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GEORGIA POWER
A SOUTHERN COMPANY

INTERIM FINAL DRAFT

PRELIMINARY REPORT OF FISH IMPINGEMENT MORTALITY AT THE PLANT HAMMOND STEAM ELECTRIC GENERATING FACILITY

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1. INTRODUCTION

The U.S. Environmental Protection Agency's (EPA) Phase II 316(b) rule for existing cooling water intake structures (69 Fed. Reg. 41576, July 9, 2004) is applicable to Georgia Power Company's Plant Hammond. The Phase II rule requires application of Best Technology Available (BTA) to meet performance standards for reducing impingement mortality, and where applicable, entrainment at affected cooling water intake structures (CWIS). Applicable performance standards are determined based on waterbody type, generating capacity utilization rate, and/or ratio of water withdrawal to mean annual flow (rivers). Waterbody type is the determinant for Plant Hammond.

Plant Hammond is located on Weiss Lake, a 12,222 hectare (ha) (30,200-acre) multi-purpose impoundment of the Coosa River in northwest Georgia, west of the city of Rome (Figure 1-1). The applicable performance standard for facilities withdrawing cooling water from lakes or reservoirs is a minimum 80 percent reduction in impingement mortality from a "calculation baseline". Facilities that withdraw cooling water from lakes or reservoirs are exempt from having to address entrainment. The Phase II 316(b) rule (40 CFR § 125.93) defines a lake or reservoir as:

"….any inland body of open water with some minimum surface area free of rooted vegetation and with an average hydraulic retention time of more than 7 days. Lakes or reservoirs might be natural water bodies or impounded streams, usually fresh, surrounded by land or by land and a man-made retainer (e.g., a dam). Lakes or reservoirs might be fed by rivers, streams, springs, and/or local precipitation".

With an average hydraulic retention time of approximately 18 days, Weiss Lake meets the 316(b) regulatory definition of a lake or reservoir. Thus, Plant Hammond must achieve the performance standard for reducing impingement mortality by 80 to 95 percent from a "calculation baseline" to be determined from existing or new studies.

The rule specifies that a Comprehensive Demonstration Study (CDS) be conducted at facilities that have not met applicable performance standards, the results of which are to be submitted to the Georgia Department of Natural Resources, Environmental Protection Division (EPD) upon application for NPDES permit renewal. This report provides preliminary results of an impingement mortality characterization study (IMCS), an important element of the CDS, conducted at Plant Hammond from mid-

October 2004 through mid-October 2005, and was prepared to provide EPD and the Georgia Department of Natural Resources, Wildlife Resources Department (WRD) with a preliminary progress report of 316(b) compliance activities conducted at the facility. Upon completion of other CDS-required activities, Georgia Power will prepare a final IMCS report for formal submittal to EPD by 7 January 2008, in accordance with the extended schedule for completing the Plant Hammond CDS approved by EPD.

The current study was conducted in accordance with the sampling plan outlined in Georgia Power Company's Proposal for Information Collection (PIC) reviewed by EPD and WRD (GPC, 2004). The PIC provided:

- A description of the proposed technologies and/or supplemental restoration measures to be evaluated under the CDS;
- A list and description of historical studies characterizing the physical and biological conditions in the vicinity of the cooling water intake structures and their relevance to the Plant Hammond IMCS;
- A summary of consultations with Federal and State resource agencies that are relevant to the study; and
- An IMCS sampling plan for field studies to support development of a scientifically valid estimate of impingement mortality at Plant Hammond.

The Phase II 316(b) rule requires that the IMCS characterize fish susceptible to impingement "in the vicinity" of the CWIS and must include:

- Taxonomic identification of fish and their life stages
- Description of abundance and temporal/spatial characteristics
- Characterization of annual, seasonal, and diel variations in impingement mortality (e.g., related to climate/weather differences, spawning, feeding and water column migration)
- Documentation of current impingement mortality of all life stages of fish at the facility

- Identification of any Federal and/or State protected species

The following sections provide a description of the Plant Hammond CWIS (Section 2), the IMCS approach (Section 3), summary of plant operations (Section 4) and discussion of the preliminary IMCS results (Section 5), which provide the basis for the Plant Hammond CWIS calculation baseline estimate (Section 6).

2. STUDY AREA DESCRIPTION

2.1 Weiss Lake

Weiss Lake is a 12,222 ha (30,200-acre) multi-purpose impoundment of Coosa River formed by Weiss Dam located in northeast Alabama. The lake is used for hydroelectric generation, flood control, navigation flow augmentation, maintenance of water quality, industrial and municipal water supply, irrigation and recreational opportunities and serves as habitat for fish and wildlife. It extends approximately 52 miles upstream from Weiss Dam through Cherokee County, Alabama approximately 11 miles into Floyd County, Georgia and beyond Plant Hammond to the Mayo's Bar Lock and Dam at Rome, Georgia. The Weiss Lake development boundary (*i.e.*, those lands included in the FERC license) includes the lake (30,200 acres) up to normal pool elevation of 564 feet (ft) mean sea level (msl) with flood easements between elevations 564 to 578 ft msl.

2.2 Plant Hammond

Plant Hammond is located in Floyd County, Georgia approximately ten miles west of Rome, Georgia along the Weiss Lake shoreline (Figure 1-1). It is a coal-fired steam electric power generating facility consisting of four generating units with a gross plant output of 800 MW. All four units operate most of the time, but because of maintenance outages and demand, the plant had an average capacity utilization rate of 59 percent from 1998 through 2002. It uses a once-through cooling water system that withdraws cooling water from Weiss Lake via a single CWIS with six bays. The six bays collectively lead to two tunnels, each accommodating four circulator pumps.

The CWIS is located at, and the face of the traveling screens is oriented parallel to, the shoreline (Figure 2-1). The intake structure is designed to withdraw water from the lower and middle portion of the water column (Figure 2-2). The intake has a maximum nameplate design intake flow/withdrawal capacity of approximately 548 million gallons per day (MGD), or 848 cubic feet per second (cfs).

The intake structure includes six standard 3/8-inch mesh vertical traveling screens for excluding debris and impinged organisms from the plant cooling system. The screens are washed removing debris and impinged organisms which are returned to Weiss Lake downstream of the CWIS via a pipe (Figure 2-2).

