TENNESSEE VALLEY AUTHORITY

An Environmental Assessment of Operation of Browns Ferry Nuclear Plant With A Thermal Limit of 90°F Maximum Temperature in Wheeler Reservoir.

JULY 1977

Docket #
Control #
Date ________ of Document:
REGULATORY DOCKET FILE

Docket # 50-259
Control # 1772150232
Date 7/26/77 of Document:
REGULATORY DOCKET FILE

772150232

Table of Contents

ABSTRACT

A combination of extreme meteorological conditions and inadequate cooling tower performance has resulted in a severe reduction in generation from TVA's three unit Browns Ferry Nuclear Plant during periods of peak system demands. These reductions were necessary to meet the current State of Alabama water temperature standards for the Wheeler Reservoir.

The current Alabama standards were adopted because it was felt at that time the standards were necessary to ensure the maintenance of the fishery habitat of the reservoir. Subsequent studies performed by TVA (summarized in Section 6) have indicated that the current standards are unnecessarily restrictive for the protection of the fishery of this reservoir. Consequently, TVA requested from the Environmental Protection Agency a temporary modification of the thermal standards specified in the NPDES permit issued for Browns Ferry.

TVA is currently exploring methods of correcting the heat dispersal problems existing at Browns Ferry. Completion of necessary modifications is anticipated about mid-1980.

This environmental assessment describes the current thermal standards, condenser cooling water system, thermal regime of Wheeler Reservoir, effects of operation on the aquatic biota of the reservoir, and the power supply situation. Based on the thermal regime resulting from the plant and the hydrothermal analysis provided herein, the assessment concludes that long-term operation of the plant at less restrictive thermal standard (maximum temperature of 90°F.) will not result in adverse environmental impacts to the biota of Wheeler Reservoir.

1.0 Introduction

The Browns Ferry Nuclear Plant was initiated in 1966 as part of TVA's program designed to meet projected load requirements. Construction of the plant began in May 1967 after the Atomic Energy Commission (AEC) issued provisional construction permits for units 1 and 2. Unit 3 was given a construction permit in July 1968. Commercial operation was achieved on units 1, 2, and 3 on August 1, 1974; March 1, 1975; and March 1, 1977, respectively.

The operation of the three units at Browns Ferry Nuclear Plant has been intermittent since the fall of 1973. Unit 1 was initially placed on line in October 1973 and operated continuously at near full load until March 1975, when it was shutdown because of the cable fire. Unit 2 was placed on line in August 1974 and operated at near full load until March 1975 when it was also shutdown because of the cable fire. Following the fire outage, all three units were placed in service in September 1976, and have operated at or near full power since that time, except for periods when load reductions were required to meet river temperature limits.

The history of the consideration of auxiliary cooling facilities and the evolving thermal criteria as these criteria were finally adopted by the Environmental Protection Agency (EPA) is described in considerable detail in the final environmental statement (issued on September 1, 1972). Aspects that pertain to the present situation at Browns Ferry Nuclear Plant are repeated herein.

The Tennessee Valley Authority has taken action to comply with applicable thermal water quality standards of the State of Alabama in the operation of the 3-unit Browns Ferry facility by installing mechanical draft cooling towers. However, inddequate cooling tower performance has resulted in drastic curtailment of power generation during peak summer periods when peak load demands are critical on the TVA system to meet thermal standards. Thermal discharges resulting from power operation are being controlled in order to meet the applicable thermal standards. This document describes (1) the need to operate Browns Ferry in a manner which will not result in water temperature in excess of 90°F after reasonable mixing for an indefinite period, and (2) the need to be able to discharge cooling tower blowdown when natural occurring water temperature is near or exceeds 86°F, and (3) the effects of operating the plant within these limits. A summary description of the design, and operation of the Browns Ferry heat removal system, along with a discussion of thermal standards, and reservoir characteristics are also included. This information provides the basis for discussions regarding the ways in which such operation can be accomplished consistent with the Federal Water Pollution Control Act Amendments of 1972.

On the basis of TVA's environmental evaluation that facility operation limiting the maximum stream temperature to 90° F. would not detrimentally affect the aquatic environment of Wheeler Reservoir, TVA sought relief from the 86° F. limitation to allow utilization of the plant's generating capacity. On July 1, 1977, TVA staff met with personnel from EPA, Region IV, to explain the power systems situation, to seek the needed thermal limitation relief, and to discuss the resulting environmental effects. During this meeting is was determined that, with EPA concurrence, the most efficient procedure for obtaining such relief would be a TVA request for adjudicatory hearing.

EPA expressed Support for TVA's environmental evaluation and proposed operation. On July 7, 1977, a meeting was held with James Warr, Chief Administrative Officer, Alabama Water Improvement Commission, to discuss these topics. An AWIC concurrence with TVA's proposed modified operation was obtained. On July 8, 1977, TVA representatives discussed the existing situation and status of other regulatory agency discussions with NRC staff.

On July 13, 1977, TVA transmitted a petiiton for adjudicatory hearing to EPA and a letter requesting concurrence in the proposed facility operation to James Warr. EPA and NRC concurrence with the proposed interim operation was received on July 15, 1977, by letter and verbal concurrence was received from the staff of the Alabama Water Improvement Commission. A confirming letter was received from the AWIC Staff dated July 18, 1977, on July 20, 1977.

2.0 Thermal Standards

The heat dispersal facilities for the Browns Ferry plant were originally designed and constructed to meet water temperature standards which were judged by TVA to be adequate to protect aquatic life (Reference Supplements and Additions to Browns Ferry Draft Environmental Statement issued November 8, 1971). The State of Alabama subsequently proposed identical standards, which would permit a temperature rise of 10°F with a maximum temperature of 93°F.

