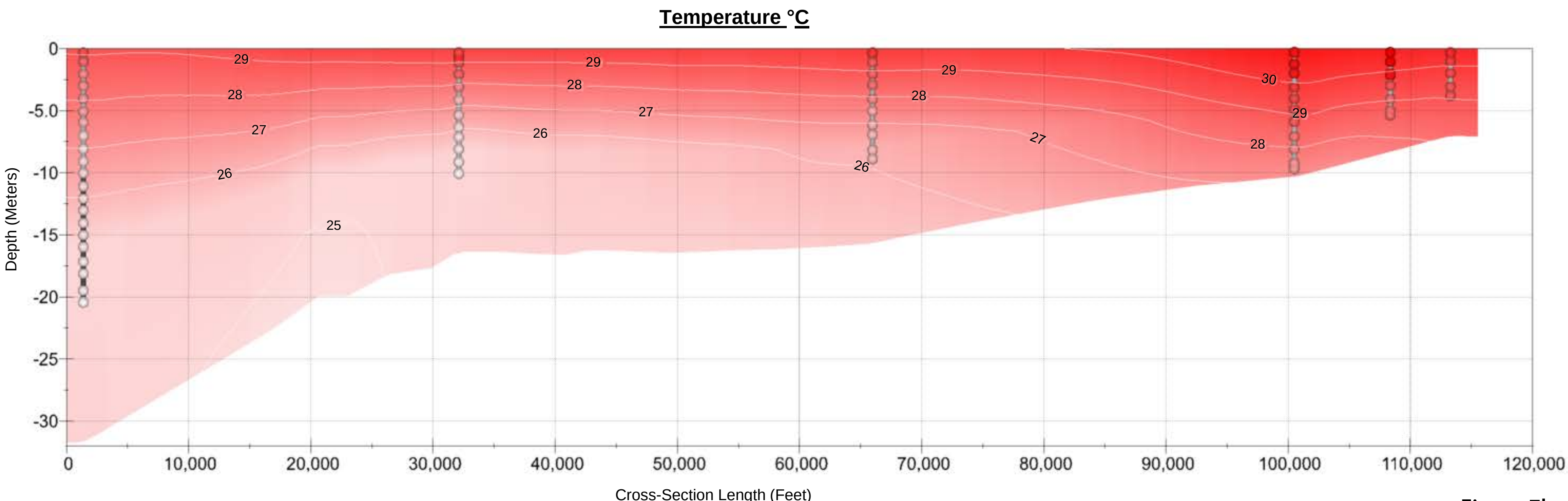


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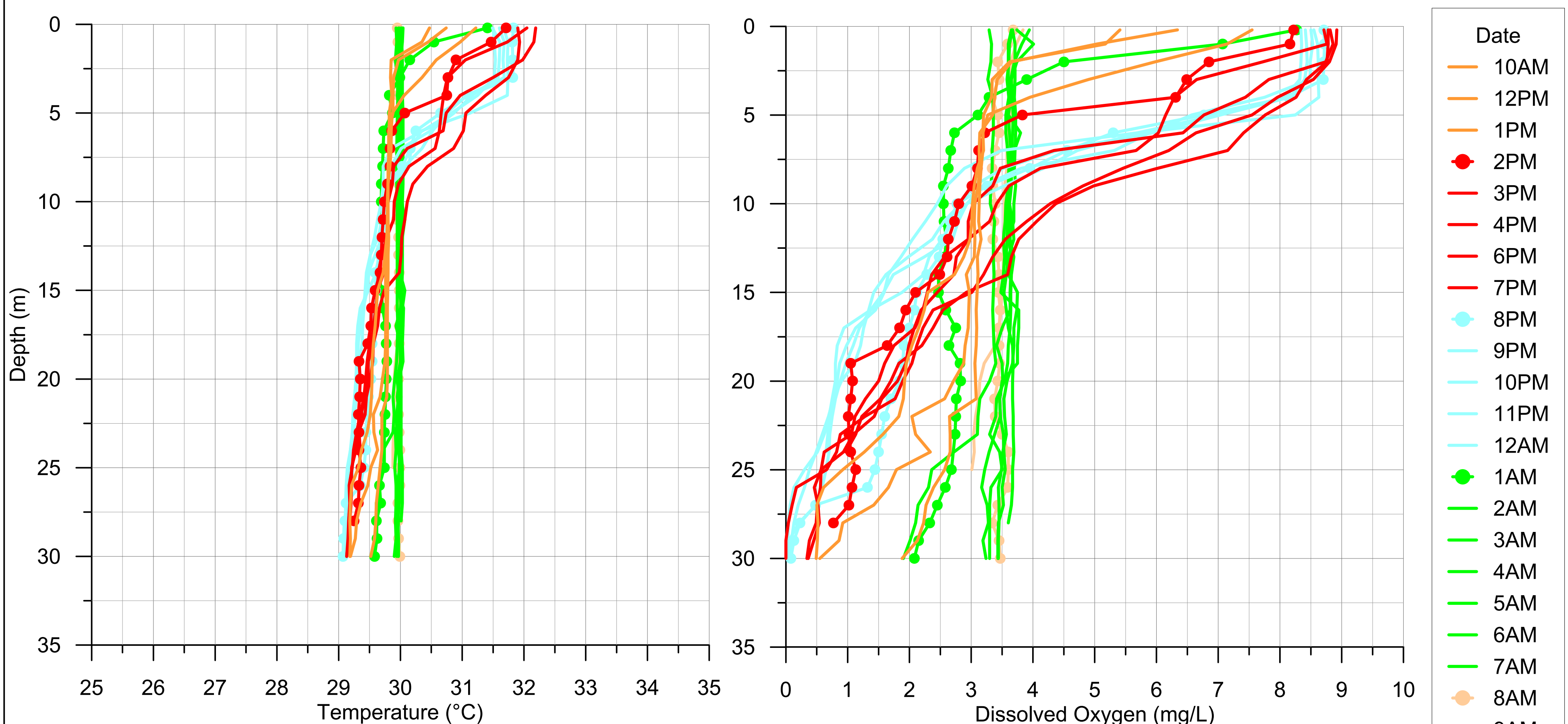
Figure 7l
Monthly Vertical Temperature and DO Isopleth Profiles at Lake Oconee - June 2016
Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on July 27-28

Interim (10AM-2PM)

Generation (2PM-7PM)

Interim (7PM-12:45AM)

Pumpack (12:45AM-7:15AM)

Interim (7:15AM-2PM)

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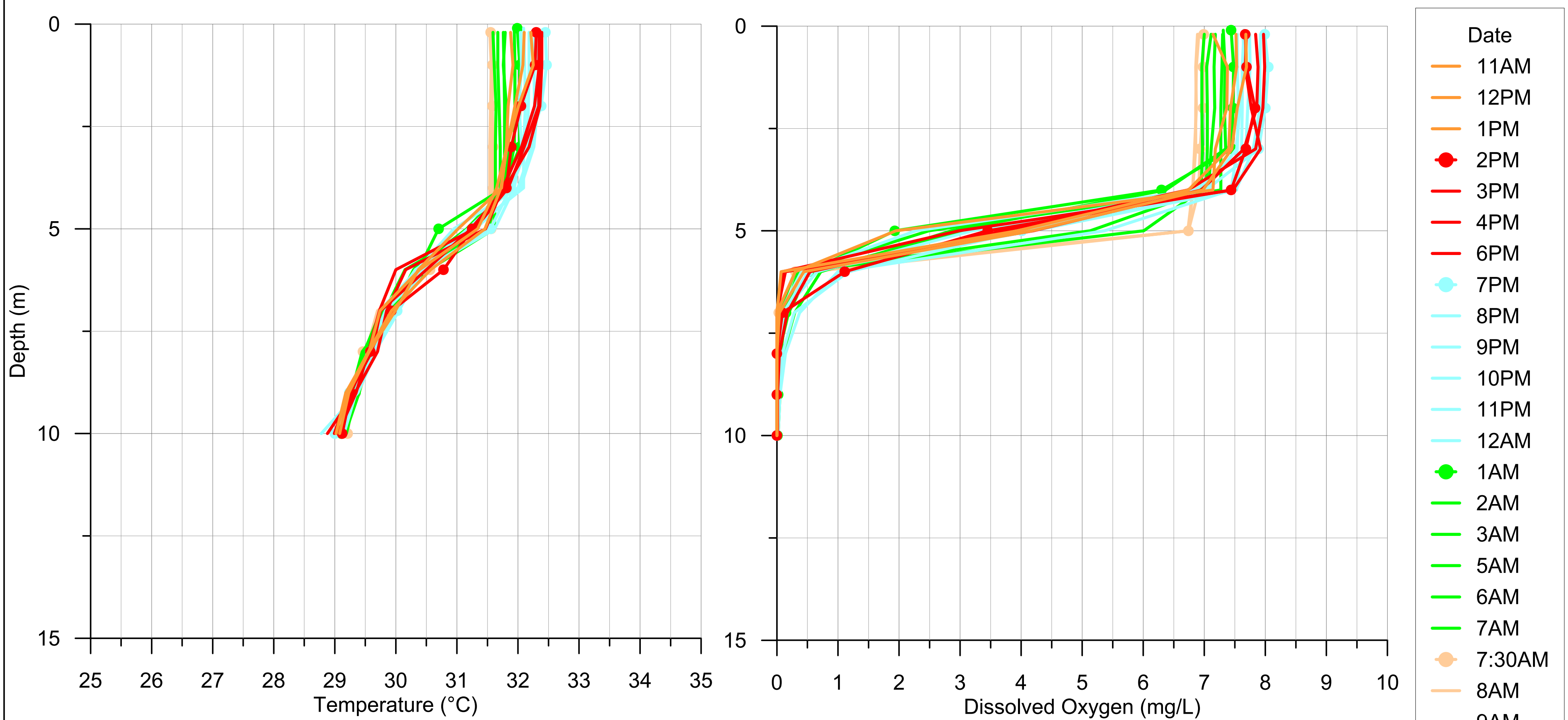
Figure 10a

24-Hour Vertical Temperature and DO Profiles in July from Station OC1

Wallace Dam Project

(FERC No. 2413)



Wallace Dam Operations on July 27-28
Interim (10AM-2PM)
Generation (2PM-7PM)
Interim (7PM-12:45AM)
Pumpack (12:45AM-7:15AM)
Interim (7:15AM-2PM)

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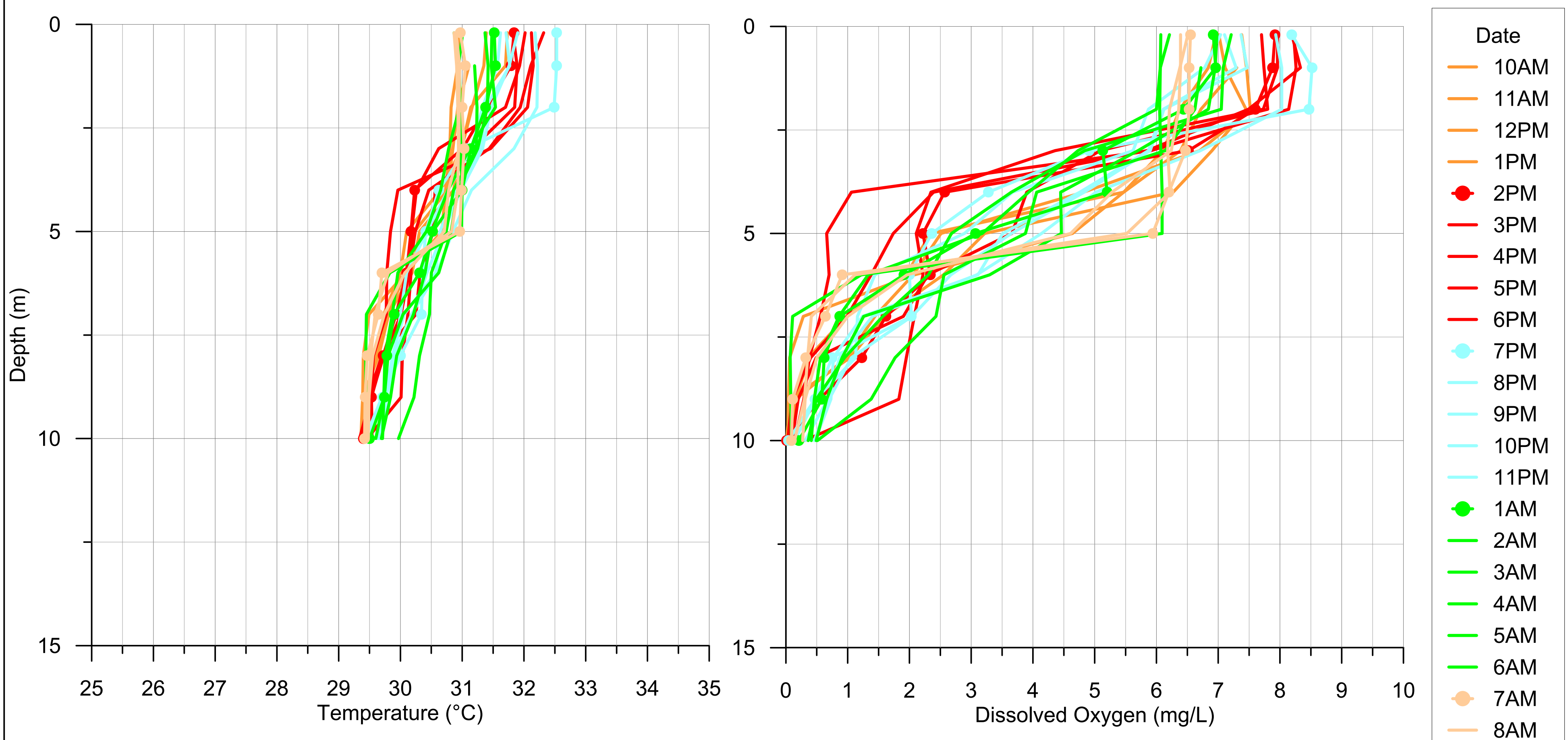
Figure 10b
24-Hour Vertical Temperature and DO Profiles in July from Station OC2
Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on July 27-28
Interim (10AM-2PM)
Generation (2PM-7PM)
Interim (7PM-12:45AM)
Pumpack (12:45AM-7:15AM)
Interim (7:15AM-2PM)

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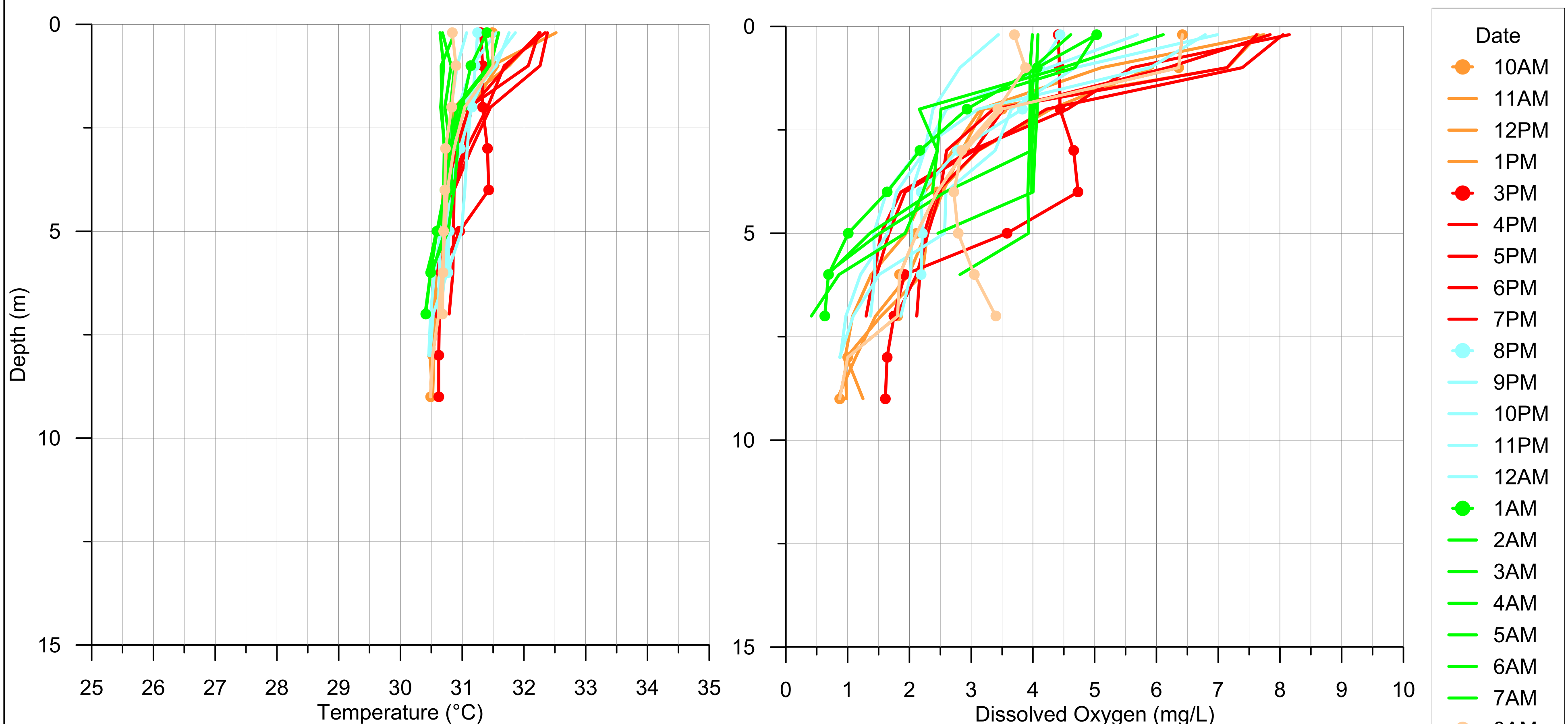
Figure 10c
24-Hour Vertical Temperature and DO Profiles in July from Station OC3
Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on July 27-28