2.3 CWIS Hydraulic Influence

The area of hydraulic influence attributable to the Plant Hammond CWIS was assessed through an acoustic Doppler current profiling (ADCP) survey conducted 13-14 May 2004. The survey included three hydraulic data collection events conducted over a 24-hour (hr) period to monitor representative diel changes in summer lake elevation. The first survey was conducted under falling stage conditions, and the second and third surveys were conducting under low and high lake levels, respectively (Table 2-1). Lake level changes occur daily due to upstream releases from two U.S. Army Corps of Engineer projects (Carters Lake and Lake Allatoona) in combination with lake level management at Weiss Dam. Lake levels are normally managed near 564 ft msl and elevations during the survey varied by 0.82 feet. The survey was conducted with all eight circulating water pumps operating at full capacity.

Data were collected by navigating the boat and operating the ADCP unit along parallel-shoreline transects each placed further away from the CWIS with each successive pass. Up to ten transects were recorded during each survey to delineate the outer boundary of flow vectors (i.e., direction) associated with the CWIS. Additionally, random traverses and cross-sectional traverses were navigated to add positions for mapping the survey results.

Real time and post-processed acoustic Doppler data were used to detect and map the extent of the area of hydraulic influence. The boundary demarcating the area of greatest extent of hydraulic influence from Plant Hammond was determined by the occurrence of water velocities and vectors dominantly unrelated to the Plant Hammond CWIS based on all survey events.

The maximum extent of hydraulic influence from the Plant Hammond CWIS was associated with the lowest lake level observed during the study. As defined by the presence of current vectors unrelated to the CWIS and for the purpose of compliance with the Phase II 316(b) rule, the area of hydraulic influence occupied an area of approximately 0.52 acres in Weiss Lake adjacent to the CWIS structure (Figure 2-3).

The area of Weiss Lake encompassed within the hydraulic zone of influence had an average velocity of 0.60 ft/s (based on grand mean of all available water column velocities within the mapped area of influence). The most distant boundary of the area of hydraulic influence (determined by locating vectors that were predominantly unrelated to the Plant Hammond CWIS) had an average velocity of approximately 0.5 ft/s. However, less than 16 percent of the vectors at this distant boundary occurred within a 20 degree deflection of the CWIS (336.6 degrees N); and only 12.6 percent occurred within a 10 degree deflection of CWIS, indicating predominate flow direction away from the CWIS. Where velocity alone is considered, the survey data indicates fish exposed to the immediate approach to the CWIS would be the most susceptible to impingement.

3. SAMPLING PLAN

The IMCS documented impingement mortality at Plant Hammond and characterized the fish community in the vicinity of the CWIS. The resulting dataset provided information necessary to determine the appropriate calculation baseline estimate against which compliance with the impingement performance standard will be evaluated (Section 6). The dataset will also be used to assist in the selection of technologies and/or operational or restoration measures needed for Plant Hammond to meet the impingement reduction performance standard.

3.1 Impingement Mortality Characterization

Impingement monitoring of the CWIS traveling screens was initiated 19 October 2004 and extended through 6 October 2005 on a pre-established biweekly (twice a month) schedule (Table 3-1). Samples were collected with a collection box that received screen-wash water diverted to the sampling device. A high pressure screen wash system conveys debris, as well as fish, that collect on the screens to a sluice-way leading to a return pipe that discharges directly to the river (see Figure 2-2).

Impingement samples were collected using sampling nets equipped with ¼-inch Delta mesh netting inserted within the collection box. Each impingement sampling event represented a 24-hr collection period split into two approximately equal 12-hr samples. The "day sample" was typically initiated about 0700 hours and extended until 1900 hours on day one and the "night sample" was taken from about 1900 hours on day one until the following morning at about 0700 hours on day two (Table 3-1). The screens were cleaned prior to each sampling event and were rotated in continuous mode throughout each 24-hr sampling event.

Fish were sorted by species and counted for each day-night collection period. A total of 48 samples were collected during the 12-month study representing day/night collection periods. All 48 samples were completely sorted and processed.

Size distributions of impinged fish in each sample were determined by processing up to 100 representative individuals for each species. Fish were weighed (in grams) and total length measured to the nearest millimeter (mm). When more than 100 fish were encountered, up to 300 additional individuals of a given species were weighed as a batch. When more than 400 individuals of a given species were collected, only a batch weight was recorded and the number estimated from the average weight of the individually processed fish and the enumerated batches.

Only three species impinged at Plant Hammond (threadfin shad, *Dorosoma petenense*[1]; gizzard shad, *D. cepedianum*; and bluegill, *Lepomis macrochirus*) exceeded the 100 individual per sample threshold established in the PIC and each required batch-processing only once during the study. All other impinged fish were processed individually.

Data collected during each impingement study were recorded on pre-printed data sheets for documenting species and size distributions during each sample, as well as the plant operating conditions. The data forms accommodated batch counts and/or batch weights as outlined above.

Plant operational parameters recorded at Plant Hammond included intake water flow rates and condenser inlet water temperature. These data were obtained and used in conjunction with the study-specific plant operation information recorded on the data sheets. Water temperature and stage data were also obtained from the USGS gage at Rome (USGS No. 02397000).

3.1.1 Calculation of Annual Impingement Mortality Estimate

In development of the calculation baseline estimate of annual impingement mortality for Plant Hammond, two estimates were determined: 1) using conventional spreadsheet calculation methods and; and 2) using Monte Carlo simulation techniques.

In each case, fish impingement data were standardized to reflect density and mass of organisms per unit volume of cooling water pumped. Data collected over each twenty-four hour sampling period were normalized by dividing the number of fish impinged by the volume of cooling water pumped during the sampling event (expressed in number or mass per 100 cubic meters (100-m^3)) resulting in a "base density" impingement rate. The volume of cooling water withdrawn was determined from plant operation records.

[1] Scientific names from Nelson et al., 2004

Estimation of annual impingement at Plant Hammond was extrapolated using the equation:

$$\sum E_i = R_i \text{ x } V_i$$

where

E_i = estimated number of fish impinged for time period i
R_i = average impingement rate per 100-m^3 for time period i
V_i = volume of cooling water pumped for time period i

Linear interpolation was used to estimate impingement for un-sampled days by multiplying the associated base density impingement rates by the volume of cooling water withdrawn for each day of the half-month period associated with the sampling event. Daily impingement estimates were then summed to yield an annual estimate of impingement mortality associated with the Plant Hammond CWIS.

In the Monte Carlo simulation analysis, the base density impingement rates were grouped based on seasonality and then randomly drawn to estimate impingement rates for un-sampled days within a specified season. This was accomplished by multiplying randomly drawn base density impingement rates by the volume of cooling water withdrawn for each day of the half-month period associated with the sampling event. Daily estimates were then summed to yield an annual estimate of impingement mortality. This process was repeated 10,000 times to incorporate all possible outcomes from the available dataset and yield a mean annual impingement mortality estimate for Plant Hammond. Additional detail is provided on the Monte Carlo simulation technique in Section 6.

