COOSA AND WARRIOR RIVER PROJECTS

E11 - IMPINGEMENT, ENTRAINMENT, AND TURBINE MORTALITY STUDY PLAN

1.0 INTRODUCTION

Stakeholders of the Coosa and Warrior Relicensing Teams have identified fish impingement, entrainment, and turbine mortality as an issue to address during relicensing of the Coosa (FERC No. 2146 – Weiss, Neely Henry, Logan Martin, Lay, and Bouldin), Mitchell (FERC No. 82) and Jordan (FERC No. 618) Projects (Coosa River Projects), and the Warrior Projects (FERC No. 2165 – Smith and Bankhead). Therefore, the E11 Issue Action Group (IAG) was formed to identify methods to address this issue area. The IAG met on January 30, 2002 to discuss potential methods to address the issue and agreed to evaluate the potential magnitude of fish impingement, entrainment, and turbine mortality using a combination of existing entrainment and turbine mortality literature and site-specific information. This study plan presents the proposed methodology for achieving this evaluation.

1.1 Project Descriptions

1.1.1 Weiss

The Weiss development, located on the Coosa River, extends 52 miles upstream from the Weiss Dam to the Mayo's Bar Lock and Dam. The lake has a surface area of 30,200 acres with 447 miles of accompanying shoreline and a maximum depth of 62 ft. The Project is a multi purpose storage reservoir with designed seasonal water level fluctuations. The project is operated in a peaking mode for hydroelectric generation.

Project facilities include a diversion dam, spillway, an interconnecting canal, a powerhouse, earth embankments, and three freeboard dikes. The diversion dam, spillway, and earth fill, non- overflow sections are 392 ft long, impounding water from a 5,273 square mile drainage area. A canal

approximately 7,000-ft long carries water from the main reservoir to the powerhouse forebay. The powerhouse contains three vertical fixed-blade propeller turbines, each rated at 39,100 horsepower (hp) under 49 ft of head, and three generators, each rated at 29.25 MWs, creating a total rated capacity for the Weiss development of 87.75 MW.

1.1.2 Neely Henry

The Neely Henry (Henry) development extends 78 miles upstream from the Henry Dam to the Weiss Dam. The lake has a surface area of 11,235 acres with 339 miles of accompanying shoreline and a maximum depth of 53 feet. Due to its relatively small size, the lake has limited storage capacity (120,600 acre-feet) with fluctuations of less than 1.5 feet per day and is operated in a run-of-river mode for hydroelectric generation.

Project facilities include a concrete gravity dam, powerhouse, and earth embankments. The powerhouse contains three vertical fixed-blade turbines, each rated at 33,500 horsepower (hp) under 35 ft of head, and three generators, each rated at 24.3 MW, creating a total rated capacity of 72.9 MW.

1.1.3 Logan Martin

The Logan Martin development extends 48.5 miles upstream from the Logan Martin Dam to Henry Dam. The lake has a surface area of 15,263 acres with 275 miles of accompanying shoreline and a maximum depth of 69 ft. The Project is a multi purpose storage reservoir with designed seasonal water level fluctuations. The project is operated in a peaking mode for hydroelectric generation. As a storage reservoir, the project is used to provide flood control during periods of high flow and flow augmentation during periods of low flow. Discharges are made typically in response to inflows from upstream project flows.

Project facilities include the dam, powerhouse and earth embankments. The dam has a storage capacity of 273,300 acre-ft and impounds water from a 7,770 square mile drainage area. The powerhouse contains three vertical fixed-blade turbines, each rated at 59,000 horsepower under 56 ft of head, and three generators, each rated at 42.75 MW, creating a total rated capacity of 128.25 MW.

1.1.4 Lay

Lay development extends 48 miles upstream from the Lay Dam to Logan Martin Dam. The lake and has a surface area of 12,000 acres with 289 miles of accompanying shoreline and a maximum depth of 88 ft. The lake is operated in a run-of-the-river mode for hydroelectric generation.

Project facilities include two concrete bulkheads, a concrete intake section, a gated concrete spillway and an earth embankment. The dam impounds water from a 9,087 square mile drainage area. The powerhouse contains six vertical turbines, each rated at 40,000 horsepower (hp) under 81 ft of head, and six generators, each rated at 29.5 MW creating a total rated capacity of 177.0 MW.

1.1.5 Mitchell

The Mitchell development extends 14 miles upstream from the Mitchell Dam to Lay Dam. The lake has a surface area of 5,850 acres with 147 miles of shoreline and a maximum depth of 90 ft. The lake is operated in a run-of-river mode for hydroelectric generation.