Interim (10AM-2PM)

Generation (2PM-7PM)

Interim (7PM-12:45AM)

Pumpack (12:45AM-7:15AM)

Interim (7:15AM-2PM)

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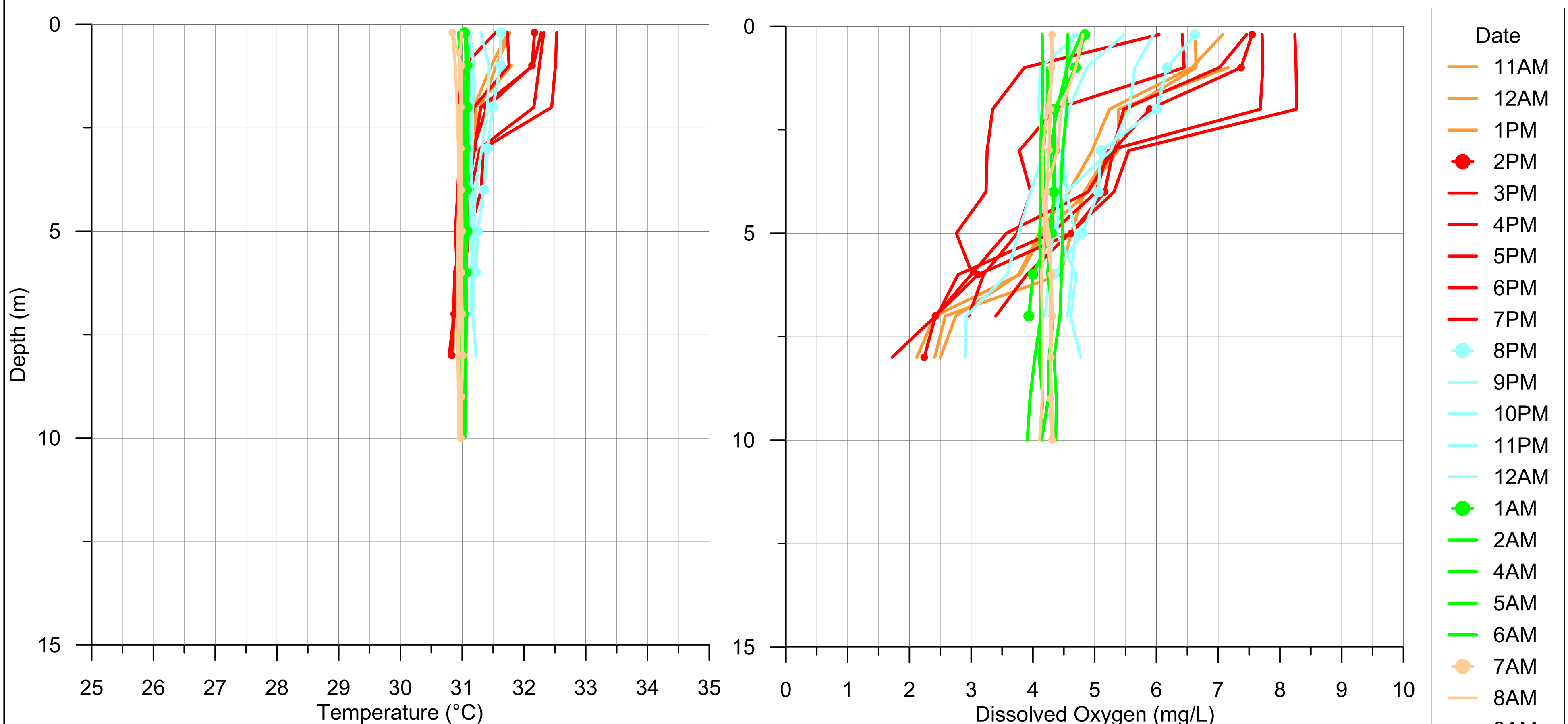
Figure 10d

24-Hour Vertical Temperature and DO Profiles in July from Station OC4

Wallace Dam Project

(FERC No. 2413)



Wallace Dam Operations on July 27-28
Interim (10AM-2PM)
Generation (2PM-7PM)
Interim (7PM-12:45AM)
Pumpack (12:45AM-7:15AM)
Interim (7:15AM-2PM)

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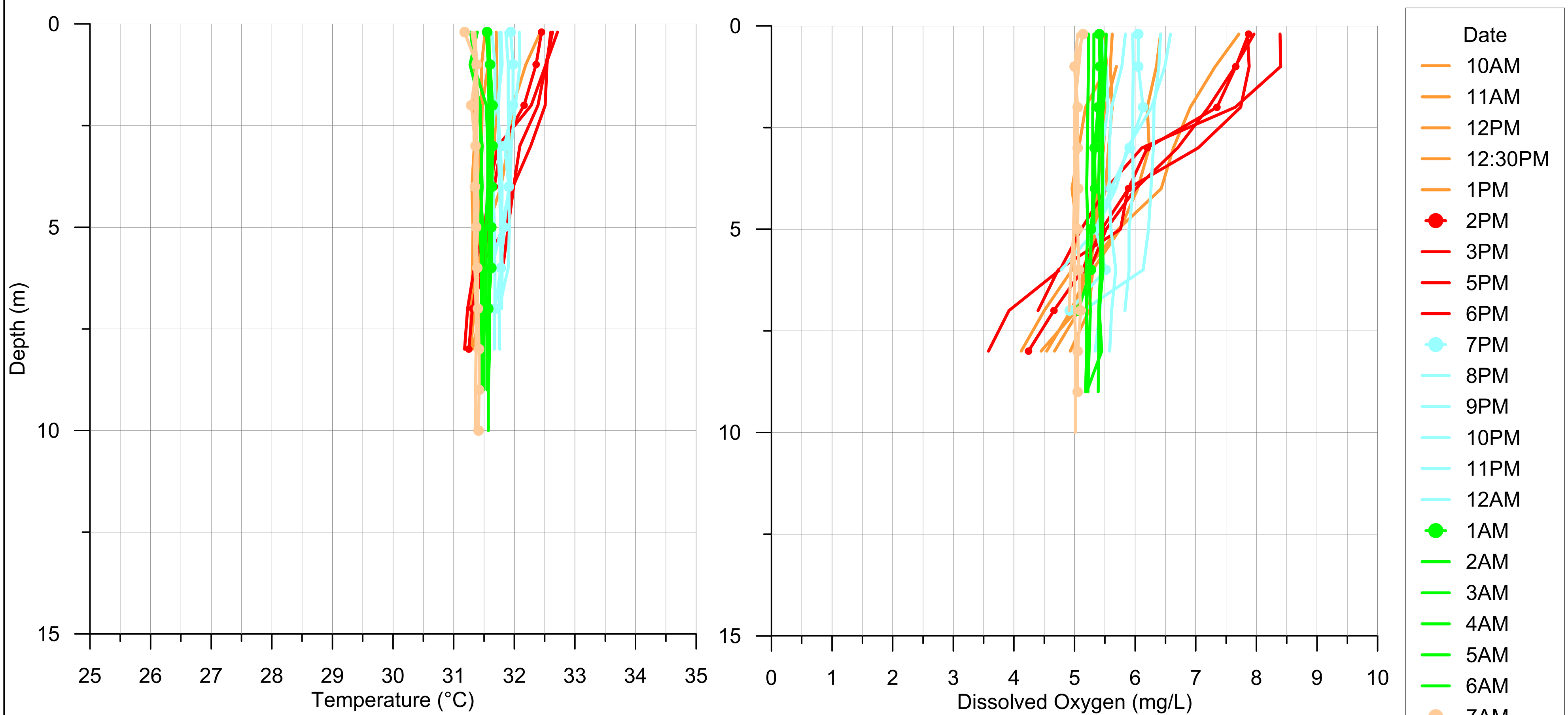
Figure 10e
24-Hour Vertical Temperature and DO Profiles in July from Station OC5
Wallace Dam Project
(FERC No. 2413)



<u>Wallace Dam Operations on July 27-28</u>
Interim (10AM-2PM)
Generation (2PM-7PM)
Interim (7PM-12:45AM)
Pumpack (12:45AM-7:15AM)
Interim (7:15AM-2PM)

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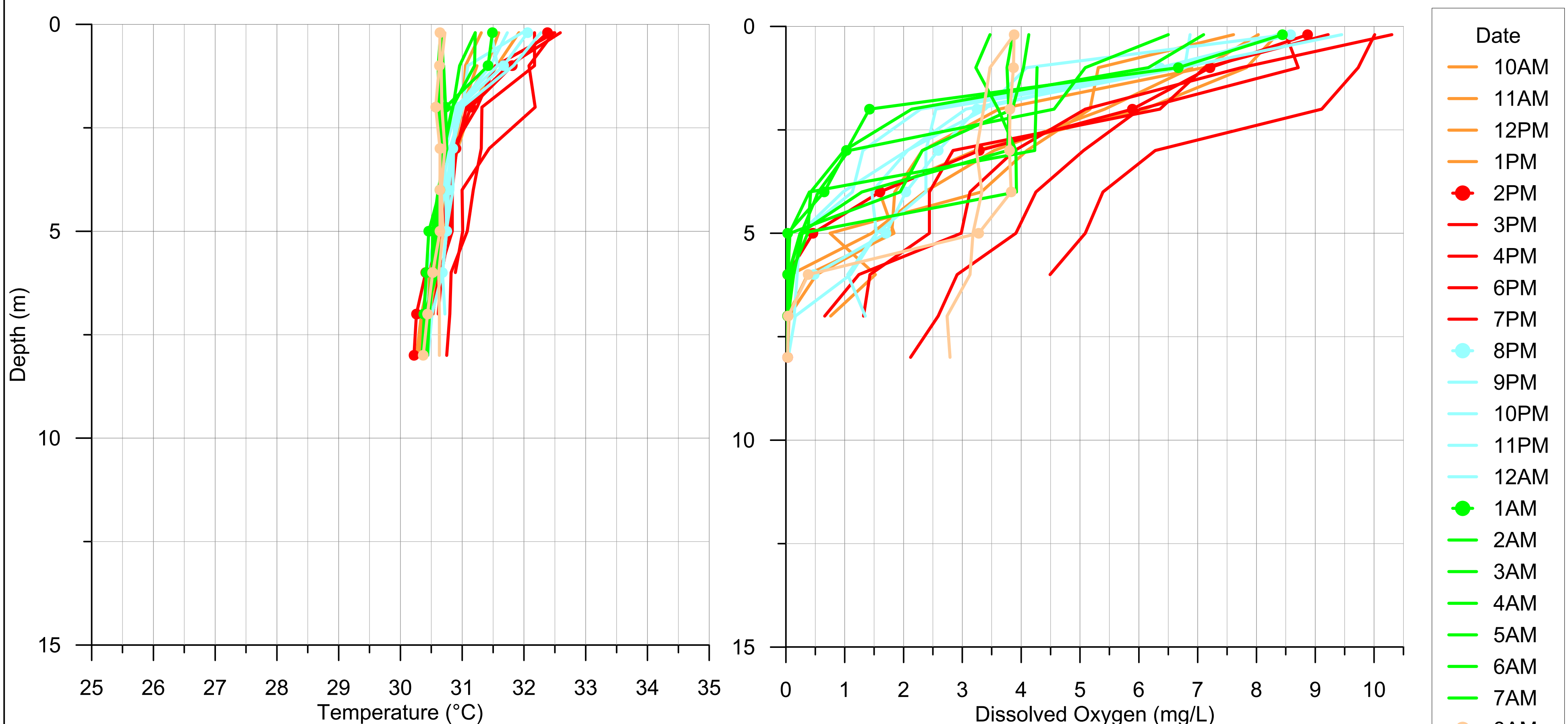
Figure 10f
24-Hour Vertical Temperature and DO Profiles in July from Station OC6
Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on July 27-28
Interim (10AM-2PM)
Generation (2PM-7PM)
Interim (7PM-12:45AM)
Pumpack (12:45AM-7:15AM)
Interim (7:15AM-2PM)

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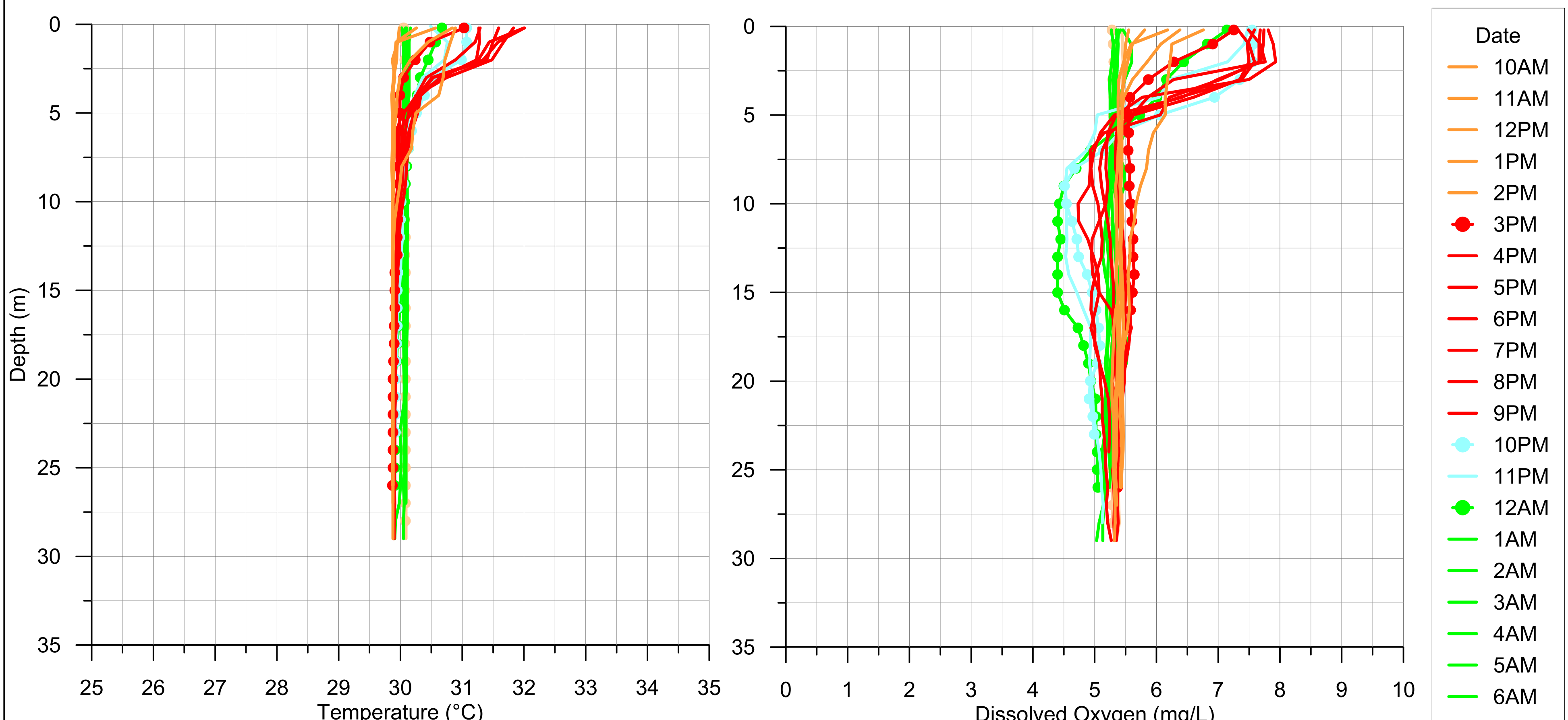
Figure 10g
24-Hour Vertical Temperature and DO Profiles in July from Station OC9
Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on August 15-16
Interim (10AM-2PM)
Generation (2:15PM-9:30PM)
Interim (9:45PM-12:00AM)
Pumpack (12:15AM-6:15AM)
Interim (6:30AM-10AM)