For both annual impingement mortality estimation techniques, a 95-percent upper confidence limit was calculated for the resulting annual estimates to account for uncertainties associated with expected diel, seasonal, and operational variability. Confidence intervals for individual species were extrapolated based on the relative abundance of each species in the impingement sample.

3.2 Fish Community Characterization

The fish community in the vicinity of the CWIS was characterized by augmenting existing fisheries data for Weiss Lake with seasonal field surveys conducted within the CWIS area of influence during the study. Assessment of fish populations in the vicinity of the CWIS provide information necessary to characterize the species and associated life stages that are potentially susceptible to impingement on the vertical traveling screens at the Plant Hammond CWIS.

Fish community characterization objectives were met through seasonal electrofishing surveys at two locations. Location 1 was established within the immediate CWIS area of hydraulic influence along the north bank of Weiss Lake upstream and downstream of the CWIS (Figure 3-1). Location 2 was established along the south bank of Weiss Lake directly across from the CWIS, outside the CWIS area of hydraulic influence (Figure 3-1).

Fish community sampling was conducted on a seasonal basis at Locations 1 and 2. Sampling was conducted during daytime and nighttime hours to address diel variations. Fish community characterization surveys were scheduled to coincide with one of the two impingement sampling events planned for each month beginning in the fall (November 2004) and repeated seasonally in the winter (February 2004), spring (May 2005), and summer (August 2005).

The Weiss Lake fish community was evaluated through conventional electrofishing survey methods that focused on population- and species-level characteristics, including spatial distribution and movements in relation to the Plant Hammond CWIS. Fish collected by the electrofishing surveys were placed in holding tanks for processing and data collection. Individual fish were identified by species and enumerated immediately following each sampling event. Up to 25 fish for each species represented were weighed to nearest gram (g) and measured to nearest mm (total length-TL) per sampling site. Batch counts and batch weights were recorded for all species represented by more than 25 fish. Each specimen was visually examined for deformities, fin erosion, lesions, and tumors (DELT). Live fish were released on site except for specimens retained for laboratory verification or as voucher specimens.

Field data were electronically logged directly via Personal Data Assistant (PDA) and/or laptop computer. Data were downloaded and transferred to a network hard drive for data processing and archival. Data were checked for completeness and field recording errors, which were noted and corrected, when needed, by the data manager.

3.3 Quality Assurance and Quality Control

Project quality assurance/quality control (QA/QC) procedures for the IMCS followed established procedures for field and laboratory studies conducted by Georgia Power's Environmental Laboratory (GPC, 2002). In addition, QA/QC activities included active participation in five of the 24 impingement mortality sampling events by senior GeoSyntec personnel. The field audits focused on:

- Performance of the collection system including the collection box and the net insert;
- Sample processing, including sorting, identification, and measurement of impinged organisms;
- Record keeping;
- Health and safety; and
- Communication with Plant personnel

Results of the QA/QC field audits were documented in technical memoranda as summarized in Appendix A.

4. PLANT OPERATIONS

4.1 Plant Loads

Annual net generation at Plant Hammond totaled 4.7 million megawatt hours (MWH) during the mid-October 2004 through mid-October 2005 study period (Figure 4-1). Compared to annual total generation from 1995 through 2004 and the 10-year mean, Plant Hammond operation during the 12-month impingement study was above the 10-year annual average generation of 3.7 MWH. Variable annual output at Plant Hammond reflects a range of maintenance, operational, and demand factors.

4.2 Cooling Water Flow

Plant Hammond is a base-load facility that typically operates all circulator pumps except during unit-specific maintenance outages. Daily flows during the study period ranged from 148,000 gallons per minute (gpm) to 413,000 gpm and averaged 383,199 gpm (Table 4-1; Figure 4-2). Cooling water flows during the 12-month study averaged 83 percent of the rated capacity of the circulating water pumps.

Cooling water flows are affected by the same range of maintenance, operational, and demand factors as is annual generation, which is reflected in variable daily pumping rates. Reduced flows from October 2004 through February 2005 and during October 2005 reflect scheduled maintenance outages. Pumping rates varied seasonally depending on the scheduled maintenance outages, unscheduled maintenance activities (e.g., to repair screens), and cooling water flows necessary to meet cooling requirements. All eight circulating water pumps were operated during 19 of 24 impingement sampling events; five or six pumps were operating during the remaining five events, all during the fall 2004 maintenance outages (Table 4-1).

4.3 Water Temperatures

Water temperatures recorded weekly at the Plant Hammond condenser inlet and daily water temperatures from the USGS gage at Rome (USGS #02397000) were used to evaluate potential seasonal trends in impingement because of the direct affect temperature has on the behavior and swimming ability of fishes. Seasonal movement patterns related to spawning and feeding activity potentially expose fish to impingement and seasonally low temperatures are known to contribute to episodic impingement of threadfin shad and gizzard shad (Loar et al., 1978).

Weekly condenser inlet temperatures recorded during the 12-month impingement study ranged from 6.7 to 26.7 degrees Celsius (°C) or 44.0 to 80.0 degrees Fahrenheit (°F) and reflected a normal seasonal temperature pattern (Figure 4-3). The weekly condenser inlet temperatures tracked the daily average water temperatures recorded at the USGS gage, which is located at the headwaters of Weiss Lake, approximately 11 miles upstream of the Plant Hammond intake.

4.4 Lake Levels

Lake levels in the vicinity of Plant Hammond change daily in response to upstream releases from two U.S. Army Corps of Engineer projects (Carters Lake and Lake Allatoona) in combination with lake level management at Weiss Dam. Lake levels are normally managed near 564 ft msl. Median storage elevation during the 12-month impingement study was 566.3 ft and daily mean lake levels varied by 14.4 ft, ranging from a low of 564.0 ft on 26 September 2005 to 578.5 ft on 25 November 2005 (Figure 4-4). Storage elevations ranged from 564.6 ft to 573.3 ft during the 24 sampling events. Lake levels during sampling events varied by less than 0.5 ft during 20 of the 24 sampling events. Storage elevations changed by up to 4.8 ft during the remaining four events, when the majority of fish were impinged (Section 5.2).

5. IMPINGEMENT RESULTS

5.1 Species Composition

A total of 32 fish species and one hybrid were collected from the traveling screens during the 12-month IMCS from 48 samples[2]. Impinged fish species represented eleven families including sturgeon (Acipenseridae; one species), shad (Clupeidae; two species), minnows (Cyprinidae; five species), suckers (Catostomidae; two species), catfish and bullheads (Ictaluridae; four species), temperate bass (Moronidae; three species), bass and sunfish (Centrarchidae; ten species), perch (Percidae; three species), sculpin (Cottidae; one species), drum (Sciaenidae; one species), and upside-down catfish (Mochokidae; one species) (Table 5-1). The single upside-down catfish (*Synodontis* sp.*)* is an exotic species from Africa that likely represents a release from an aquarium.