Project facilities include a gated concrete spillway and two powerhouses. Only one of the four units in the original powerhouse is still in service. The dam impounds water from a 9,827 square mile drainage area. The original (1923) powerhouse, located at the middle of the spillway on its

upstream side, contains four turbine-generator units. Units 1 through 3 have been retired, with Unit 4, rated at 20.0 MW, remaining in service. The new (1985) powerhouse, located at the west abutment, contains Units 5 through 7, each rated at 50.0 MW. This yields a total rated capacity for the Mitchell development of 170 MW.

1.1.6 Jordan-Bouldin

The Jordan Project extends 18 miles upstream from the Jordan Dam to Mitchell Dam. The lake has a surface area of 5,880 acres. The Jordan Project shares its reservoir with the Bouldin development via a 3-mile long intake canal that conveys water to the 920 acre Bouldin forebay. Including the Bouldin forebay, Jordan Lake has a surface area of 6,800 acres with 118 miles of accompanying shoreline and a maximum lake depth of 110 ft. Since, there is no flood control storage in either Jordan Lake or the Bouldin forebay the projects operate in an approximate run-of-river mode. The Jordan and Bouldin Dams together impound water from a 10,165 square mile drainage area.

Project facilities at the Jordan Project include two concrete bulkheads, a concrete intake section and a gated concrete spillway. The powerhouse contains four vertical turbine-generator units, each rated at 25.0 MW. This yields a total rated capacity for the Jordan Project of 100.0 MW.

The water retaining structures at the Bouldin development have a total length of 9,428 ft. The structures include a 2,200 ft long earth embankment (top elevation 265 ft msl), a 228 ft long concrete intake section (top elevation 264 ft msl), and a 7,000 ft long earth embankment (top elevation 265 ft msl). There is no spillway structure; the Jordan Dam spillway serves both developments. The powerhouse contains three vertical turbine-generator units, each rated at 75.0 MW. This yields a total rated capacity for the Bouldin development of 225.0 MW (FERC, 1997).

1.1.7 Smith

The Smith development, located on the Black Warrior River, extends 35 miles upstream from the dam and spreads significantly into several tributaries. The lake has a surface area of 21,200 acres, 500 miles of accompanying shoreline and a maximum depth of 264 ft at the dam, and a maximum width of less than 1.5 miles. The Project is a multi purpose storage reservoir with designed seasonal water level fluctuations. The project is operated in a peaking mode for hydroelectric generation.

Project facilities include the dam, powerhouse, a spillway, and headworks. The dam impounds water from a 944 square mile drainage area. The storage capacity of Smith Lake is 1,390,000 acre-ft at the normal pool elevation of 510-ft msl. The powerhouse is built into the right abutment about 500 ft downstream from the dam centerline. The powerhouse contains two vertical Francis type turbines, each rated at 111,500 horsepower at 210 ft of net head, and two generators, each rated at 78.75 MWs creating a total rated capacity of 157.5 MWs.

1.1.8 Bankhead

The Army Corps of Engineer's (ACOE) John Hollis Bankhead Lock and Dam located on the Warrior River, was originally constructed as a navigation and flood control structure in 1916. The Bankhead development extends 77.8 miles upstream from the ACOE's John Hollis Bankhead Dam. The lake has a surface area of 9,200 acres and 400 miles of accompanying shoreline and a maximum depth of 74 ft.

Project facilities include the ACOE's concrete gravity dam, the concrete gravity spillway with 22 vertical lift gates and the concrete intake structure. Alabama Power owns and operates the powerhouse, which contains

a single vertical shaft turbine-generator unit rated at 52.5 MW under a design head of 66.5 ft. The 100-ft long intake canal is 54 ft wide at the upper end, 25 ft upstream of the spillway, and narrows to 50 ft wide at the intake opening.

2.0 METHODS

2.1 Impingement

Trash racks are present at each of the Coosa and Warrior River developments and prevent debris from moving into and damaging the penstocks and turbines. Fish impingement potentially occurs when high water velocities trap (pin) fish against the intake trash racks. If the fish cannot free itself from the trash racks, then mortality usually ensues. The potential for fish impingement will be based on:

- the spacing between the trash rack bars,
- intake velocities at the trash racks,
- typical sizes of fish estimated to be entrained (from the entrainment estimate),
- general swimming speeds for species estimated to be entrained, and
- general observations from plant operators will also be used as deemed appropriate.

2.2 Entrainment

Fish entrainment is the passage of fish through the trash rack, penstock, and turbines into the tailrace of a development. Fish entrainment at the each of the Coosa and Warrior River developments will be assessed through a desktop study. The goal of this study is to characterize and provide an order-of-magnitude estimate of potential fish entrainment using existing literature and site specific information. The primary inputs for this analysis will be to:

- Define the entrainment database that can be applied to the Coosa and Warrior River Projects,
- Calculate an estimated fish entrainment rate (seasonal rates, if possible), and
- Predict the species composition and length frequency of fish entrained.