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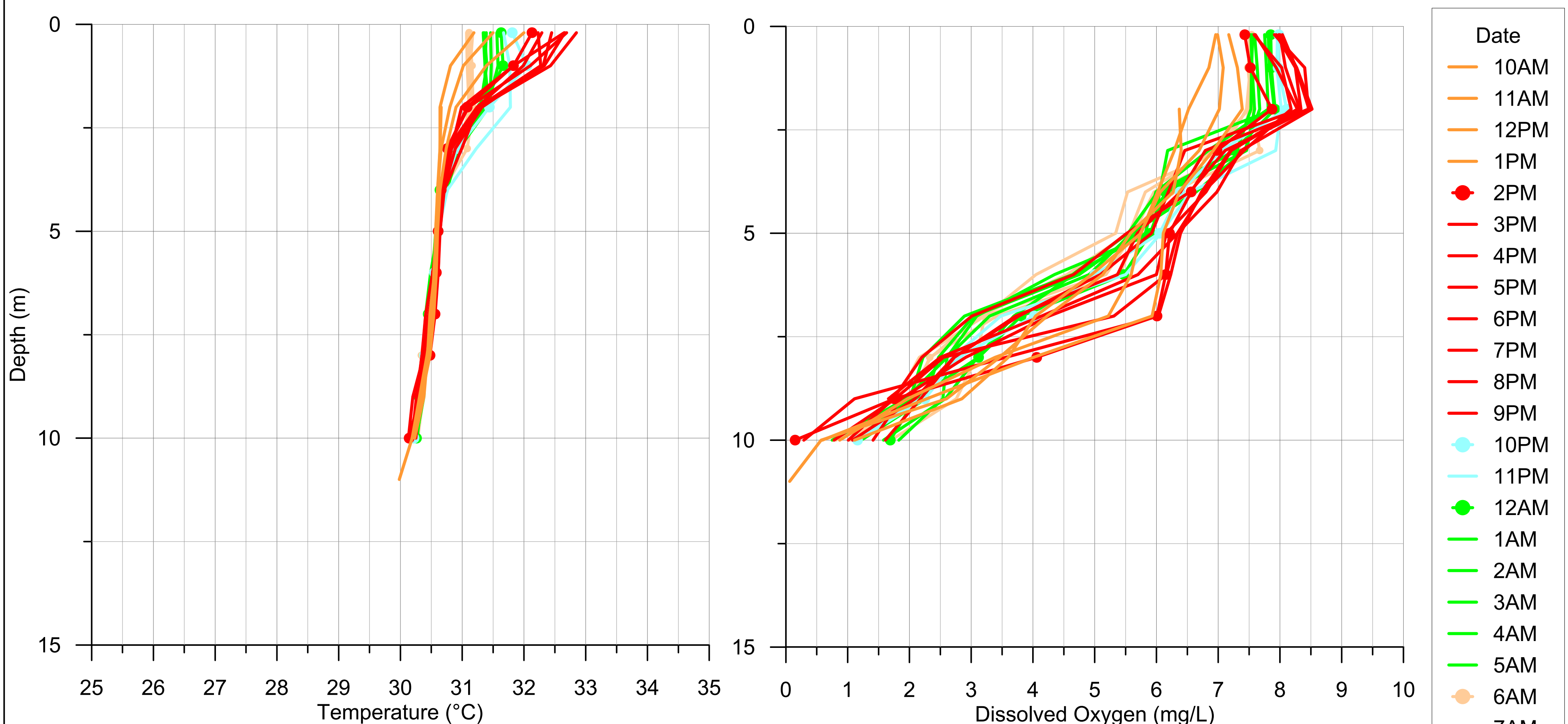
Figure 11a
24-Hour Vertical Temperature and DO Profiles in August from Station OC1
Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on August 15-16

Interim (10AM-2PM)

Generation (2:15PM-9:30PM)

Interim (9:45PM-12:00AM)

Pumpack (12:15AM-6:15AM)

Interim (6:30AM-10AM)

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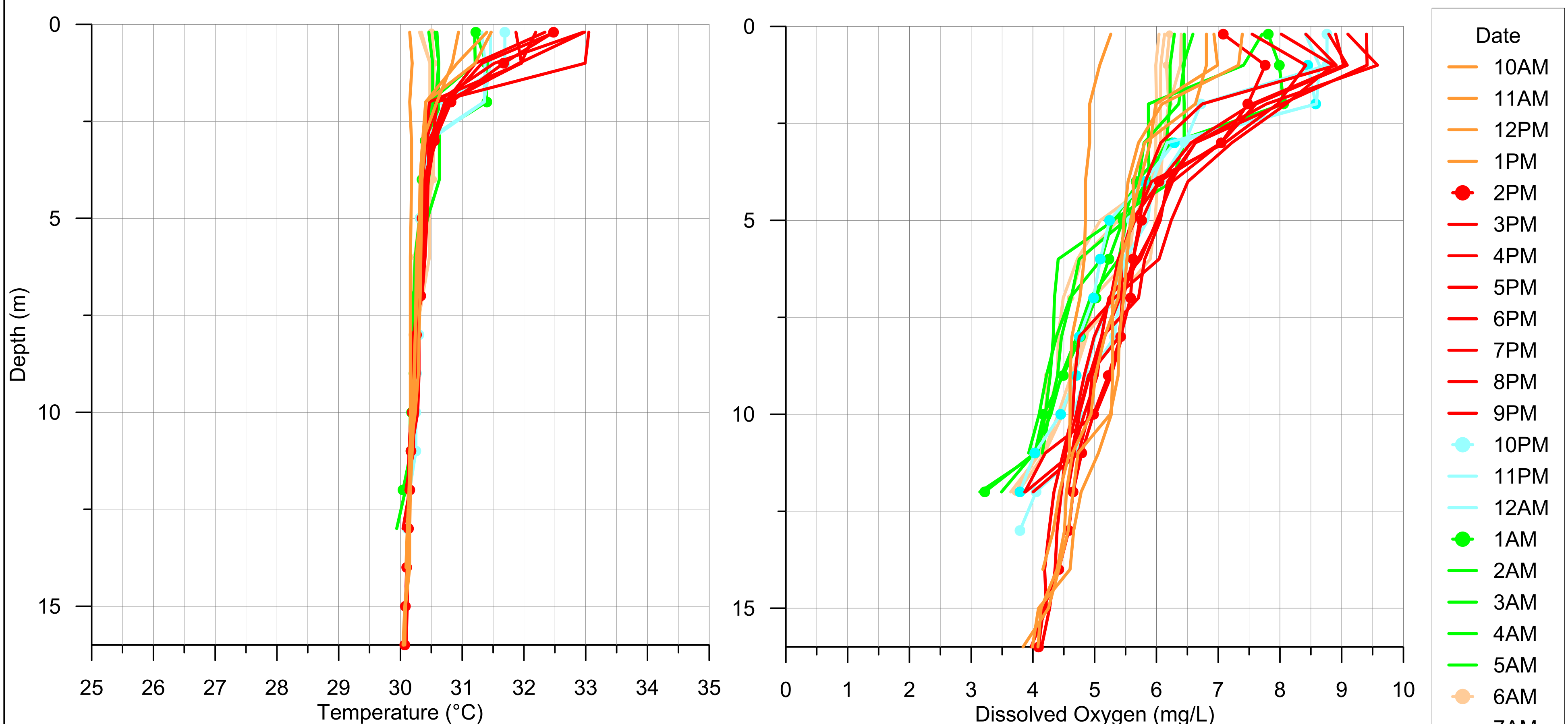
Figure 11b

24-Hour Vertical Temperature and DO Profiles in August from Station OC2

Wallace Dam Project

(FERC No. 2413)



Wallace Dam Operations on August 15-16
Interim (10AM-2PM)
Generation (2:15PM-9:30PM)
Interim (9:45PM-12:00AM)
Pumpack (12:15AM-6:15AM)
Interim (6:30AM-10AM)

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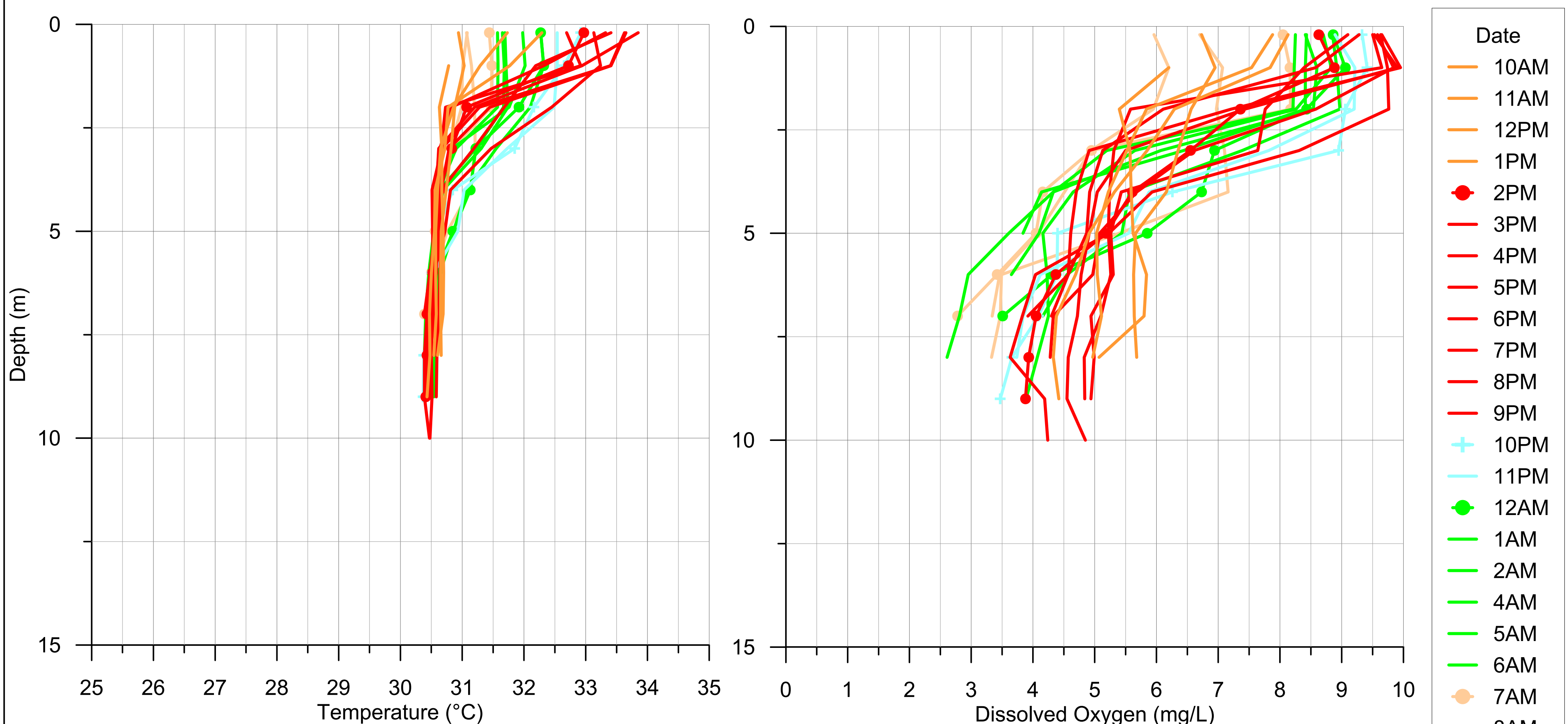
Figure 11c
24-Hour Vertical Temperature and DO Profiles in August from Station OC3
Wallace Dam Project
(FERC No. 2413)



<u>Wallace Dam Operations on August 15-16</u>

Interim (10AM-2PM)

Generation (2:15PM-9:30PM)

Interim (9:45PM-12:00AM)

Pumpack (12:15AM-6:15AM)

Interim (6:30AM-10AM)

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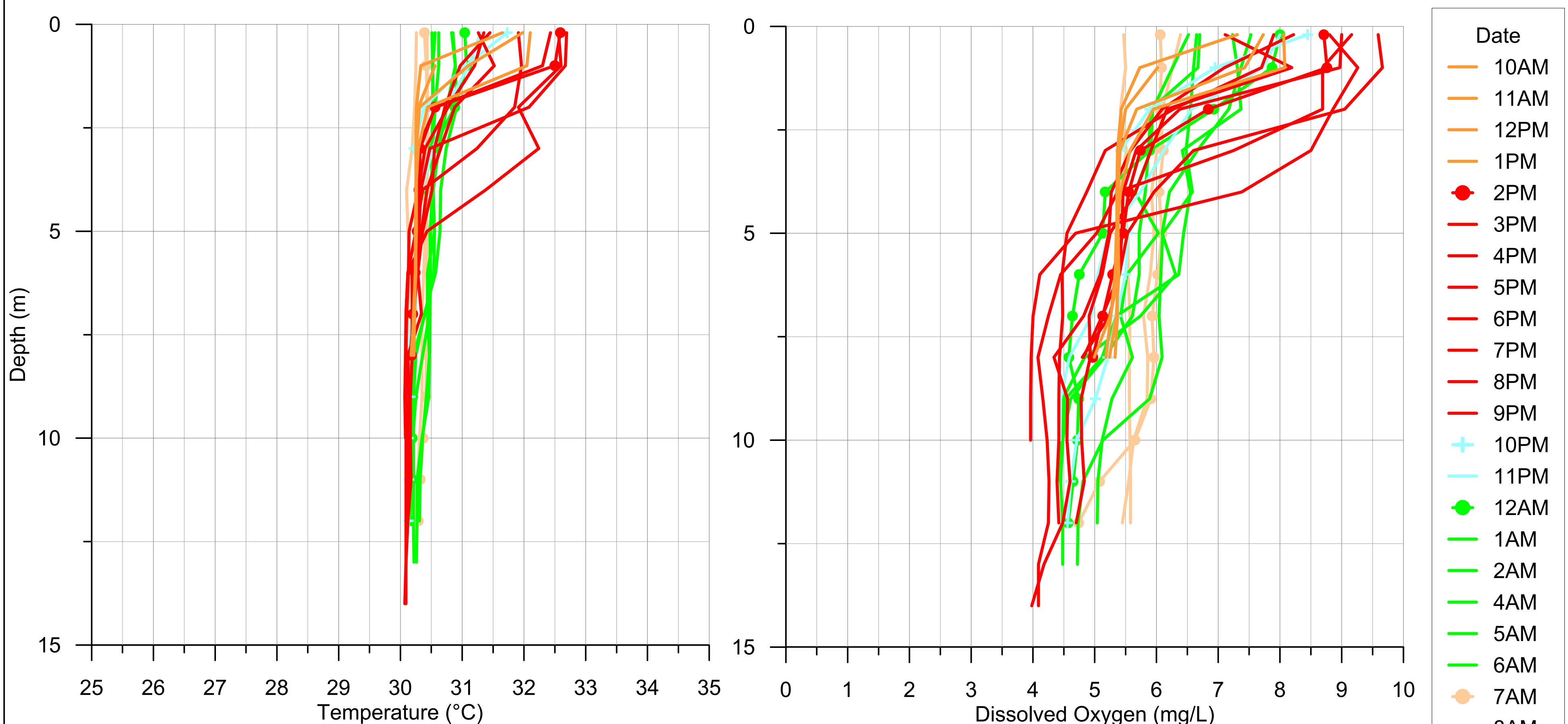
Figure 11d

24-Hour Vertical Temperature and DO Profiles in August from Station OC4

Wallace Dam Project

(FERC No. 2413)



Wallace Dam Operations on August 15-16

Interim (10AM-2PM)

Generation (2:15PM-9:30PM)

Interim (9:45PM-12:00AM)

Pumpack (12:15AM-6:15AM)

Interim (6:30AM-10AM)

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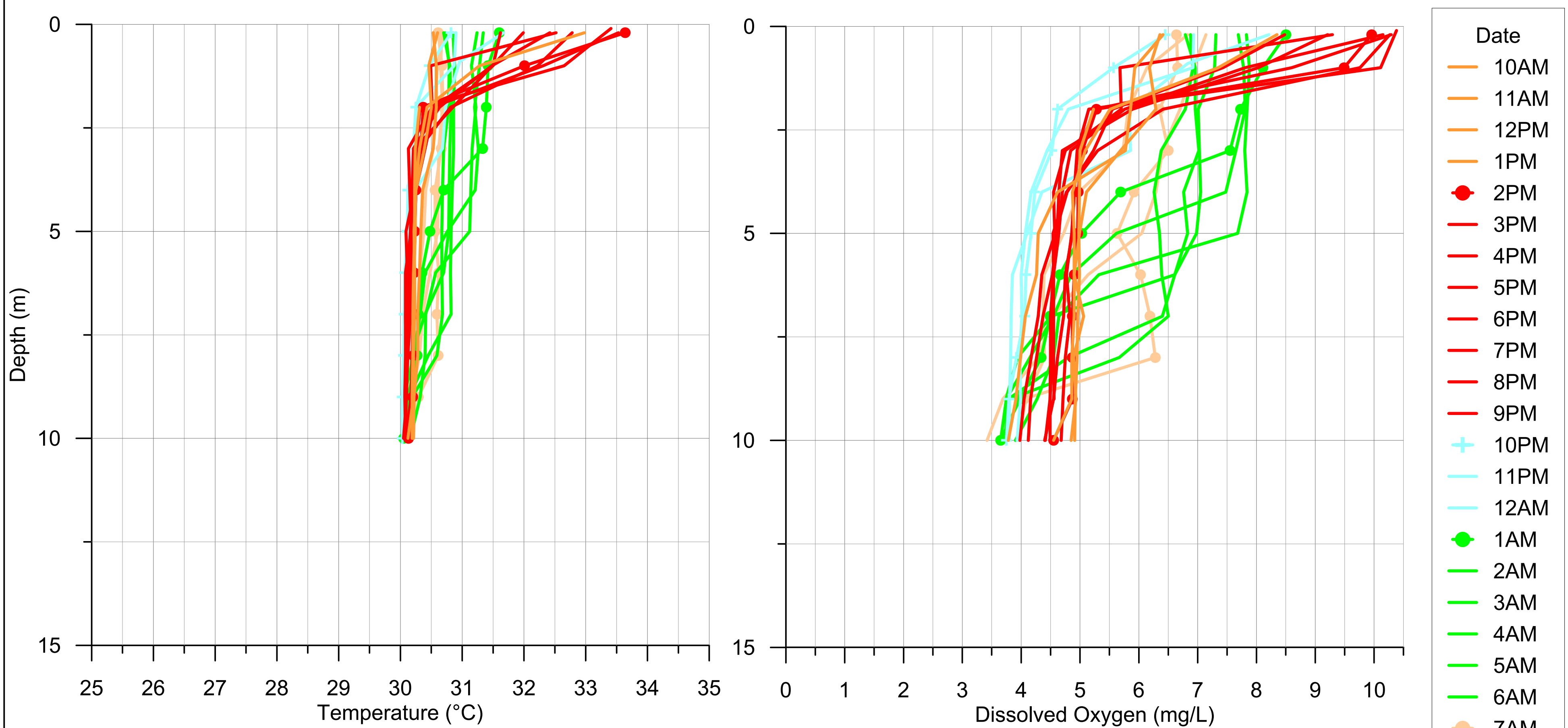
Figure 11e