Impinged fish accounted for 19 of 37 fish taxa previously reported from Weiss Lake (Table 5-1; APC, 2000). Fourteen species were impinged that were not on the 2000 annotated Weiss Lake checklist. With few exceptions, species collected during the IMCS were encountered during seasonal fish community surveys in the vicinity of the CWIS. Impinged species not collected during the community surveys included lake sturgeon (*Acipenser fulvescens*), black bullhead (*Ameiurus melas*), banded sculpin (*Cottus carolinae*), white crappie (*Pomoxis annularis*), yellow perch (*Perca flavescens*), blackbanded darter (*Persian nigrofasciata*), and upside-down catfish (*Synodontis* sp.). Seven species collected during the fish community surveys that were not impinged included longnose gar (*Lepisosteus osseus*), mooneye (*Hiodon tergisus*), grass carp (*Ctepharyngodon idella*), red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), bluntnose minnow (*Pimephales vigilax*), and longear sunfish (*Lepomis megalotis*). Grass carp and red shiner are non-native species that have been introduced to the Coosa River basin (Fuller et al., 1999).

No state or federally listed species were collected during the IMCS. Listed threatened or endangered fish species are not known to occur in Weiss Lake. Lake

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[2] Asiatic clams (*Corbicula*), which accounted for 38 percent of the impinged organisms collected during this study, are considered exotic/nuisance species and have no recreational or commercial value. As such, they were excluded from the study results on the basis that they do not represent "shellfish" in the context of the Phase II rule. .

sturgeon is of special interest to the WRD because of its probable extirpation from the Coosa River Basin and the lake sturgeon reintroduction program that was begun December 2002 when restocking efforts were undertaken in the Etowah, Coosawattee, and Oostanaula Rivers. As of December 2004, 32,179 fingerling sturgeon had been released. Lake sturgeon accounted for 1.0 percent (19 individuals) of the impinged fishes collected during the 12-month IMCS. The majority of collected lake sturgeons were apparently not damaged during the impingement and/or collection process. Field observations of fish recovered from the collection box, after being held up to 12 hours, survived and were released alive in the collection box. Based on the condition of the impinged lake sturgeon, it is likely that their survival is good when they are returned directly to the river via the screen-wash return pipe.

The number of species impinged at Plant Hammond (n=32, plus hybrid Lepomis) during this 12-month study is higher than noted for some other facilities located on southeastern impoundments. A one-year study at Georgia Power Company's Plant Branch located on Lake Sinclair, Georgia yielded 20 species (GPC, 2005). Similar one-year studies at Duke Power Company's Allen Steam Station located on Lake Wylie, North Carolina (Edwards et al., 1978) and the South Carolina Electric and Gas (SCE&G) V.C. Summer Nuclear Station on Monticello Reservoir, South Carolina (Dames & Moore, 1985) yielded 17 and 18 species, respectively.

5.2 Relative Abundance

A total of 1,817 fish were collected from the Plant Hammond CWIS during the 12-month study (Table 5-2). The samples were numerically dominated by 11 fish species that accounted for 96.8 percent of the fish collected during the IMCS (Table 5-2; Figure 5-1). The predominance of a few species in the impingement samples is typical as historical impingement studies have shown that five to 10 species often comprise 90 percent or more of annual impingement estimates (EPRI, 2004).

The eleven most abundant species impinged (bluegill, gizzard shad, freshwater drum [*Aploditus grunniens*], yellow bass [*Morone mississippiensis*], channel catfish [*Ictalurus punctatus*], silver chub [*Macrhybopsis storeriana*], blue catfish [*Ictalurus furcatus*], lake sturgeon, black crappie, threadfin shad, and Mobile logperch [*Percina kathae*]) accounted for 87.9 percent of the biomass collected during the study (Table 5-2). Bluegill accounted for 34.8 percent of the total biomass, followed by gizzard shad, freshwater drum, yellow bass, channel catfish, silver chub, blue catfish, lake sturgeon, black crappie, threadfin shad, and Mobile logperch. The remaining 22 species contributed less than 0.5 percent each to the total number collected and generally less than 1.0 percent of the total biomass (Table 5-2). Exceptions included a few larger specimens of smallmouth buffalo (*Ictiobus bubalus*) and white bass.

The top 11 impinged species accounted for 73.9 percent of the fish collected during seasonal community electrofishing surveys in the vicinity of the CWIS (Table 5-2) Notable differences in relative abundance between the impingement and fish community samples included higher relative abundance in the impingement samples for bluegill (28.2 vs. 14.3 percent), threadfin shad (24.7 vs. 4.3 percent), and Mobile logperch (4.0 vs. 0.04 percent). The relative abundance of gizzard shad was notably higher in the community samples, 36.1 vs. 20.5 percent, whereas the relative abundance of other commonly impinged species (silver chub, blue catfish, channel catfish, black crappie [*P. nigromaculatus*], freshwater drum, and yellow bass) were similar between the impingement and fish community surveys (Table 5-2).

Differences in relative abundance observed between the impingement and fish community survey data reflect variability in susceptibility to impingement that is indicative of habitat preferences and behavior among species. High relative abundance of clupeids such as gizzard shad and threadfin shad is typical of impingement at other southeastern facilities, which has been consistently attributed to schooling behavior, distribution in the water column, negative reotaxis response to intake flows (i.e., swimming with the flow toward the CWIS), and their susceptibility to swimming impairment and/or mortality due to exposure to cold water temperatures (Loar et al., 1978).

In contrast, typically low abundance of sunfish species reflects their demersal position in the water column, association with cover, and relatively small home ranges that limit spatial movements. Greater relative abundance of bluegill in the impingement samples at Plant Hammond represents a single sampling event (December 6, 2004), which was conducted during a high water event resulting from major rainfall in the watershed. During the sampling lake levels increased nearly five feet. The total number of fish impinged during the event was 449 of which 442 were bluegills. These fish were likely displaced from preferred upstream habitats by the high water. That single event accounted for 86 percent of bluegill collected during the entire study. Only 71 bluegills were collected during the other 23 sampling events.