These inputs will be developed as described in the following sections.

2.2.1 Define the entrainment database

Over seventy site-specific studies of resident fish entrainment and mortality at hydroelectric sites in the United States have been performed and reported on to date. These studies provide order-of-magnitude estimates of annual fish entrainment (FERC, 1995). Descriptive information has been gathered from each entrainment study and includes:

- Location: geographical proximity, river basin
- Project size: discharge capacity and power production
- Physical project characteristics: trash rack spacing, intake velocity, etc.
- Project operation: e.g., peaking run-of-river, etc
- Biological factors: fish species composition
- Impoundment characteristics: general water quality, impoundment size, flow regime

This information will be assembled into a Screening Matrix for the IAG to review and select specific studies that are most applicable to the Coosa and Warrior River Projects. See Section 3.0 of this Study Plan.

2.2.2 Calculate Estimated Fish Entrainment Rates

The entrainment rate information from the selected entrainment studies will be consolidated to show fish entrainment rates on a seasonal basis (when available). Preference will be given to netting entrainment rates over hydroacoustic entrainment rates. Since entrainment rates based on hours of turbine operation cannot directly account for differences in station flow volume, entrainment rates both in fish entrained per hour and fish entrained by volume of water passed through the project turbines (fish/million cubic feet) will be used when available. The data will be grouped by season where appropriate to determine an entrainment rate for each season of the year. The seasonal rates will be used to develop an average seasonal entrainment rate.

Seasonal entrainment estimates will be summed to determine annual fish entrainment for the Coosa and Warrior River Projects.

2.2.3 Estimate Species Composition and Length Frequency Distribution

The species composition data from each accepted entrainment study will be analyzed and compiled to determine the general species and sizes of fish typically entrained at other hydroelectric projects. This information will be grouped to yield seasonal estimates of species-specific length frequency data for entrained fish. These data will be compared and combined with ADCNR fisheries data (cove rotenone data and annual baseline sampling) to:

- Identify fish species potentially susceptible to entrainment,
- Estimate the expected relative abundance and size distribution of each potentially entrained fish species, and
- Estimate the seasonality of potentially entrained fish species.
- These species composition estimates will be organized by fish group (i.e., family or genus) and size-class, then applied to seasonal estimates of fish entrainment to produce annual species composition estimates of fish entrainment.

2.3 Turbine Mortality

As fish move through hydroelectric turbines, a percentage is killed due to turbine mortality (i.e. blade strikes, shear forces, pressure changes, etc.). Turbine passage survival studies have been performed at numerous hydroelectric projects throughout the country over the past 15 or more years. Characteristics of these identified projects will be compared to the characteristics of the Coosa and Warrior River Projects and appropriate studies will be selected for the transfer of turbine mortality data for each development (see Section 4.0 of this Study Plan). Selected turbine survival rate data will be obtained from the literature and used to estimate the number of fish killed due to turbine mortality. The following turbine characteristics

are recommended as general criteria in accepting turbine mortality studies for use in this analysis:

- design type (Kaplan, Francis, etc.)
- operating head
- runner speed
- diameter, and peripheral runner velocity

These characteristics are commonly attributed to turbine passage mortality (Cramer and Oligher, 1963; Bell, 1991; Eicher, 1987; EPRI, 1992).

To the extent possible, turbine mortality rate data available from source studies will be related to the species-family group and size class of fish estimated to be entrained at the Coosa and Warrior River Projects. Where multiple tests are available for a given species-family group/size class, a mean survival rate will be computed. For species-family groups/size classes where no applicable data can be found or accepted, the survival rate reported for a similar group/size class will be substituted.

Once turbine mortality rates are developed from the study database, the rates will be applied to the entrainment estimates for each development. This will be accomplished by multiplying fish entrainment estimates by the composite mortality rates for each family/genus group and size class (where applicable). This step will yield the total number of fish potentially killed at each development on an annual basis.