24-Hour Vertical Temperature and DO Profiles in August from Station OC5

Wallace Dam Project

(FERC No. 2413)



Wallace Dam Operations on August 15-16

Interim (10AM-2PM)

Generation (2:15PM-9:30PM)

Interim (9:45PM-12:00AM)

Pumpack (12:15AM-6:15AM)

Interim (6:30AM-10AM)

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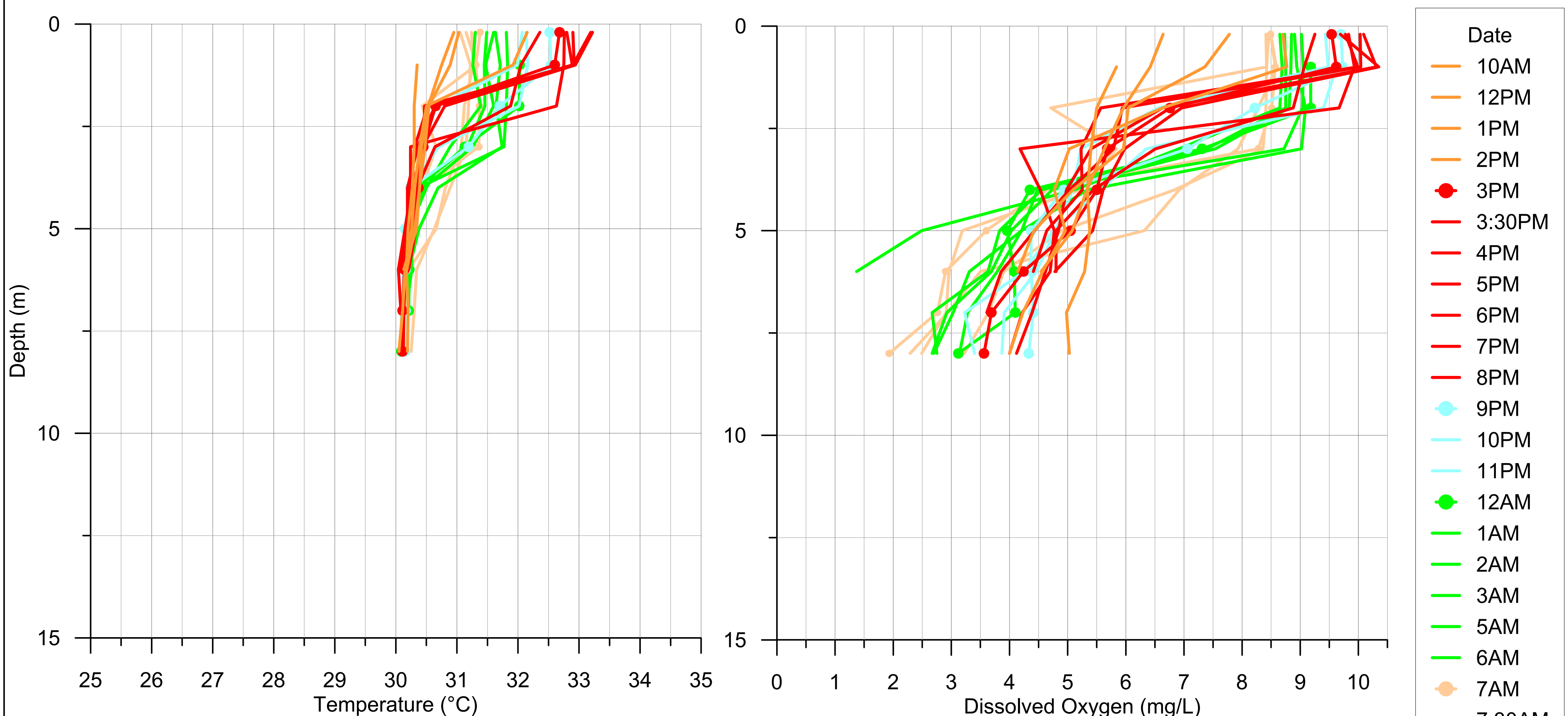
Figure 11f

24-Hour Vertical Temperature and DO Profiles in August from Station OC6

Wallace Dam Project
(FERC No. 2413)



Wallace Dam Operations on August 15-16

Interim (10AM-2PM)

Generation (2:15PM-9:30PM)

Interim (9:45PM-12:00AM)

Pumpack (12:15AM-6:15AM)

Interim (6:30AM-10AM)

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Figure 11g

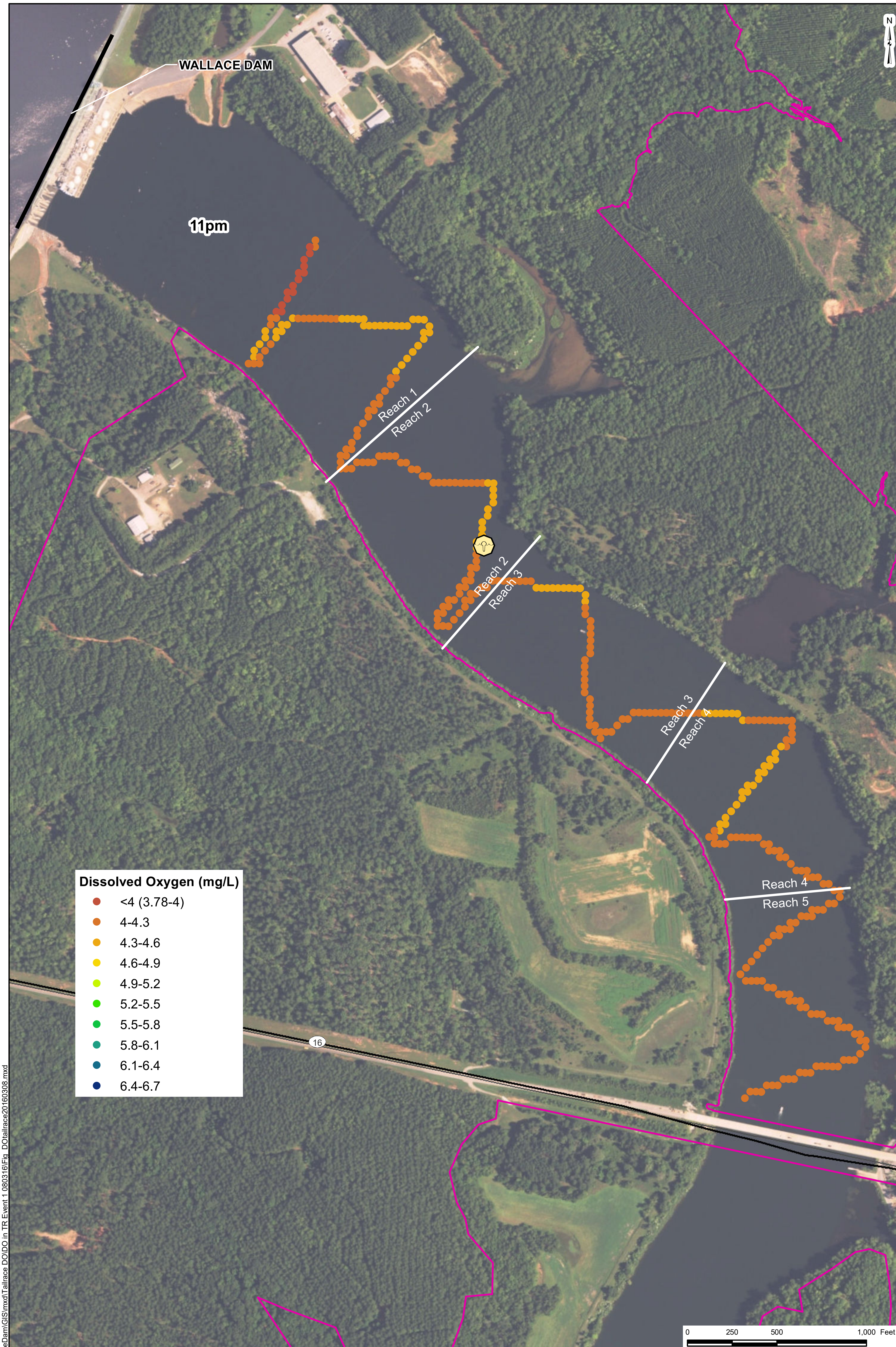
24-Hour Vertical Temperature and DO Profiles in August from Station OC9

Wallace Dam Project

(FERC No. 2413)

APPENDIX C

Tailrace Hourly Transect Data from the Water Resources Study



N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 1 080316\Fig_DOtailrace20160308.mxd

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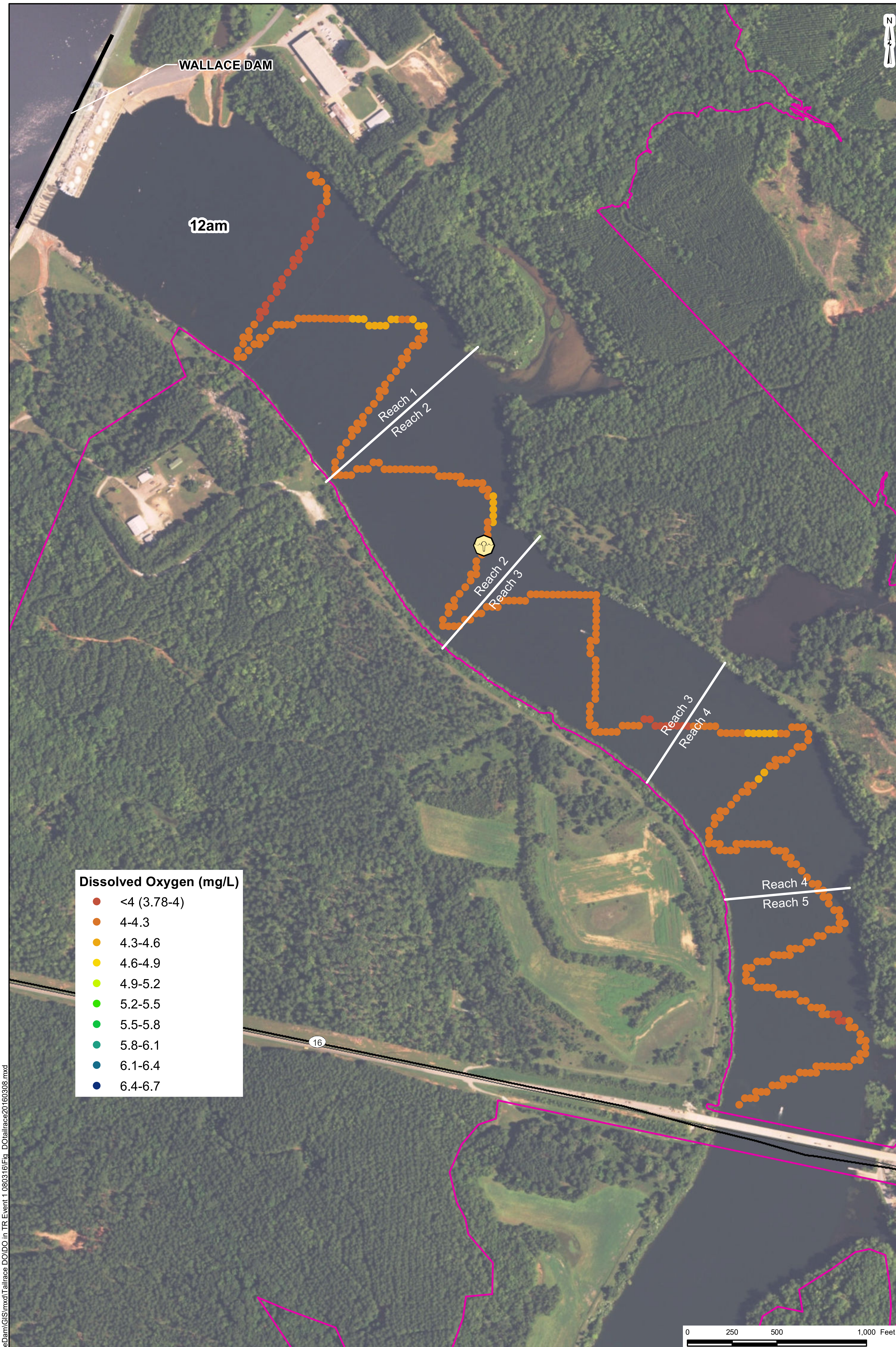
Figure 14a
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)



Tailrace Buoy
State Highway
Project_Boundary

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Figure 14b
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)

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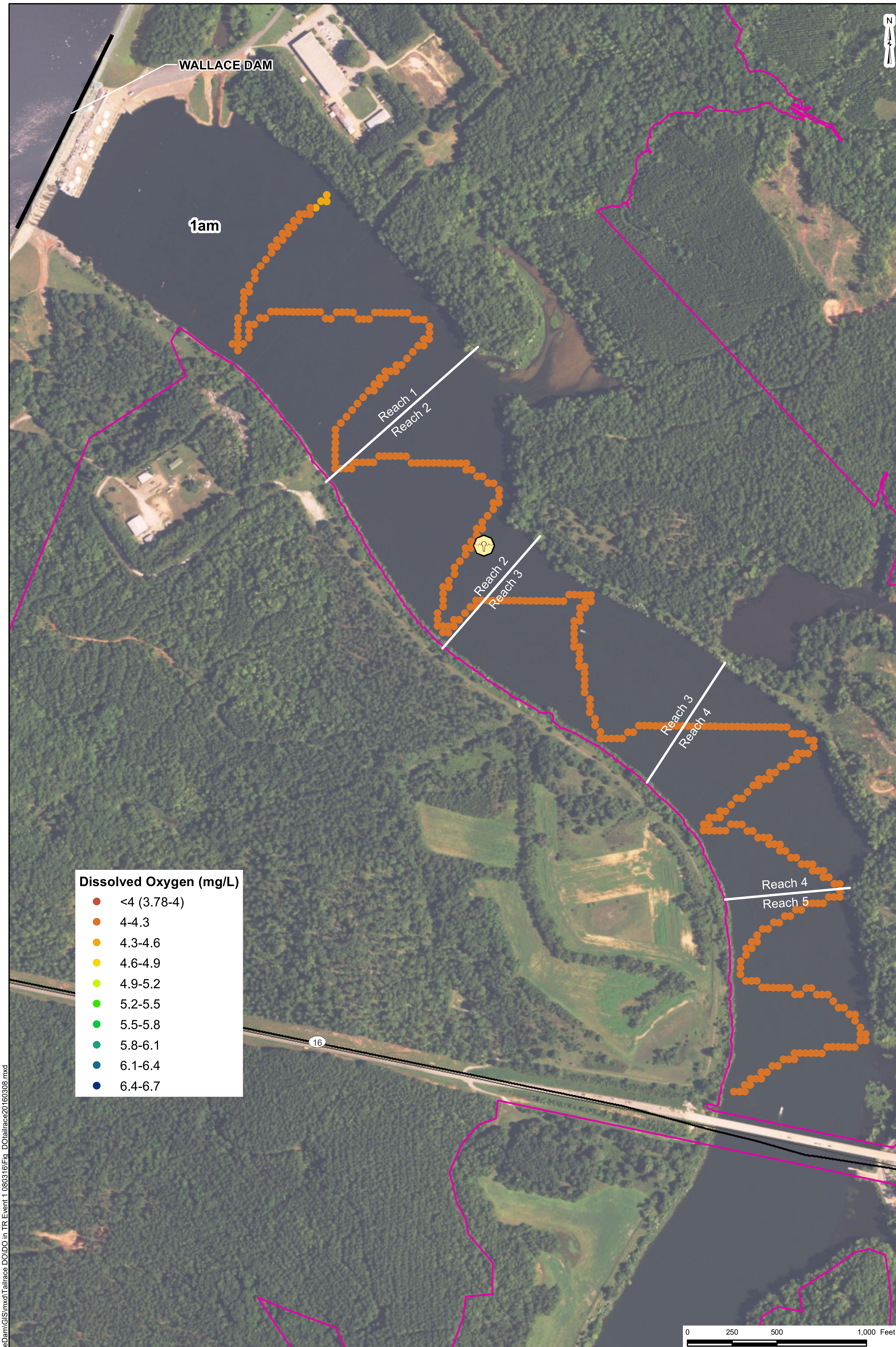

Tailrace Buoy

State Highway

Project_Boundary

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Figure 14c

Hourly Tailrace Monitoring: 8/3/16 - 8/4/16

Wallace Dam Project

(FERC No. 2413)