The high relative abundance of shad in the impingement samples (45.2 percent) reflects both their abundance in Weiss Lake and susceptibility to impingement. Gizzard shad accounted for 318 of 366 impinged fish collected during the 20-21 April 2005 sampling event, which was the second highest daily rate for the study. Lake levels increased by 1.3 ft during that event when 62 percent of the gizzard shad collected during the study were encountered. Threadfin shad accounted for the majority of fish impinged during the two March sampling events, when 60 percent of threadfin shad collected during the study were collected. Water levels during those events changed by 0.48 ft (10 March) and 4.05 ft (23-24 March). The latter sampling event ranked as the third highest daily impingement rate (285 fish) of the study.

A review of shad impingement at other southeastern facilities found that approximately 98 percent of fish impinged at 24 power plants were clupeids and that relative abundance exceeded 75 percent at 15 sites (Loar et al., 1978). Based on this current study and data available from historical studies at other facilities, the high relative abundance of shad on the CWIS at Plant Hammond is consistent with the studies reported by Loar et al. (1978).

Overall, there was an apparent relationship between increasing lake levels during the sampling event and impingement rates. Four of six largest impingement events were associated with increased lake levels of more than 1.3 ft. Impingement rates were less than 70 fish per day when changes in lake levels during the sampling event varied by less than 1.0 ft.

5.3 Size Distribution

Fish impinged at Plant Hammond typically were small-bodied fishes (e.g., threadfin shad and silver chub) or juvenile larger-bodied fish (e.g., gizzard shad and bluegill). The range and average total length of each species impinged during the 12-month study is summarized in Table 5-3. Based on 1,111 measured fish, the average total length of 24 of the 32 impinged species was less than 149 mm (approximately 6 inches), 14 of which averaged less than 100 mm (approximately 4 inches).

Length-frequency distributions of the 11 most commonly impinged species indicate that the majority of impinged fish were less than 149 mm in total length (Table 5-4). The majority of threadfin shad were less than 109 mm in total length and all impinged silver chubs were less than 149 mm (Table 5-4). Of the eleven most commonly impinged species, threadfin shad were represented by the highest percentage of individuals less than 99 mm (99.5 percent), followed by blue catfish (78.1 percent), channel catfish (63.4 percent), silver chub (53.6 percent), Mobile logperch (46.6 percent), black crappie (28.5 percent), bluegill (27.7 percent), lake sturgeon (10.5 percent), and gizzard shad (7.2 percent). The total length of all impinged yellow bass and freshwater drum was greater than 99 mm (Table 5-4).

Fish longer than 149 mm (6 inches) in total length were infrequently impinged and represented a few larger individuals of 15 different species (Table 5-3). Collectively, these larger fish represented only 14.6 percent of the total number of impinged fish. Overall, the size data indicates primarily juveniles and sub-adult fish were impinged at Plant Hammond during the 12-month study, which is consistent with impingement at other southeastern facilities (Dames & Moore, 1985; Edwards et al., 1976; Loar et al., 1978).

The length-frequency distribution of fish in the vicinity of the intake structure, as monitored through the fish community surveys, was also examined. As expected, the relative abundance of impinged fish was generally representative of the fish community assemblage in the source water, but fish collected during the community sampling were larger. Figure 5-2 compares size distributions of impinged fish and the fish collected during the community surveys. Fish longer than 149 mm represented only 14.6 percent of the fish collected during the impingement studies, whereas fish >149 mm accounted for 51.6 percent of the fish community samples.

5.4 Seasonal Occurrence

The occurrence of fish species impinged on the Plant Hammond traveling screens during the 12-month study varied from only 4 percent (1 of 24) of the sampling events for eight different species to 75 percent (18 of 24 sampling events) for bluegill. None of the 32 impinged species occurred in all 24 samples. The occurrence of the other 10 commonly impinged species ranged from 7 sampling events (lake sturgeon) to 15 sampling events (silver chub). The 21 remaining species occurred during fewer than 7 of the 24 sampling events (Figure 5-3).

The majority of fish were impinged during five sampling events including one in December 2004 and four consecutive events in March and April 2005 (Figures 5-3 and 5-4). Those five events collectively accounted for 74 percent of the impingement during the 12-month study. The 6-7 December sampling event accounted for nearly 25 percent of the impinged fish removed from the traveling screens. As discussed above that event included primarily bluegill (Figure 5-4) and was associated with a large increase in lake levels during the sampling event, suggesting bluegill had been displaced from their preferred habitat upstream of Plant Hammond. Impingement rates during the other four top ranked events reflected the highest impingement rates for the study of threadfin shad, gizzard shad, and silver chub (Figure 5-4).

Major impingement events of threadfin shad typical of other southeastern facilities was not exhibited at Plant Hammond during this study. Peak impingement of threadfin shad typically occurs during the winter, especially where the source waterbody is a reservoir (Loar et al., 1978; Edwards et al., 1978, and Dames & Moore, 1985). However, maximum impingement of threadfin shad did occur during March 2005 when water temperatures dropped below 10°C (50°F). Swimming ability of fish in general and specifically threadfin shad at these lower water temperatures have a direct affect on increased impingement. Gizzard shad are also susceptible to cold shock when water temperatures decline rapidly (Coutant and Cox, 1976). In the case of the only significant impingement event for gizzard shad (Figure 5-3), water temperatures were warming and there was no apparent decline in water temperatures during the 20-21 April 2005 sampling event (see Figure 4-3).

5.5 <u>Diel Distribution</u>

Diel distribution of impingement at the Plant Hammond intake was determined through 12-hr daytime and nighttime samples. Overall, 59.6 percent of the fish collected during the 12-month study occurred in the night samples which were generally collected between 2000 and 0800 hours (Table 5-5). On an event by event basis there were no consistent differences between the daytime and night samples. Although rates were higher during the night sampling period on 14 of 24 occasions, a paired-t test indicated there were no significant statistical differences ($\alpha<0.05$) in the diel impingement rates.

The overall higher nighttime rates shown in Table 5-5 primarily reflect fish impinged during the 6-7 December 2005 and 23-24 March 2005 sampling events. Those two occasions accounted for 43 percent of the fish collected during the 24 night-time samples. Bluegill accounted for the higher night-time rates during the December event when water levels increased 4.48 ft during the 12-hr sampling period compared to only a 0.84 ft increase during the day-time sample. Similarly, more threadfin shad were collected at night during the March event when lake levels increased over 4 ft during the study.

Night samples accounted for less than 50 percent of impinged fish on 10 occasions and the day samples were somewhat higher when the total rates were lowest. A notable exception occurred during the 20-21 April 2005 sampling event, which was the second highest of the study (Figure 5-3). During that event, 71.5 percent of the fish were collected during the day when impingement rates of gizzard shad were highest. In contrast to the two major night-time events, lake levels were relatively stable, only declining approximately 0.4 ft during the sampling event.