2.4 Filters

Due to certain site-specific characteristics of the Coosa and Warrior River Projects, it may be appropriate to adjust entrainment estimates. Factors affecting entrainment rates that may warrant investigation for adjustment of estimates include:

- seasonal stratification at the intakes (dissolved oxygen),
- intake velocities,
- fish habitat available at the intakes, and/or

- other factors identified by IAG members

2.5 Analysis and Reporting

To ensure consensus during this study, each step of this process will be discussed with and reported to the IAG. IAG member comments will be addressed at each step of the study. Upon completion of the study, a Draft Report will be prepared and distributed to IAG members for review and comment. The Draft Report will summarize the results of the study, contain appropriate tables and figures depicting estimated fish impingement, entrainment, and turbine mortality, and will contain all pertinent correspondence and discussion from IAG members. After an appropriate review period, the Draft Report will be revised to address final comments by all IAG members and submitted to the Coosa Ecological Resource Advisory Team (EcoRAT) and Warrior Cooperative Relicensing Team (WCRT) as the Final Report. It may also be necessary for the IAG to prepare periodic reports for the Coosa EcoRAT and WCRT during this process.

3.0 ENTRAINMENT DATABASE

3.1 Screening Matrix

Kleinschmidt reviewed multiple sources of information and prepared a Screening Matrix for establishing an Entrainment Database for use with the Coosa and Warrior River Projects. This matrix is presented in Table 1 and presents information for the 9 developments and from 68 other hydroelectric projects where entrainment studies have been performed and reported. Note that there are gaps in the matrix due to the amount of information currently available to Kleinschmidt. These gaps can be filled as deemed appropriate by the IAG.

3.2 Recommended Entrainment Studies

Kleinschmidt reviewed the Screening Matrix and winnowed the list down to the most applicable studies for use in the Coosa and Warrior River Entrainment Database. Several criteria were applied during this process:

- Type of fishery – warm water
- Geographic location – southeast
- Detail of study information available or quality of the study

When these criteria were applied, 12 entrainment studies remained in the database. These studies are presented in Table 2 and are subject to review and discussion with the IAG. Based on the recommendations of the IAG, the entrainment database will be expanded and/or modified.

4.0 TURBINE MORTALITY DATABASE

4.1 Screening Matrix

Kleinschmidt reviewed multiple sources of information and prepared a Screening Matrix for establishing a Turbine Mortality Database for use with the Coosa and Warrior River Projects. This Matrix is presented in Tables 3a and 3b and presents information for the 9 developments and from 57 other hydroelectric projects where turbine mortality studies have been performed and reported. Note that there are gaps in the matrix due to the amount of information currently available to Kleinschmidt. These gaps will be filled as deemed appropriate by the IAG.

4.2 Recommended Turbine Mortality Studies

Kleinschmidt reviewed the Screening Matrix and winnowed the list down to the most applicable studies for use in the Coosa and Warrior River Turbine Mortality Database. Several criteria were applied during this process:

- Type of fishery – warm water preferred
- Species of fish tested – removed all salmonid or ocean run species.
- Detail of study information available or quality of the study.

When these criteria were applied, 43 turbine mortality studies remained in the database. These studies are presented in Tables 4a and 4b and are subject to review and discussion with the IAG. Since many of the studies were performed for specific fish species or sizes, Kleinschmidt recommends that the IAG accept all 43 studies for the Coosa and Warrior River Projects Turbine Mortality Database. Once we have completed entrainment estimates, we will provide additional information on these studies so that the IAG can select specific studies to apply at each development.

LITERATURE CITED

Bell, M. C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. United States Corps of Engineers. Fish Passage Development and Evaluation Program. Portland, OR.

Cramer, F. K., and R. C. Oligher. 1963. Passing fish through hydraulic turbines. Transactions of the American Fisheries Society 93:243-259.

Eicher Associates, Inc. 1987. Turbine-related fish mortality: review and evaluation of studies. Research Project 2694-4. Prepared for Electric Power Research Institute, Palo Alto, CA.

EPRI (Electric Power Research Institute). September 1992. Fish Entrainment and Turbine Mortality Review and Guidelines. TR-101231 Research Project 2694-01. Prepared by Stone & Webster Environmental Services.

Federal Energy Regulatory Commission (FERC). 1995. Preliminary assessment of fish entrainment at hydropower projects – volume 1 (Paper No. DPR-10). Office of Hydropower Licensing, FERC, Washington, DC.

COOSA AND WARRIOR RIVER PROJECTS

E11 - IMPINGEMENT, ENTRAINMENT, AND TURBINE MORTALITY STUDY PLAN

Table of Contents

List of Tables

Coosa and Warrior River Projects

Alabama Power Company

E11- Impingement, Entrainment, and Turbine Mortality Study Plan

March, 2002

Prepared by:

Kleinschmidt
Energy & Water Resource Consultants

ALABAMA POWER COMPANY

DRAFT

E11 - Impingement, Entrainment, and Turbine Mortality Study Plan

March, 2002

Prepared by:

KLEINSCHMIDT ASSOCIATES
Energy and Water Resource Consultants
West Columbia, South Carolina