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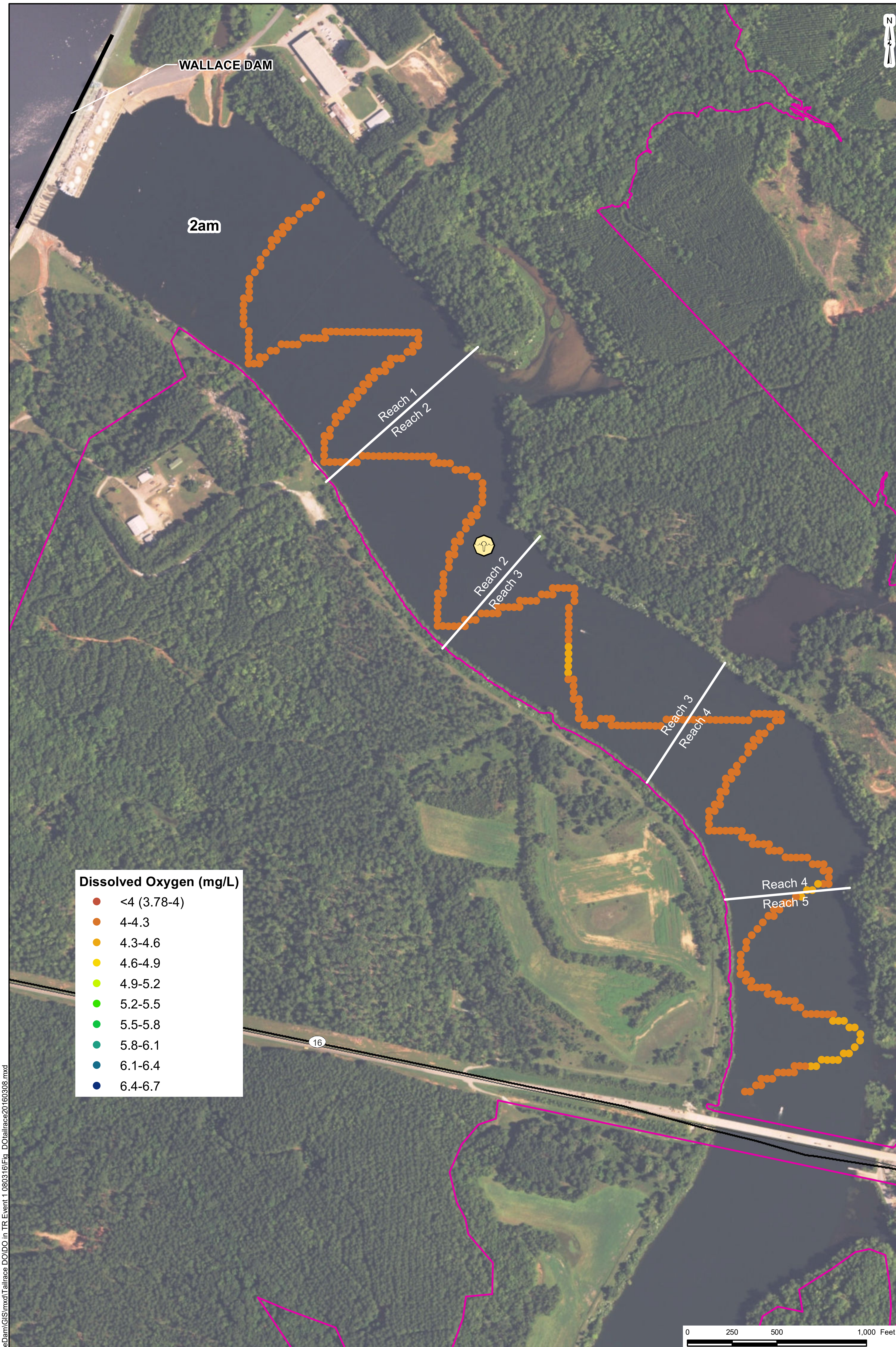

Tailrace Buoy

State Highway

Project_Boundary

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Figure 14d
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)

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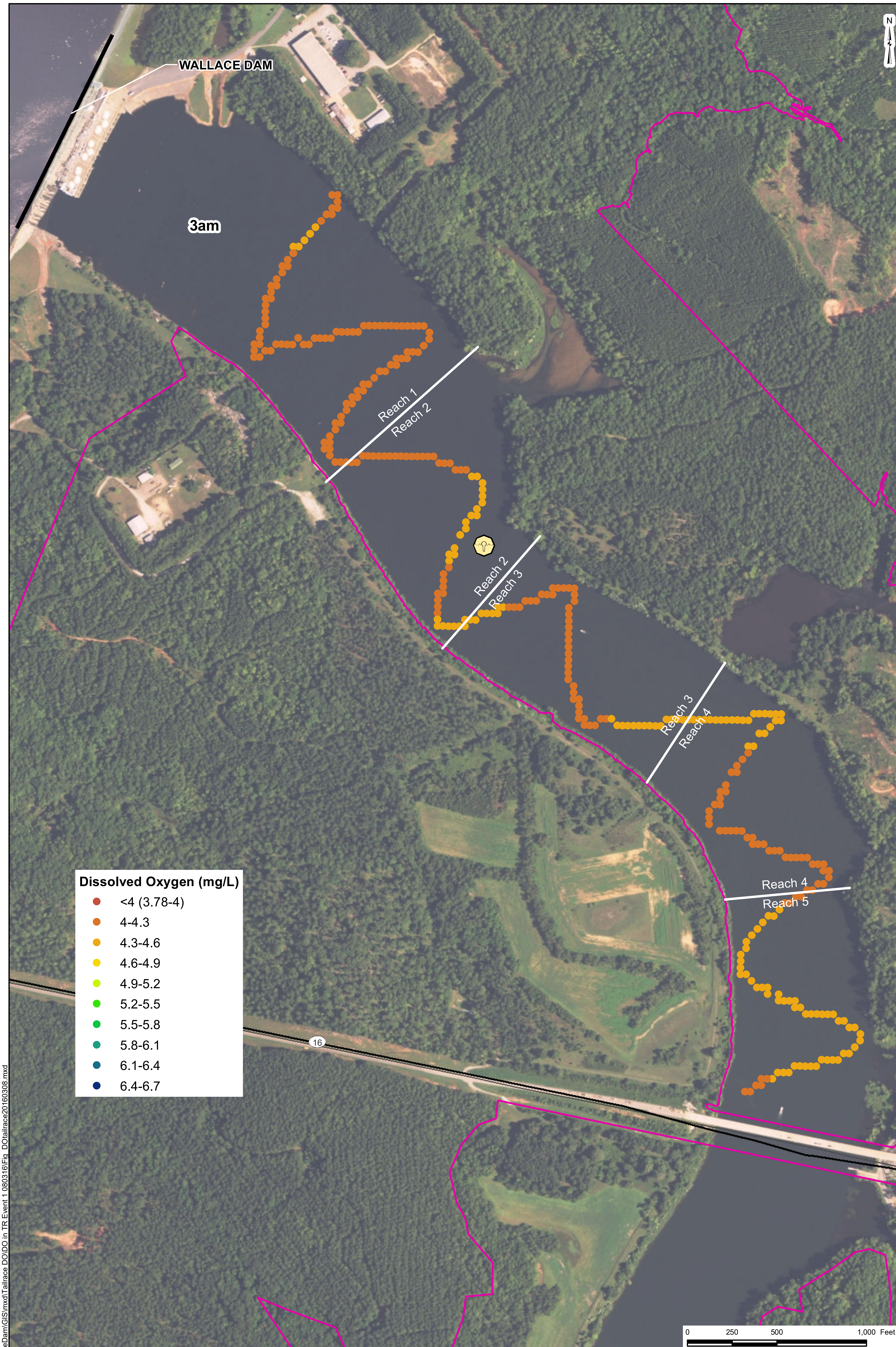

Tailrace Buoy

State Highway

Project_Boundary

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Figure 14e
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 1 080316\Fig_DOtailrace20160308.mxd

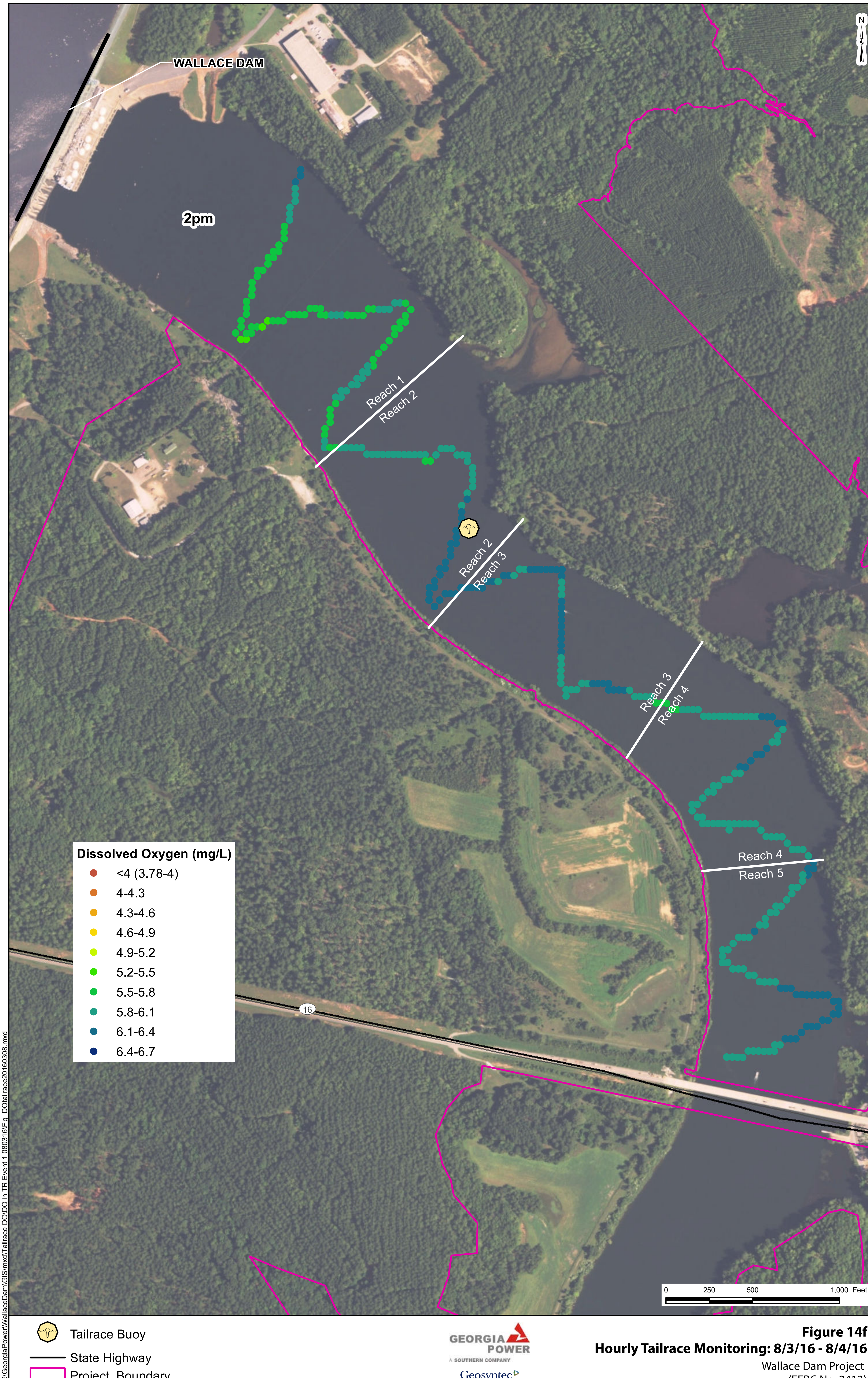

Figure 14f
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)

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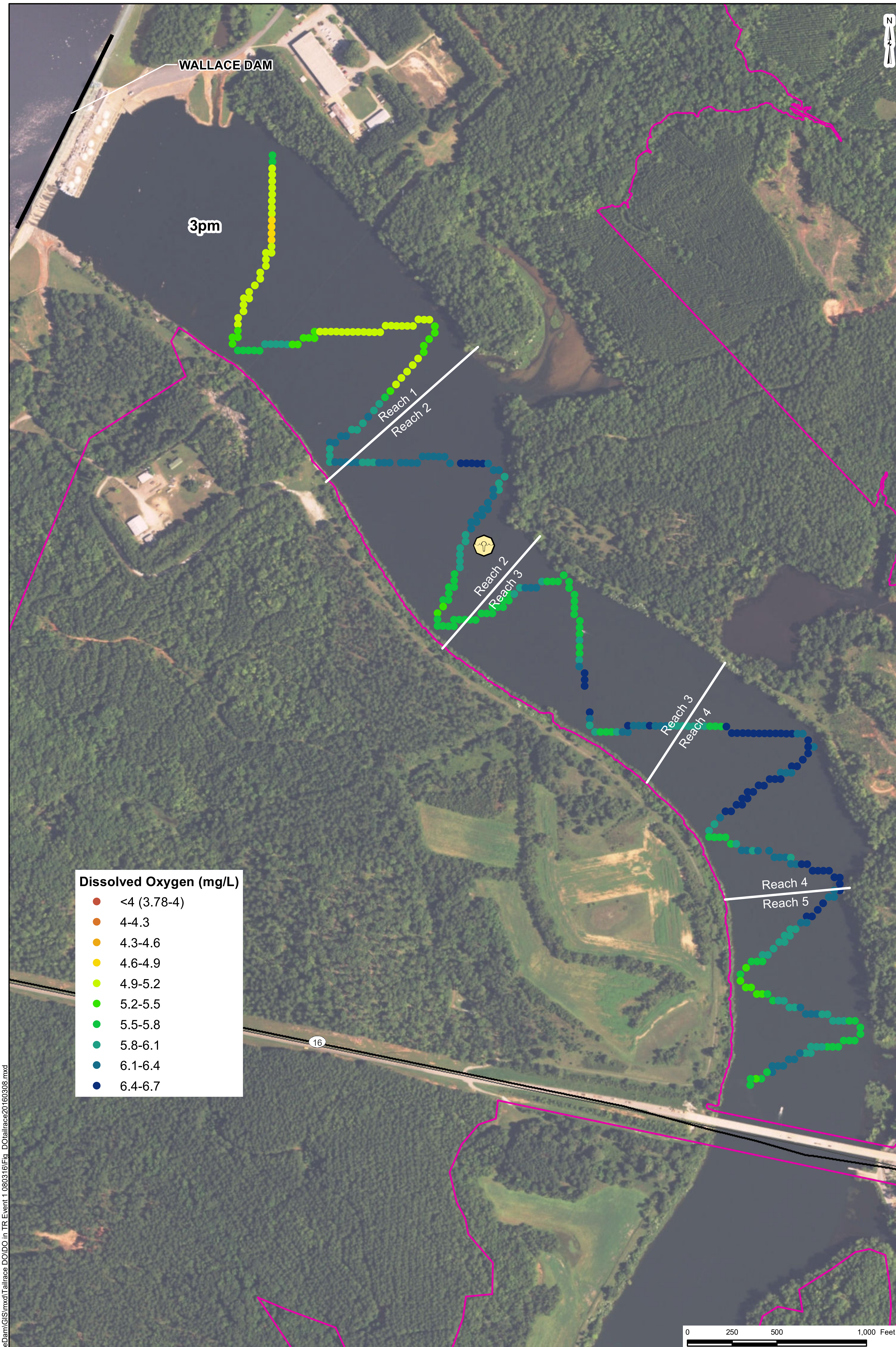

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 1 080316\Fig_DOtailrace20160308.mxd

Tailrace Buoy
State Highway
Project_Boundary

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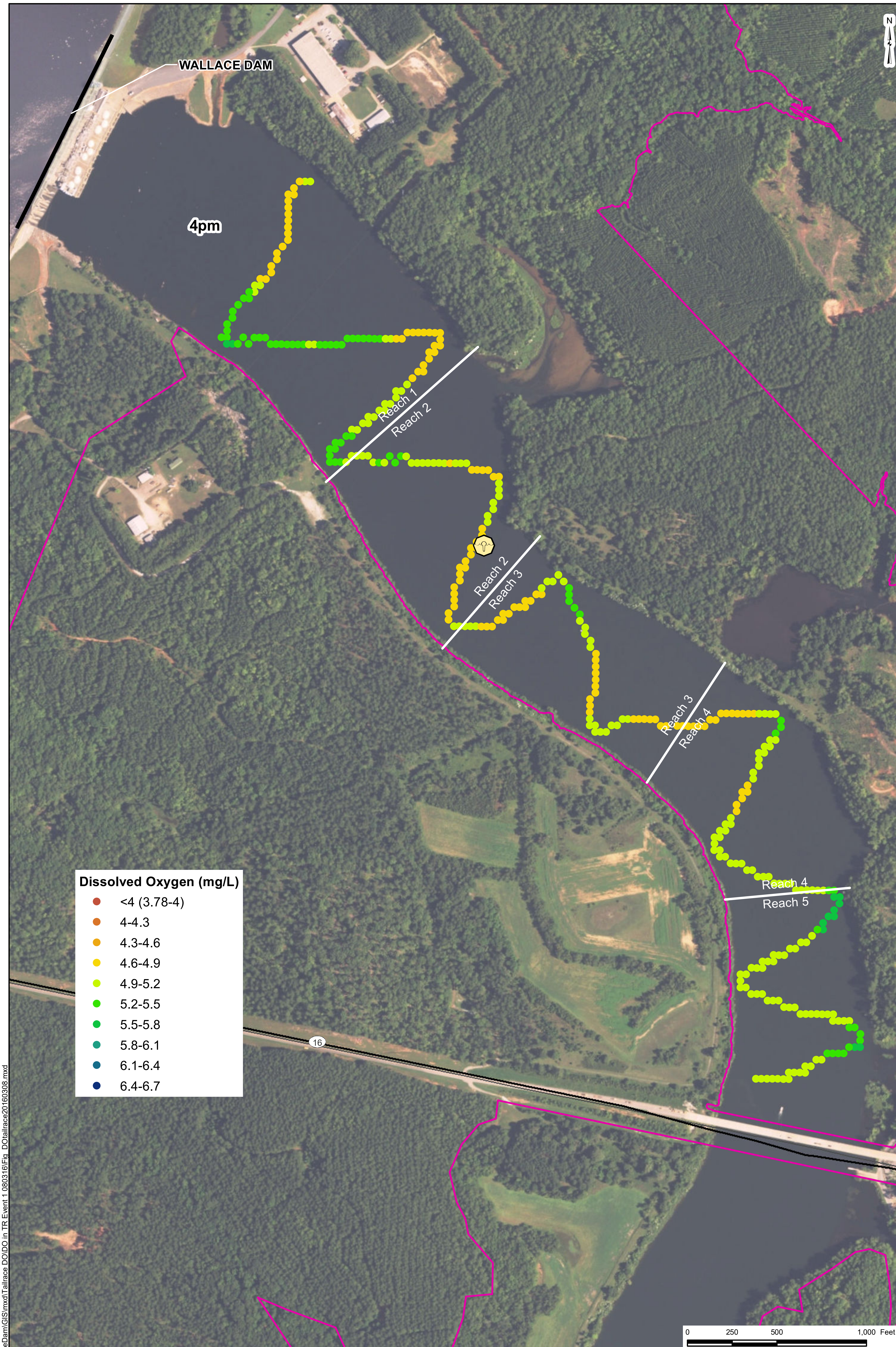
Figure 14g
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)