6. CALCULATION BASELINE

The “calculation baseline” for Plant Hammond, as provided by § 125.93 of the rule, is an estimate of impingement mortality that occurs on the basis that:

- the facility CWIS was designed as a once-through system;
- the opening of the cooling water intake structure is located at, and the face of the standard 3⁄8-inch mesh traveling screens are oriented parallel to, the shoreline near the surface of Weiss Lake; and
- current operational practices, procedures, and structural configuration at the facility are those that are maintained without structural or operational controls for the purposes of reducing impingement mortality.

The rule allows for the calculation baseline to be estimated using current biological and impingement mortality data collected in the vicinity of CWIS structure and/or through the use of data from other facilities with comparable design, operational, and environmental conditions. Georgia Power has developed the calculation baseline for Plant Hammond based primarily on the results of the October 2004 through October 2005 impingement sampling with consideration of the fish community surveys conducted in the vicinity of the CWIS. Also considered were historical data from other facilities in the southeast that demonstrate results of the current study are generally comparable and representative of impingement at power plants located on reservoirs.

The calculation baseline estimate for Plant Hammond was determined by using the results from the 24, 24-hour impingement sampling events (2 samples per month x 12 months).

6.1 <u>Conventional Spreadsheet Calculation Method</u>

As presented previously, linear interpolation was used to estimate impingement for un-sampled days by multiplying the associated measured base density impingement rates by the volume of cooling water withdrawn for each day of the half-month period associated with the sampling event. Daily cooling water withdrawal rates vary somewhat, thereby resulting in variable estimates of daily impingement. This "expansion" process was repeated for each day of each half-month period of the year and summed to produce an annual estimate for impingement.

For example, 52 fish were impinged in the 29 December 2004 sample. The four circulating water pumps collectively withdrew 2.07 million m^3 (547.92 million gallons) of cooling water on that day translating to 0.00251 fish impinged per 100 m^3. This measured impingement rate was then multiplied by the actual volume of water pumped for each day of the second half of December 2004 resulting in an estimated 1,028 organisms impinged for that period. This was repeated for each day of the year with the corresponding half-month impingement rate yielding an annual impingement estimate of 27,423 fish with a total biomass of 672 kg (1,482 lbs).

6.1.1 Statistical Analysis

To help account for the annual, seasonal, and diel variability expected in impingement rates, the base density impingement rates were used to calculate an upper bound (i.e., 95% upper confidence limit [UCL]) for the annual impingement mortality estimate (for number and biomass). The 95% UCL estimates the 95th percentile of the sampling distribution of the sample average. For example, given 100 sets of measurements, each set selected at random from the same population having a known mean, then 95 of the computed mean values would be expected to be above the true mean and 5 would be expected to be below the true mean. This attribute represents the desired UCL "coverage" of the mean (i.e., 95%). Any method used to calculate 95% UCL should have this property; while at the same time, not substantially overestimate the true mean.

Base density impingement rates for Plant Hammond were plotted. The Shapiro-Wilk's test for normality indicating the dataset was consistent with a log-normal distribution ($p < 0.05$). Therefore, log-transformed data were used to calculate the 95% UCL on the mean base density impingement rates (See Appendix B for probability plot and related statistics).

The 95% H-UCL (i.e., the H-statistic) method was selected as the most statistically appropriate method for calculating the 95% UCL for the Plant Hammond impingement data[3]. The mean base impingement rate at the Plant Hammond CWIS is 0.00368 fish per 100-m^3. The H-statistic derived 95% UCL on the mean base density impingement rate is 0.00807 fish per 100-m^3, which extrapolates to an estimated adjusted annual impingement rate of 58,697 fish.

The same statistical analysis was used for biomass impinged at Plant Hammond. Fish biomass impingement rates from the 24 sampling events, resulted in an annual impingement estimate of 672 kg (1,482 lbs with a 95% UCL of 1,752 kg (3,862 lbs). The most appropriate 95% UCL methodology for biomass was the non-parametric Chebyshev.

Based on the 95% UCLs, the conventional estimate of annual impingement mortality for Plant Hammond during the study period was 58,697 fish weighing 1,752 kg (3,862 lbs). Threadfin and gizzard shad combined, comprised 21.5 percent of the total number of fish and 45.1 percent of the total biomass. Bluegill, as the most dominant fish taxon impinged, accounted for 28.2 percent of the total sample and 34.8 percent of the total biomass.

6.2 Monte Carlo Simulation

Because the impingement rate is, for the most part, a random event, particularly within any given season, assigning a measured fixed value (i.e., impingement rate) to simulate values for pumping rates on days when no samples were taken does not adequately account for this randomness. Consequently, a more robust simulation method, the Monte Carlo technique, was applied to the impingement data.[4]

Monte Carlo simulation is a proven and widely accepted statistical technique by which a quantity is calculated repeatedly (e.g., estimate of annual impingement rate), as many as thousands of times, using randomly selected parameter values (e.g., measured impingement rates) for each calculation. The results approximate the full range of possible outcomes, and the likelihood of each. This simulation technique was developed during World War II and is named after the casinos in Monte Carlo, Monaco, where the primary attractions are games of chance. The random occurrence in games of chance is

[3] The Florida Department of Environmental Protections "FLUCL" tool was used to determine which of many available calculation methods for the 95% UCL was the most appropriate (i.e., best "coverage" of the mean without overestimating it) for this dataset (FDEP, 2005).

similar to how Monte Carlo simulation selects variable values at random to simulate a particular modeling scenario. In rolling a die, it is intuitive that one of six numbers will come up, but it is not known *a priori* which value it will be for any particular roll. It is the same with variables that have a known range of values, such as for impingement data, but an uncertain value for any particular time or event.

In applying Monte Carlo simulation to the Plant Hammond impingement dataset consideration was given to the seasonality in impingement rates as reflective of seasonal abundance of fish in Weiss Lake. In addition to variability of pumping rates, the temporal presence and abundance of fish and shellfish, and their individual susceptibility to impingement on the CWIS traveling screens were the primary implicating factors affecting variability in measured impingement rates. Therefore, "seasons" were assigned to the impingement rates to correspond to times of the year when impingement rates were "high" or "low". This partitioning of the dataset allowed the Monte Carlo simulation to only draw from the "high" rates measured in the "high" season during that period of the year. Conversely, only low rates were drawn upon during the "low" season. This strategy prevented selection of measured impingement rates from times of the year when rates where seasonally "high" to simulate impingement rates at times when rates were seasonally "low", and vice versa.