Tailrace Buoy

State Highway

Project_Boundary

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Figure 14h
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16

Wallace Dam Project
(FERC No. 2413)

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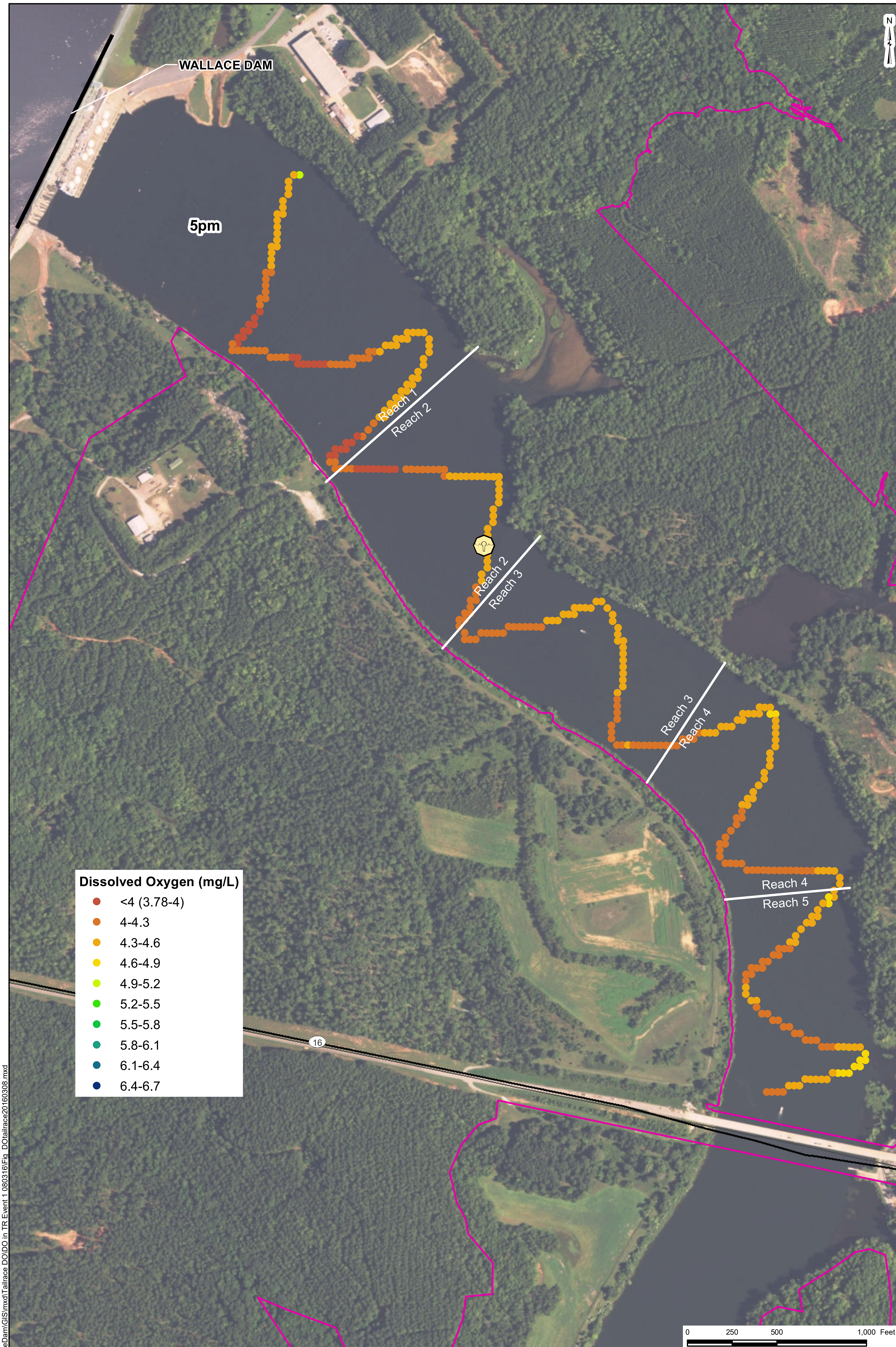

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 1 080316\Fig_DOtailrace20160308.mxd

Tailrace Buoy
State Highway
Project_Boundary

GEORGIA POWER
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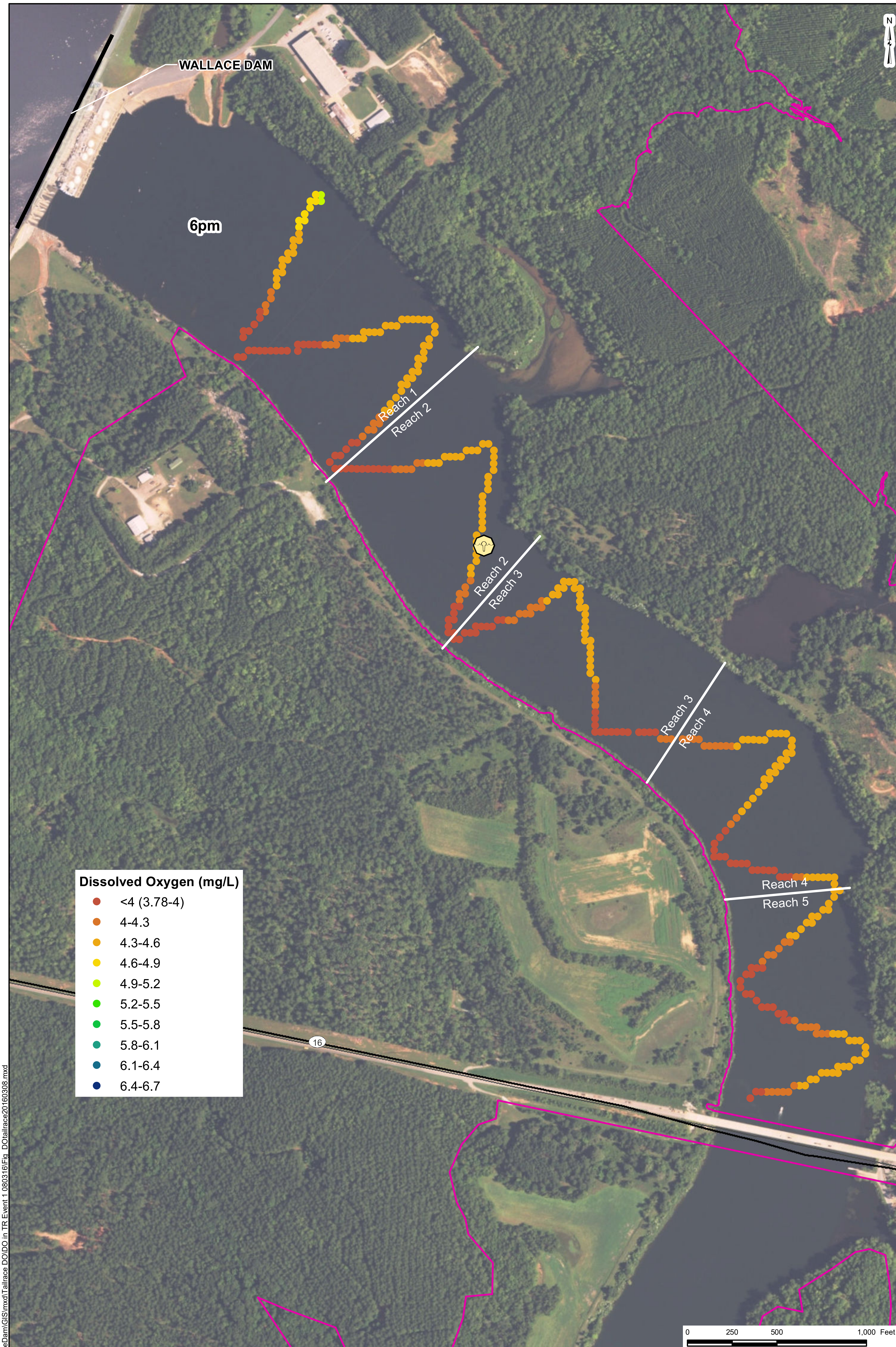
Geosyntec consultants

Figure 14i
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)



Tailrace Buoy

State Highway

Project_Boundary

GEORGIA POWER
A SOUTHERN COMPANY

Geosyntec consultants

Figure 14j
Hourly Tailrace Monitoring: 8/3/16 - 8/4/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 1 080316\Fig_DOtailrace20160308.mxd

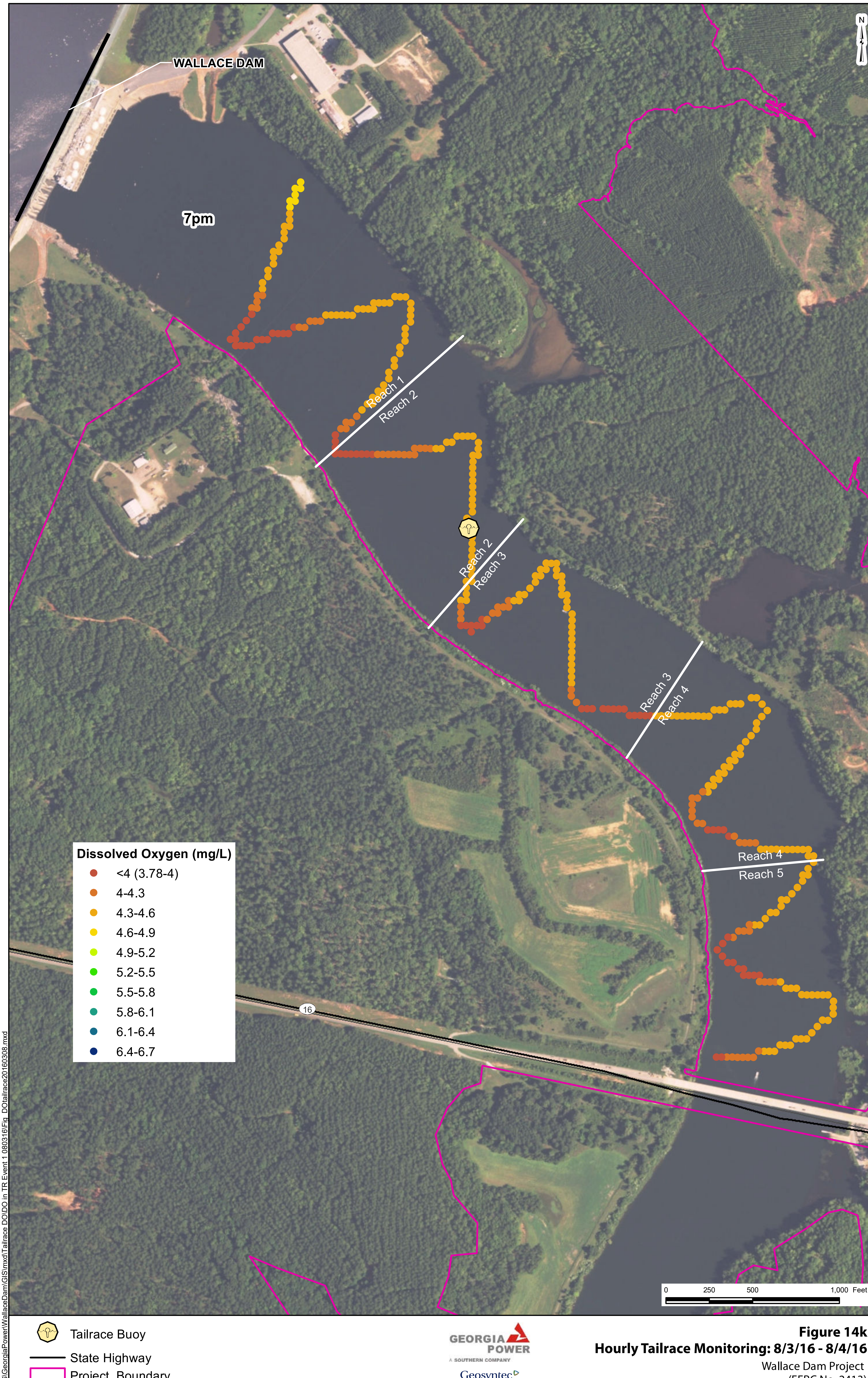


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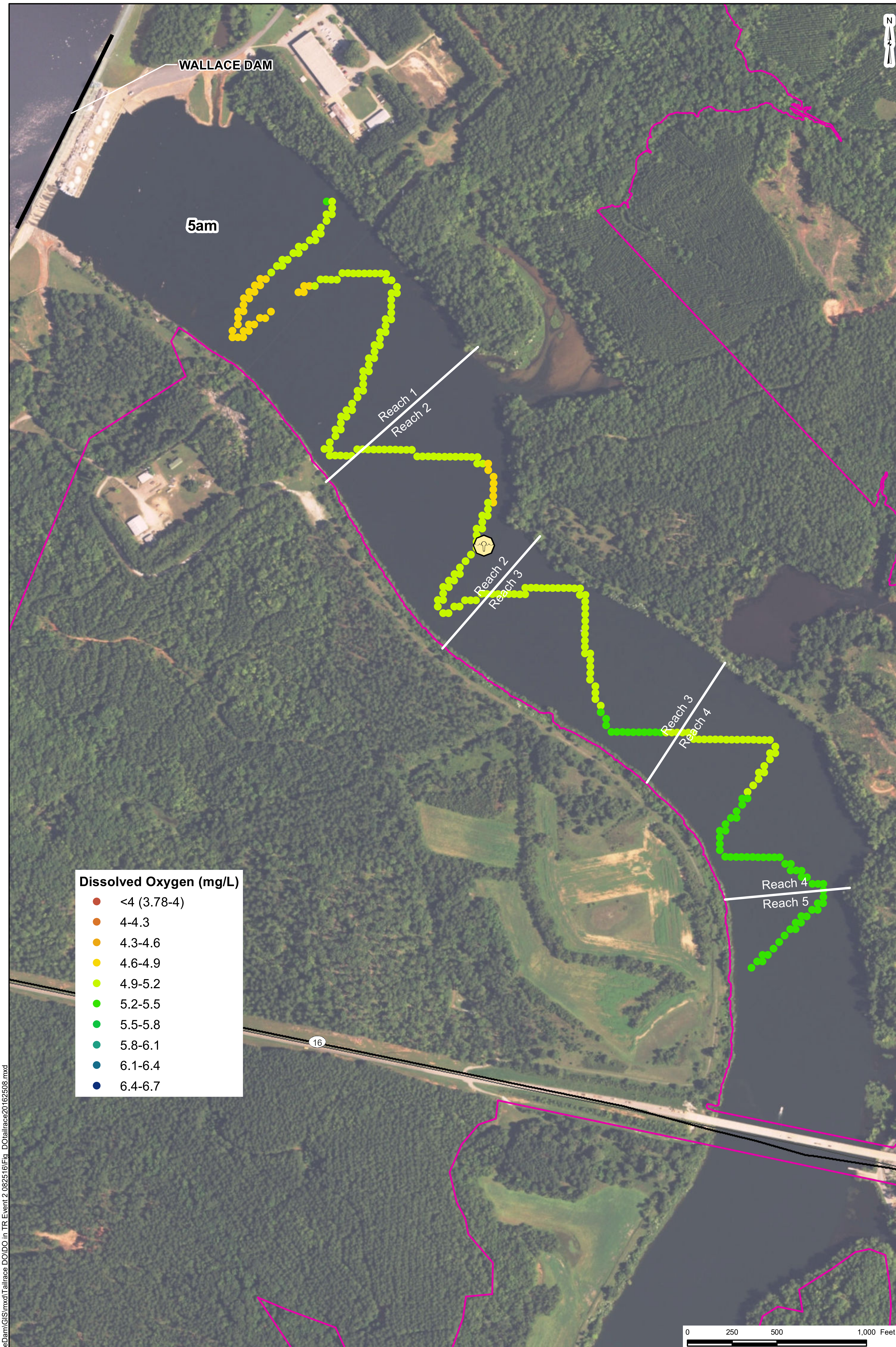
Figure 14k

Hourly Tailrace Monitoring: 8/3/16 - 8/4/16

Wallace Dam Project

(FERC No. 2413)



Tailrace Buoy

State Highway

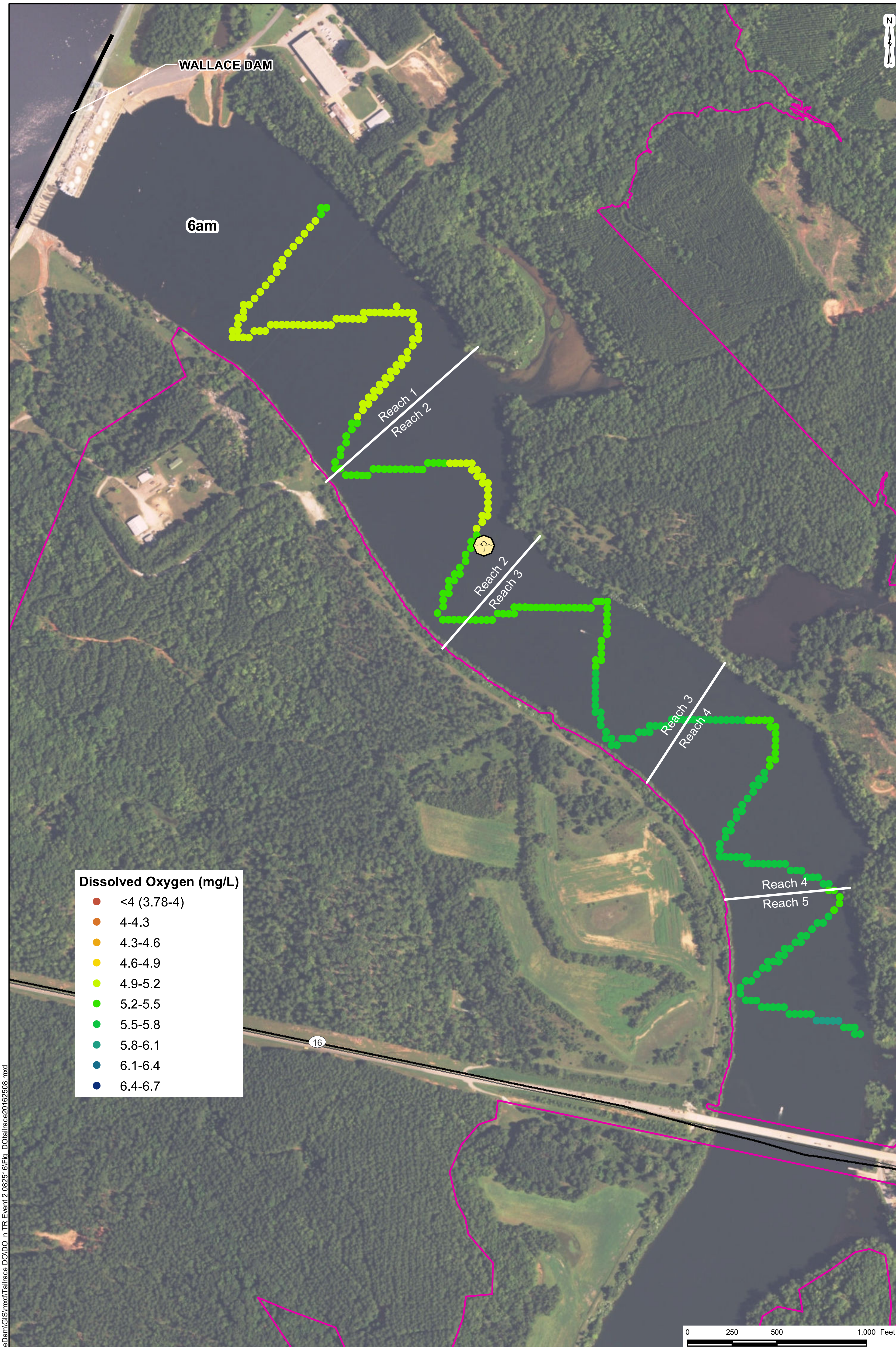
Project_Boundary

Figure 15a

Hourly Tailrace Monitoring: 8/25/16

Wallace Dam Project

(FERC No. 2413)



Tailrace Buoy
State Highway
Project_Boundary

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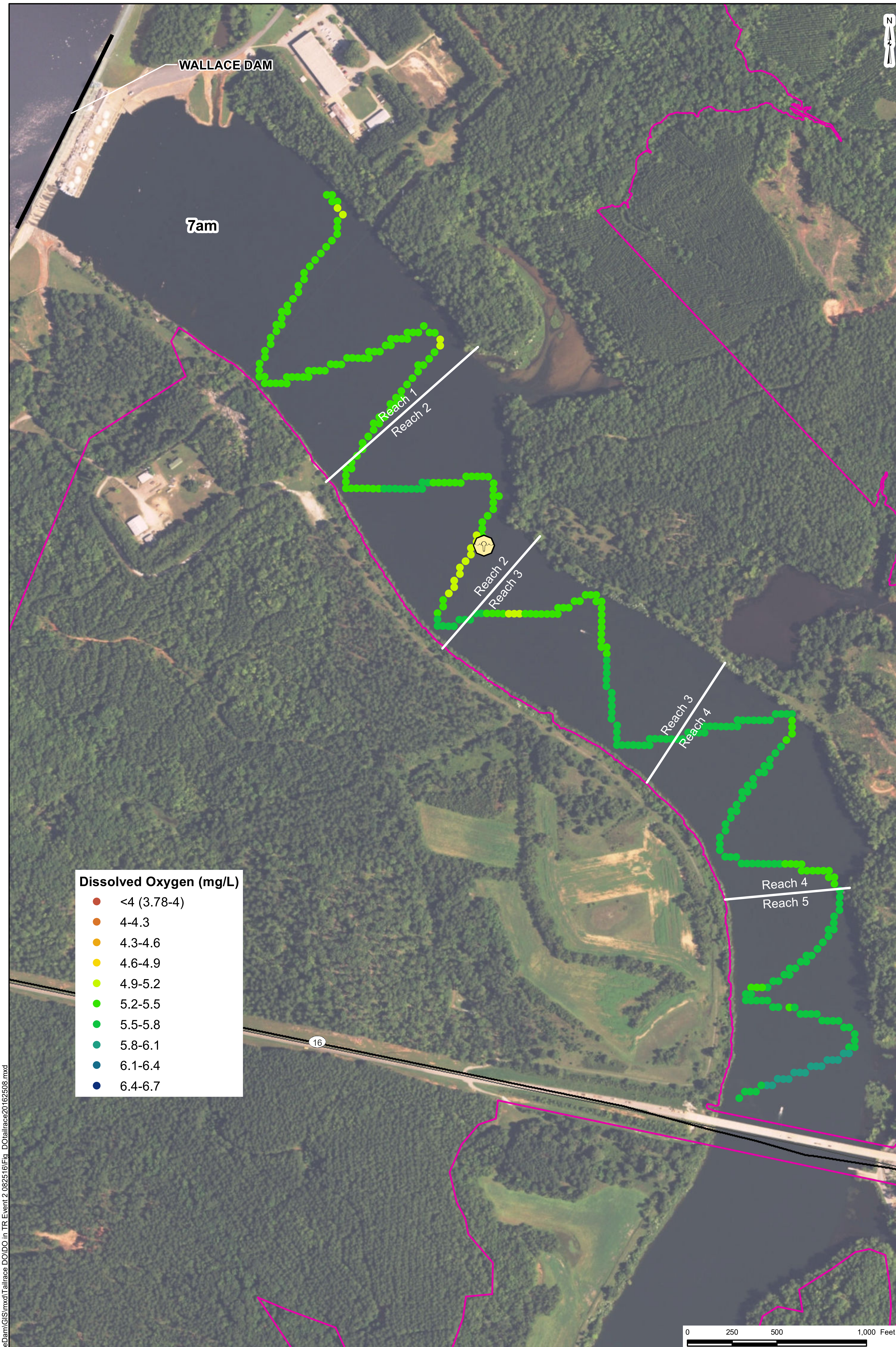
Figure 15b
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd



Tailrace Buoy
State Highway
Project_Boundary

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Figure 15c
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

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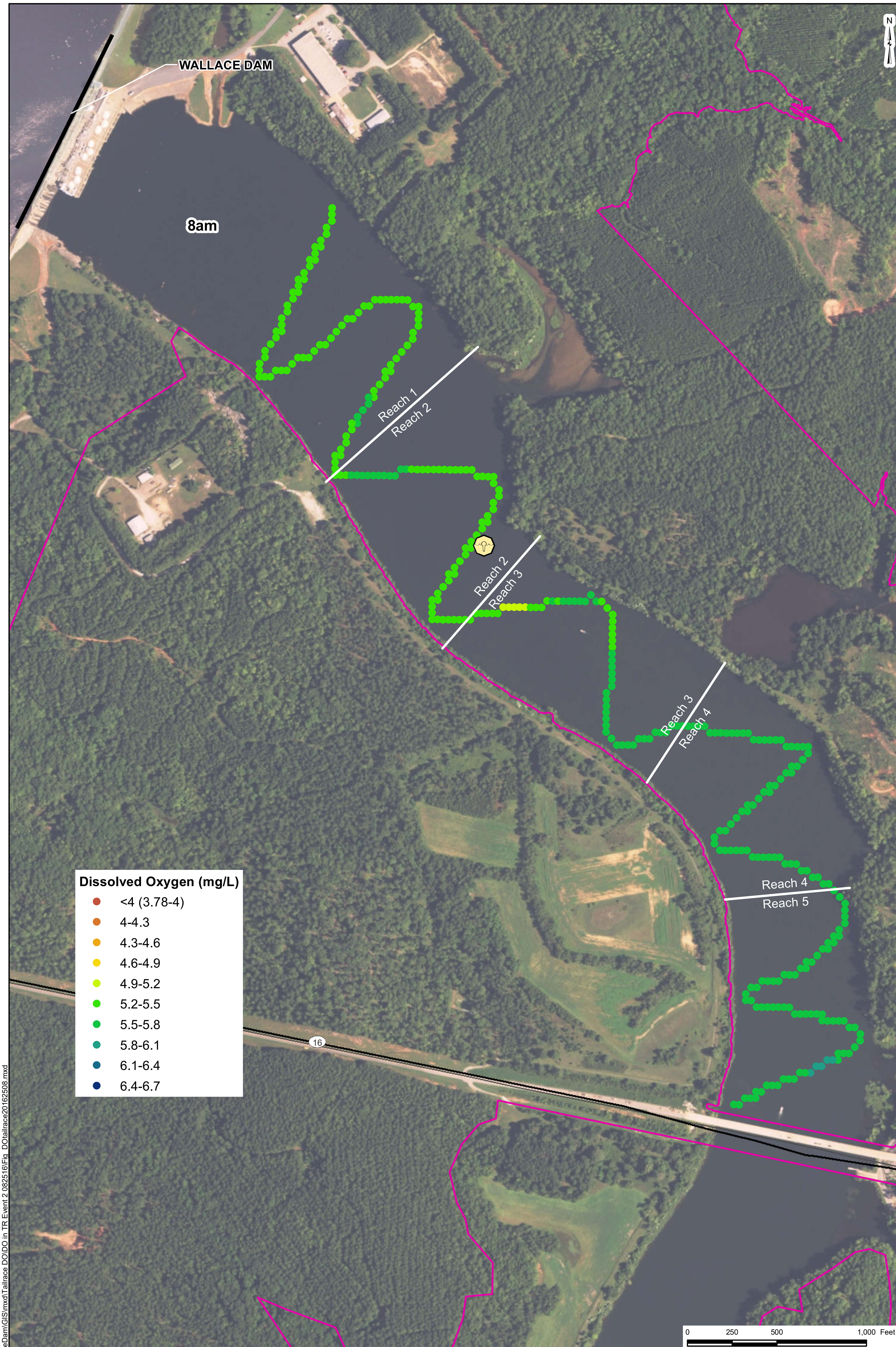

Tailrace Buoy
State Highway
Project_Boundary

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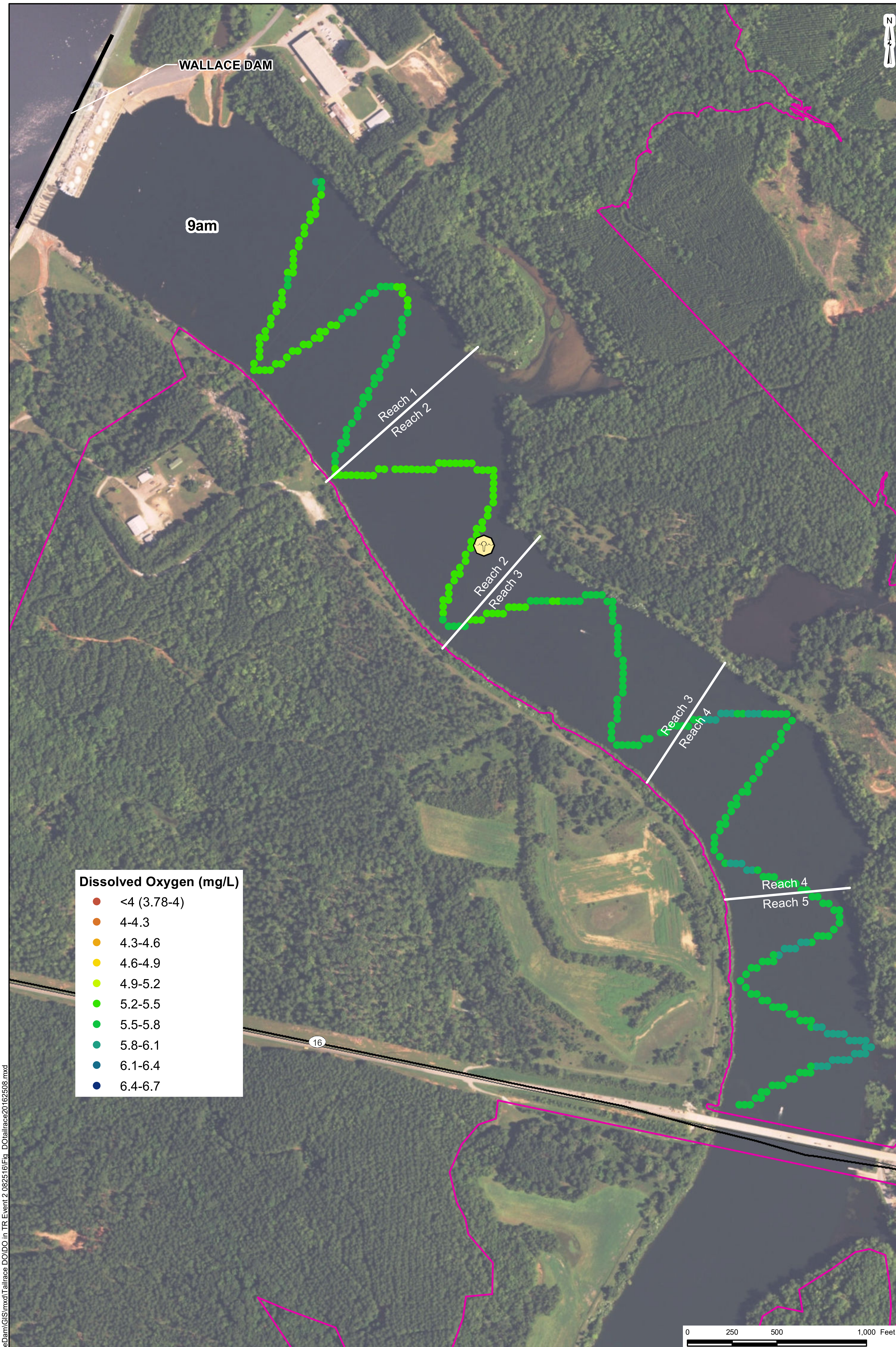
Figure 15d
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd



Tailrace Buoy
State Highway
Project_Boundary

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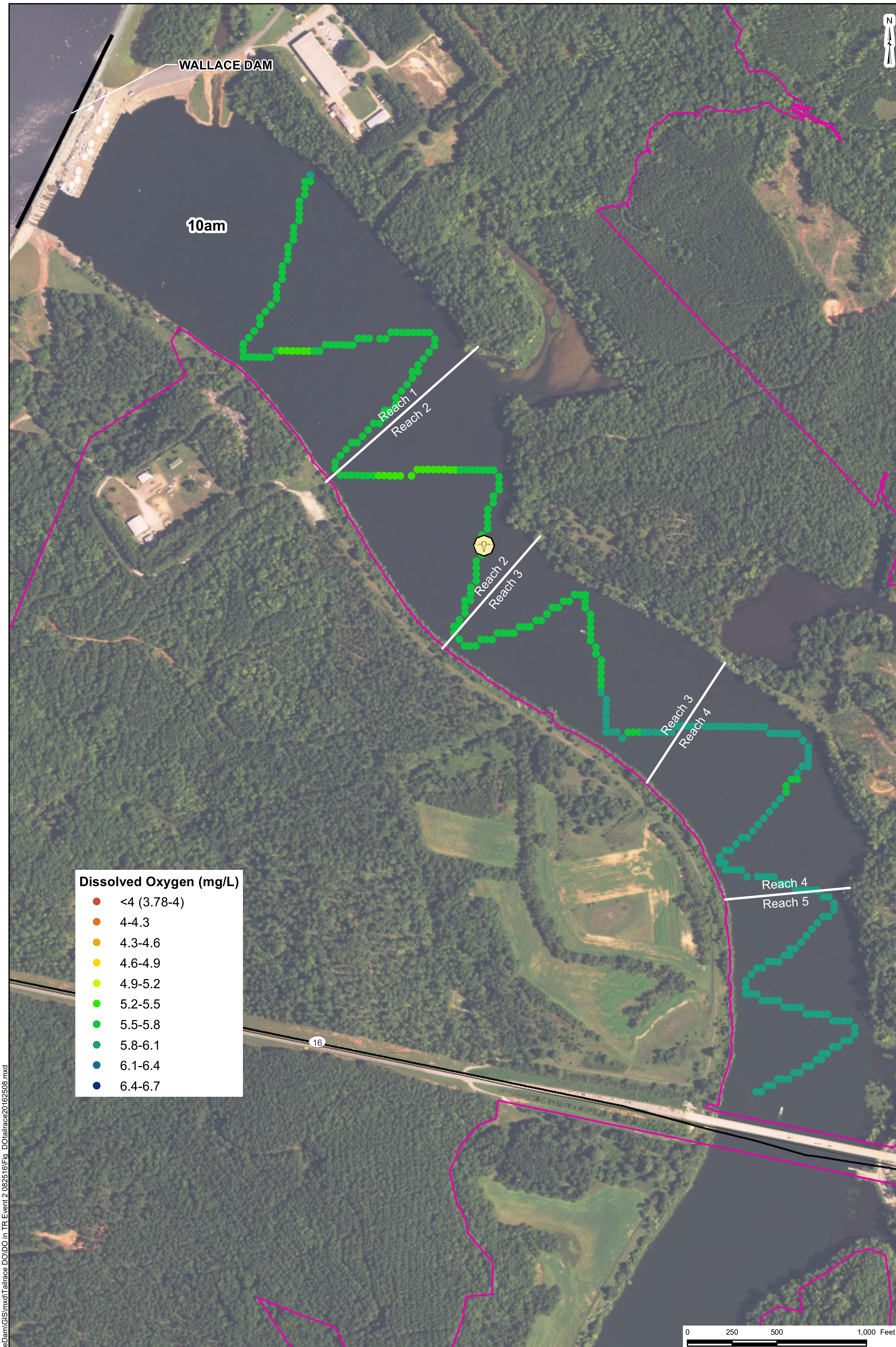
Figure 15e
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd



Tailrace Buoy
State Highway
Project_Boundary

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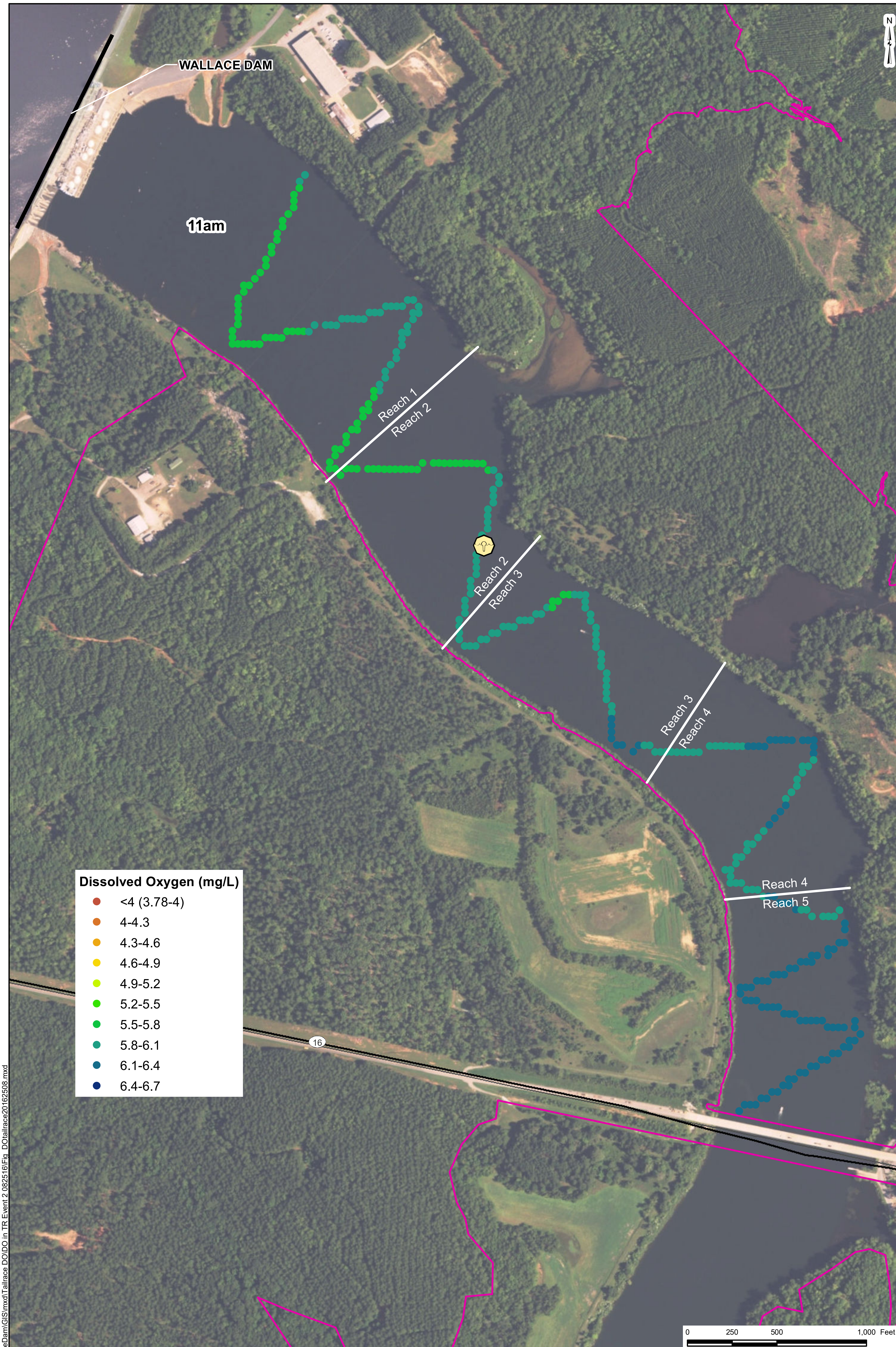
Figure 15f
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd



Tailrace Buoy
State Highway
Project_Boundary

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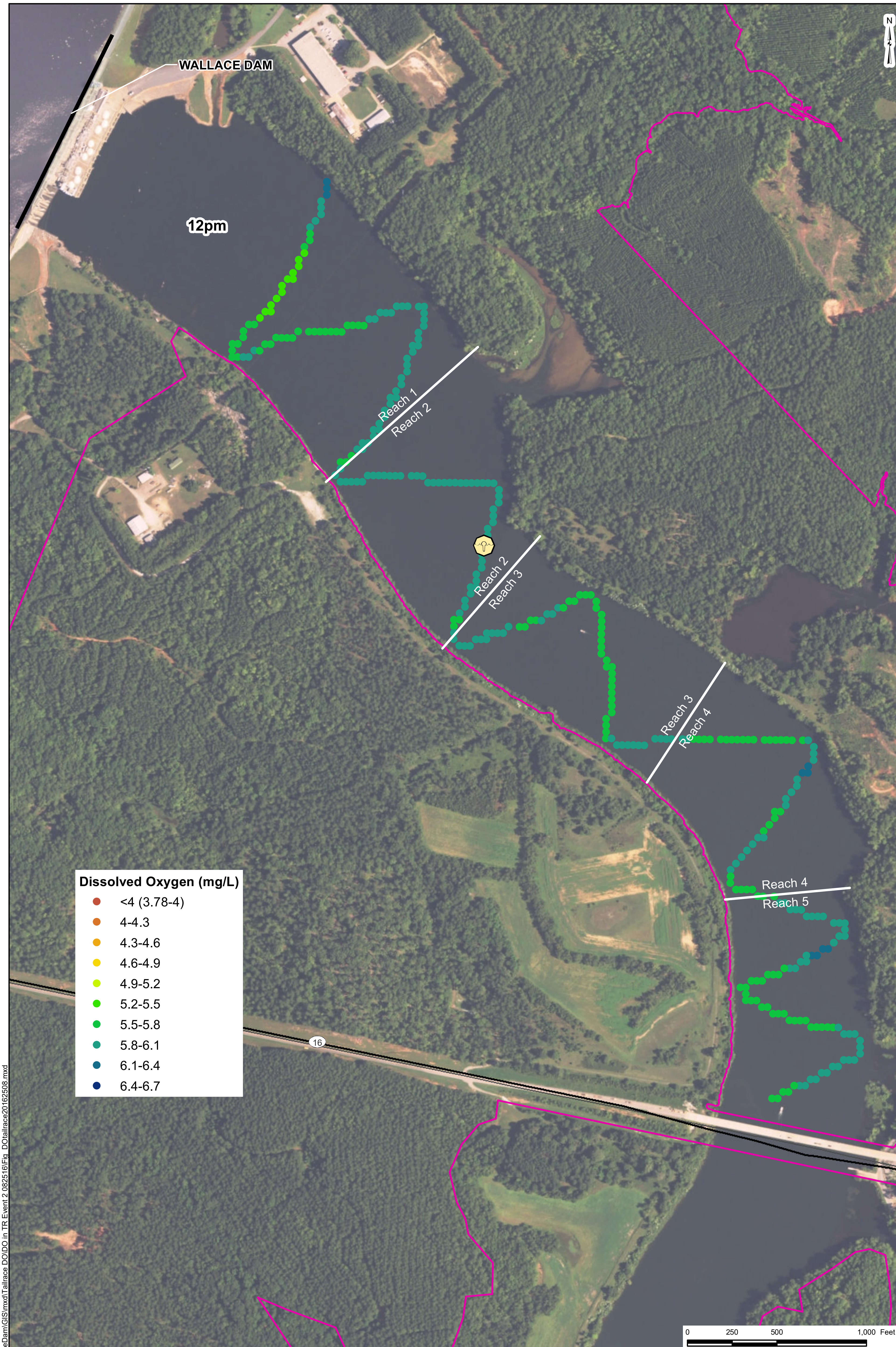
Figure 15g
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd



Tailrace Buoy
State Highway
Project_Boundary

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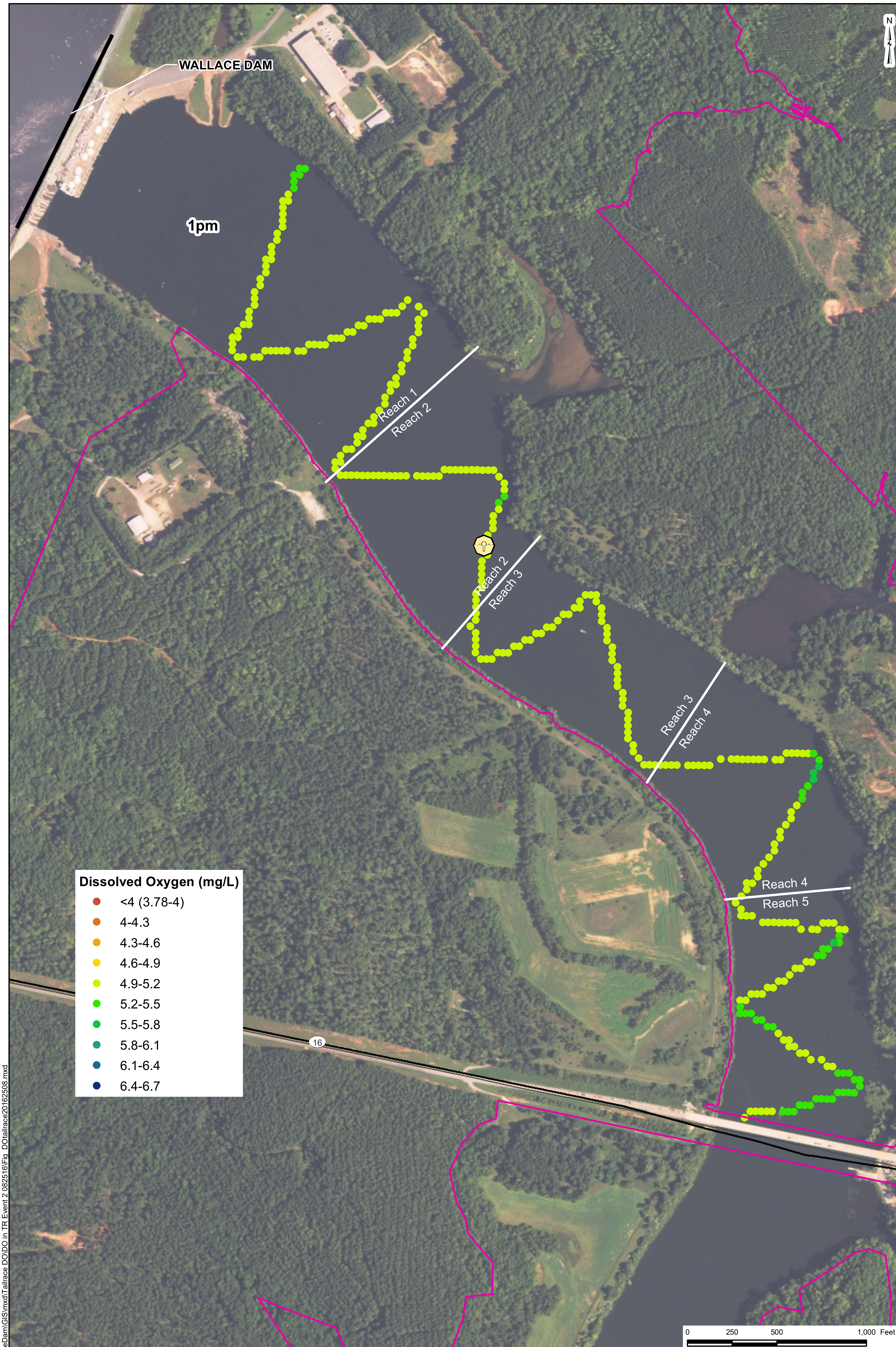
Figure 15h
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd



Tailrace Buoy
State Highway
Project_Boundary

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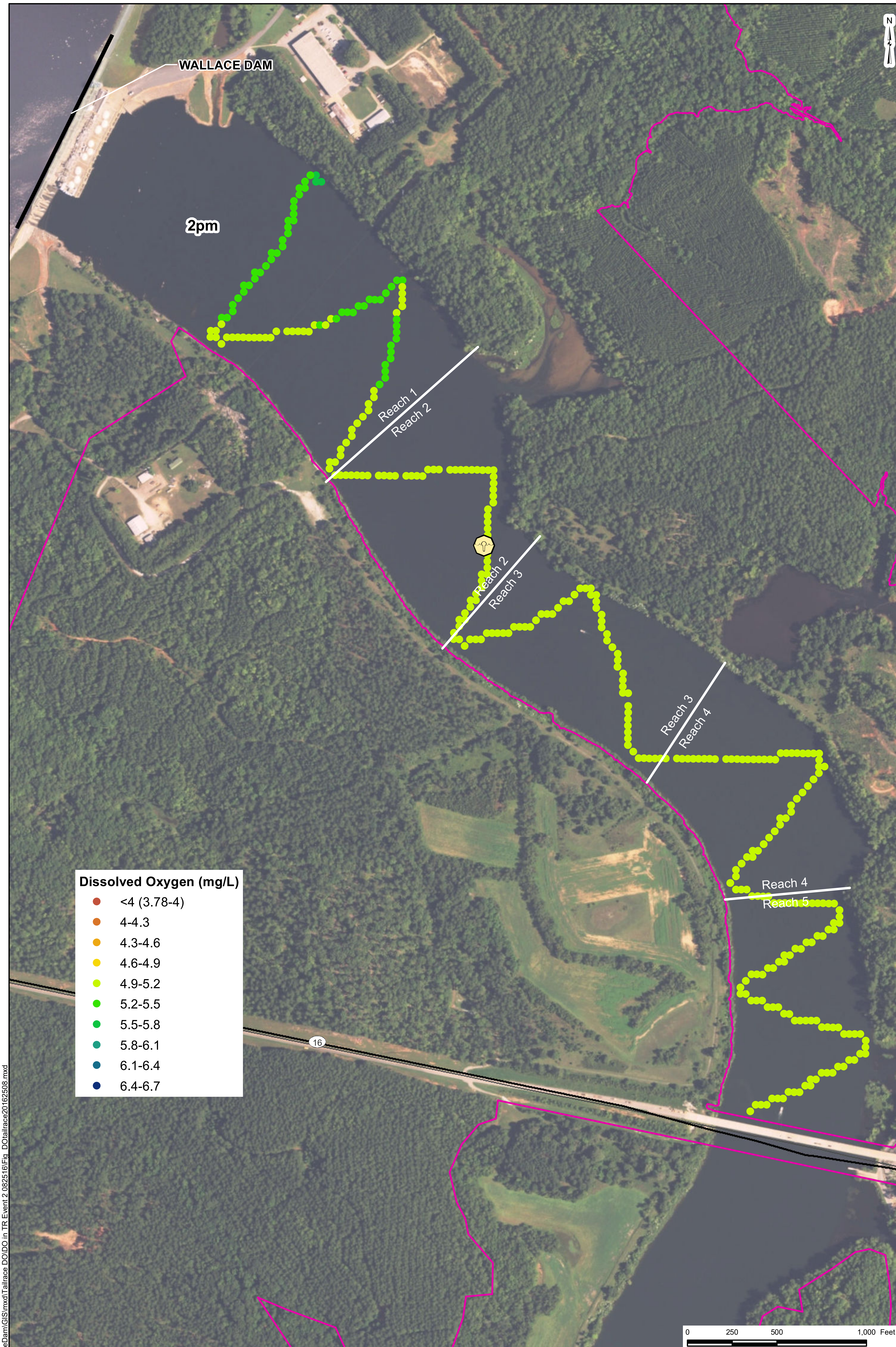
Figure 15i
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)



Tailrace Buoy

State Highway

Project_Boundary

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Figure 15j
Hourly Tailrace Monitoring: 8/25/16
Wallace Dam Project
(FERC No. 2413)

N:\G\GeorgiaPower\WallaceDam\GIS\mxd\Tailrace DO\DO in TR Event 2 082516\Fig_DOtailrace20162508.mxd