During the study period, generally higher impingement rates were measured at Plant Hammond from December 2004 through early June 2005 with lower rates measured in October and November 2004 and then again from late June 2005 through October 2005. Higher impingement rates were associated with peak abundance of bluegill in the winter and shad in the spring. Thus, in developing an estimate of annual impingement for Plant Hammond, the Monte Carlo simulation randomly drew from seasonally representative pools of data (Figure 6-1). The simulation procedure for estimating impingement during the study period followed this sequence:

1. For each day of the yearlong study period (October 2004 through October 2005), a measured impingement rate (number or biomass per 100-m^3) (Table 5-5) was randomly drawn by the computer from the existing pool of data for the five and half-month period representing either high impingement (n=11) or from the period representing low impingement

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[4] In development of the final Phase II 316(b) rule, U.S. EPA employed similar Monte Carlo analysis to address uncertainty in fish yield estimates used in evaluating economic impacts (EPA, 2004).

(n=13) depending on the calendar date of the un-sampled day for which the estimate of impingement was to be generated.

2. The randomly drawn measured impingement rate was multiplied by the volume of cooling water pumped specific to an operable day, thereby generating a daily estimate of impingement. This process was repeated until a daily estimate of impingement was calculated for each day.

3. Daily impingement estimates were then summed to derive an annual estimate of impingement and this value stored by the computer.

4. The above process was repeated 10,000 times, thus resulting in 10,000 possible outcomes for the estimate of annual impingement based on the available data as seasonally partitioned.

5. Descriptive statistics (i.e., mean and 95% UCL) were performed on the resulting output data distribution (Appendix B).

6. The same process was repeated for estimating the biomass.

The table below presents the results of the conventional and Monte Carlo simulation methods for calculating annual impingement mortality estimates for Plant Hammond.

Plant Hammond Annual Impingement Estimates

		Annual Estimate	**95% UCL**
Conventional	Number	27,423	58,697
	Biomass (kg)	672	1,752
Monte Carlo	Number	27,060	30,290
	Biomass (kg)	667	768

The Monte Carlo derived values provide the best estimate of impingement for Plant Hammond because:

- The uncertainty associated with impingement being a random event is better integrated into the estimate of annual impingement.

- Impingement rates for sampled days are randomly drawn from actual measurements and assigned to un-sampled days rather than assigned arbitrarily.

- The resulting annual estimate of impingement is based on a conservative estimate of the mean drawn from thousands of possible outcomes, not on a single estimate.

- The high number of simulation trials captures a wide array of potential impingement outcomes based on actual sampling data and provides a robust and unbiased estimate of the mean impingement.

Thus, specific to actual plant operations during the study period, the 95 % UCL estimate of annual impingement mortality documented for Plant Hammond is 30,290 fish with a total biomass of 768 kg (1,693 lbs). <u>These estimates represent the calculation baseline of impingement mortality at the Plant Hammond CWIS</u>. Species relative abundance in the "sampled" dataset was used to estimate the annual expanded 95^{th} percentile UCL for number of each species (Table 6-1) and the biomass of each species (Table 6-2). Threadfin shad and gizzard shad, combined, comprised 45 percent of the total number of fish and 21.5 percent of the total biomass. Bluegill comprised 28 percent of the total number of fish impinged and 35 percent of the total biomass. Other species that accounted for one percent of more of the annual numerical estimate (95% UCL) included silver chub, Mobile logperch, yellow bass, channel catfish, blue catfish, freshwater drum, and lake sturgeon. Those seven species combined with the shad and bluegill accounted for 96 percent of the impinged fish and 86 percent of the impinged biomass.

The relatively high ranking of silver chub and Mobile logperch, reflect movement of stream fishes into the headwaters of Weiss Lake. Other impinged species associated with stream or riverine habitats were impinged in much lower numbers including several cyprinid species, banded sculpin, redbreast sunfish (*Lepomis auritus*), spotted bass (*Micropterus punctulatus*), and black banded darter (Tables 6-1 and 6-2). Yellow bass are not native to Georgia, but have been introduced into the Coosa River basin (Fuller et al., 1999).

6.3 Perspective

It is important to note that the Plant Hammond calculation baseline estimate given above is conservative in that it assumes that all fish impinged and returned to Weiss Lake suffer mortality. The apparent good condition of many of the impinged fish, including lake sturgeon lends support to the contrary.

Impinged species that are of special interest to resource agencies in the Coosa River basin include striped bass (*Morone saxatilis*) and lake sturgeon. Striped bass of the Atlantic strain were originally stocked in Weiss Lake from 1972-1986 and the upper Coosa River in 1973-1992, and are now naturally reproducing in the upper Coosa River (Davin et al., 1999). Adults migrate up the Coosa River to spawn in early spring upstream of Plant Hammond at Mayo's Bar and in the Oostanaula River above Rome. Only two striped bass were collected during the study, which yielded a 95% UCL of 30 striped bass (Table 6-1).

Lake sturgeon is of special management interest because of the WRD's reintroduction program that began in December 2002 with the release of 1,100 fingerlings to the Coosa River. A total of approximately 45,000 lake sturgeon has been stocked through 2005 (Beisser, 2006). Lake sturgeons are believed to have been severely depleted or extirpated from the Coosa River basin and the WRD program is an attempt to reestablish this species. A total of 19 lake sturgeon were collected during the study, which yielded a 95% UCL of 283 fish (Table 6-1). The majority of impinged individuals were from the 2004 and 2005 releases upstream of Weiss Lake in the Oostanaula and Etowah Rivers. Notably, survival rate of impinged lake sturgeon returned to the lake is believed high.

A review of historical impingement studies at other southeastern facilities indicate that the estimated annual impingement at Plant Hammond (30,290 fish; 95% UCL) was low compared to other Phase II facilities with CWISs located on impoundments (Loar et al., 1978; Edwards et al., 1978; Dames & Moore, 1985). The low relative abundance of clupeids (45%), especially threadfin shad (25%) at Plant Hammond was in contrast to results from other southeastern facilities where it is typical for threadfin shad to be the most abundant impinged species. A primary difference between the Plant Hammond results and impingement at other facilities was the absence of notable episodic impingement events of clupeids (especially threadfin shad), which have been related to weather extremes (Loar et al., 1978).

Annual estimated impingement at Duke Power's Allen Steam Station (898,911 fish) was nearly 30 times greater than the Plant Hammond 95% UCL and nearly 70 times greater than the likely more comparable base annual estimate. The Allen Steam Station estimate was derived from a study design (26 biweekly 24-hr sampling events) comparable to the Plant Hammond study; however, it is not apparent that the Duke annual impingement estimate represents an upper confidence limit value. Edwards et al. (1978) attributed over 95 percent of the threadfin shad impingement at Allen Steam Station to low water temperatures. Another one-year impingement study, at SCE&G's V.C. Summer Nuclear Station, located on Monticello Reservoir in South Carolina, yielded an annual estimate of 85,000 fish, of which 83 percent were gizzard shad with the highest rates during the winter months (Dames & Moore, 1985). Again, there is no indication that this estimate represented a statistical upper bound.

The number of impinged species at Plant Hammond (33) was higher than at other Phase II facilities located on southeastern impoundments. The Allen Steam Station study yielded 18 species with threadfin shad representing over 98 percent of the impinged fish. Several impinged species (gizzard shad, threadfin shad, channel catfish and bluegill) were common to those impinged at Plant Hammond. Similarly, 17 impinged species were reported from the V.C. Summer Nuclear Station (Dames & Moore, 1985). The higher number of impinged species at Plant Hammond likely represents differences in the fish assemblages in the impoundments and/or the geo-spatial position of the CWIS relative to upstream drainage basins. A checklist compiled for Weiss Lake (APC, 2000) includes 37 fish species and recent intensive fall electrofishing surveys of the lower Etowah River (Hakala, 2002a) and Oostanaula River (Hakala, 2002b) above Mayo's Bar added an additional 18 species that could potentially occur in the vicinity of Plant Hammond (Table 5-1). The majority of the 38 species collected during the IMCS were previously documented from Weiss Lake or from upstream of Mayo's Bar. Seven species were collected during the IMCS that were not previously reported from the referenced sources: lake sturgeon, red shiner, pugnose minnow (*Opsopoeodus emilliae*), bluntnose minnow, bullhead minnow (*Pimephales vigilax*), yellow bass, and the upside-down catfish. As previously discussed, lake sturgeon have been recently re-introduced to the Coosa River and red shiner, yellow bass, and upside-down catfish have been introduced to the system.

The Etowah and Oostanaula rivers form the Coosa River at Rome approximately 12.5 miles upstream of the Plant Hammond CWIS. Species strongly associated with stream habitats (e.g., silver chub, and Mobile logperch) were commonly impinged at Plant Hammond. Although stream fishes would not be expected to be common in the impounded headwaters of Weiss Lake, they obviously occur incidentally based on the impingement results.

Historical impingement studies also demonstrate that it is typical for impingement rates of sportfish to be low (Edwards et al., 1978; Dames & Moore, 1985). It is also typical for a few species (5-10) to account for over 90 percent of annual impingement at power plants in general (EPRI, 2004).

The data obtained during the one-year study of the Plant Hammond CWIS provided results consistent with the Weiss Lake fish community, with infrequent occurrences of stream fishes from the upstream drainages, and the relative susceptibility of the different species found in the source waterbody to impingement. The high relative abundance of bluegill reflects both their abundance in the source waterbody and the influence of a single episodic impingement event during high water levels that accounted for 86 percent of the 513 bluegill collected during the study. Excluding bluegill, clupeids accounted for 63 percent of the remaining annual estimate.

7. REFERENCES CITED

Alabama Power Company (APC). 2000. Coosa/Warrior Relicensing Project. Initial Information Package for the Weiss Development (FERC No. 2146). Alabama Power Company, Birmingham, AL

Alden Research Laboratory, Inc and Electric Power Research Institute. 2004. Evaluation of Plant Hammond with respect to the Environmental Protection Agency's proposed 316(b) rules for existing facilities. Holden, MA.

Beisser, G. 2006. Personal communication, Georgia Department of Natural Resources, Wildlife Resources Division, Region 1 Fisheries Management, Calhoun, GA.

Coutant, C.C. and D. K. Cox. 1976. Acute cold-shock resistance of gizzard shad. Page 159-161 *in* G. W. Esch and R. W. McFarlane, editors. Thermal Ecology II. Proceedings of a symposium held at Augusta, Georgia, April 1975. Technical Information Center, Energy Research and Development Administration.

Dames & Moore. 1985. 316(b) Demonstration for the Virgil C. Summer Nuclear Station. Prepared for South Carolina Electric and Gas Company, Columbia, SC.

Davin, W. T., J. Hodges, and C. Hoffman. 1999. Evidence of striped bass spawning in the Upper Coosa River Basin, Georgia. Pages 170-179 in Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, Vol. 53.

Edwards, T.J., W.H. Hunt, L.E. Miller, and J.J. Sevic. 1978. An evaluation of the impingement of fishes at four Duke Power Company steam-generating facilities. Pages 373-380 in J.W. Esch and R.W. McFarland (eds.), Thermal ecology II. National Technical Information Service, Springfield, Va.

EPA. 2004. Regional Analysis Document for the Final Section 316(b) Phase II Existing Facilities Rule. EPA-821-R-02-003. United States Environmental Protection Agency, Office of Science and Technology, Engineering and Analysis Division. Washington, DC 20460.

EPRI. 2004. Impingement abundance monitoring technical support document. EPRI Publication 1008470. Palo Alto, CA.

FDEP (2005). Florida Department of Environmental Protection. Upper Confidence Limit Tool (FLUCL) for Chapter 62-780, F.A.C. http://www.dep.state.fl.us/waste/.

Fuller, P.L., L.G. Nico, and J.D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publication 27, Bethesda, MD.

Georgia Power Company (GPC). 2002. Quality Assurance Plan for Georgia Power Company Environmental Laboratory, ENV-QAP Revision 2, dated 03/14/2002. Smyrna, GA.

Georgia Power Company (GPC). 2004. Plant Hammond comprehensive 316(b) demonstration study: proposal for information collection. Atlanta, GA.

Georgia Power Company (GPC). 2005. Preliminary report of fish impingement mortality at the Plant Branch Steam Electric Generating Facility. Atlanta, GA.

Hakala, J.P. 2002a. Lower Etowah River standardized sampling report, fall 2002. Georgia Department of Natural Resources, Wildlife Resources Division, Summerville, GA.

Hakala, J.P. 2002b. Lower Oostanaula River standardized sampling report, September 2001. Georgia Department of Natural Resources, Wildlife Resources Division, Summerville, GA.

Loar, J.M., J.S. Griffith, and K.D. Kumar. 1978. An analysis of factors influencing the impingent of threadfin shad at power plants in the Southeastern United States. Pages 245-255 in L.D. Jensen, ed. Forth National Workshop on Entrainment and Impingement, EA Communications, Melville, NY.

Nelson, J.S., E.J. Crossman, H. Espinosa-Perez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society, Special Publication 29, Bethesda, MD.