In April 1971, EPA held a Standard-Setting Conference for the interstate waters of the State of Alabama in Montgomery, Alabama. One of the recommendations made by EPA at this conference was that the State of Alabama adopt temperature standards that would limit the maximum temperature rise of a stream by the addition of heat to no more than 5°F with a maximum allowable water temperature not to exceed 90°F, except that in the Tennessee River Basin and portions of the Tallapoosa River Basin which have been designated by the Alabama Department of Conservation as supporting smallmouth bass, sauger, and walleye, the temperature shall not exceed 86°F. Wheeler Reservoir has been officially designated as this type fishery. The State of Alabama did not immediately adopt these recommended temperature standards. Meanwhile, EPA had approved temperature standards for Costal and Piedmont zone streams in both Virginia and North Carolina that would allow a 5°F rise and a maximum temperature of 90°F. While changes to more restrictive standards were often mentioned, it was not until December 1971 that EPA informed TVA that it would not accept any maximums for the waters of the Tennessee River Basin in Alabama other than the following:

> "Temperature shall not be increased more than 5°F above the natural prevailing background temperatures, nor exceed a maximum of 86°F."

These temperature standards proposed by EPA for the State of Alabama were published by EPA in the March 11, 1972, Federal Register. Alabama adopted these standards and EPA approved them on September 19, 1972.

Based on the studies described in Section 6 of this assessment, TVA believes the thermal standard of 86°F maximum temperature is unnecessarily restrictive for the protection of the aquatic biota in the Wheeler reservoir.

3.0 Condenser Cooling Water Systems

3.1 Diffuser System

The original condenser cooling water system for the Browns Ferry Nuclear Plant consisted of a once-through system. It was recognized early in the plant design stages that the condenser water should be discharged directly into the surface stratum of Wheeler Reservoir. Instead, it was decided that by means of a diffuser, the condenser water should be mixed as quickly as possible with as much unheated river water as possible. By this procedure, no excessively warm surface stratum would exist and the mixing zone would be restricted to a relatively small area.

Based on TVA studies which were discussed in the draft environmental statement and the experience of others at the time Browns Ferry was designed, it was concluded that these heat dispersal facilities would adequately protect the waters of Wheeler Reservoir for the following uses: public water supply, swimming and other whole body water-contact sports, fish and wildlife, and agricultural and industrial water supply.

Each unit has its own distinct flow system consisting of pumps capable of producing a flow of 1,450 cfs (total of 4,350 cfs for three units), conduit leading to a turbine condenser, and a discharge conduit leading to an underwater diffuser in Wheeler Reservoir.

Figure 3.1-1 shows the physical relationship of the cooling water conduit and diffuser pipes to the main channel and to the overbank areas of Wheeler Reservoir at the plant site. The diffuser system design is shown in Figure 3.1-2. Thermal diffusion is accomplished by means of three perforated pipes, connected to the discharge conduits of the three units. These perforated corrugated steel pipes are laid side-by-side across and partially buried in the bottom of the 1,800-foot-wide channel. The channel is approximately 30 feet deep. The pipes are 17 feet, 19 feet, and 20 feet 6 inches in diameter and of differennt lengths. Each has the last 600 feet perforated on the downstream side with more than 7,000 two-inch diameter holes. Thus, approximately 22,000 holes spaced 6 inches on centers in both horizontal and vertical directions distribute the cooling water into the river for thermal mixing.

As discussed above, the diffuser system was designed to meet a temperature criteria of 10°F thermal rise above ambient water temperature with a maximum temperature not to exceed 93°F after reasonable mixing. In light of EPA's letter of December 17, 1971, which stated that the only acceptable thermal standard for the State of Alabama would provide for a 5°F rise and 86°F maximum temperature, and TVA's policy to take appropriate action on a timely basis to meet any further applicable standards, TVA determined that the diffuser system was not adequate to ensure acceptable conformance with this proposed standard. The alternatives of mechanical draft cooling towers, natural draft cooling towers, spray canal system, and cooling lake for heat dissipation were reevaluated and it was decided at that time that mechanical draft cooling towers would provide the best long-term solution to meet the more stringent thermal standards. The towers would supplement the diffuser system in order to comply with the new standards.

3.2 Cooling Towers

By contract with the Ecodyne Corporation of Santa Rosa, California, TVA purchased and had installed a system of six mechanical draft cooling towers. The towers were completed in May 1976, but were not needed for condenser cooling during the summer of 1976 because the plant was not in operation. It was not until the spring of 1977 that the towers were actually placed in service.

A flow schematic diagram for the towers is shown in Figure 3.2-1. This modified system is designed to be operated in either open, helper, or closed modes, depending on plant generation, riverflow, and ambient water temperatures. For a typical year, helper mode operation is expected during the early spring and fall periods, and closed cycle operation is expected during all or most of the summer months to meet the present state thermal standards.

During closed-mode operation of the mechanical draft cooling towers, a certain portion of the condenser circulating water must be removed from the cooling towers as blowdown. This blowdown limits the concentration of dissolved solids in the water which would otherwise interfere with operation of the towers and associated equipment. The amount of blowdown has been estimated to be about 110 ft^3/s.

The quantity of makeup required in the closed mode operation is dependent on the following items: (1) amount of blowdown, (2) the amount of evaporation from the towers, and (3) drift losses. With a blowdown dissolved solids concentration factor of 2, the total makeup required has been approximately 6 percent of the circulating waterflow, or 220 ft^3/s.

Based on tests conducted by TVA and the manufacturer in May 1977, it has been concluded that the modified cooling system is not adequate to permit normal plant operation while on closed-cycle cooling. Recent operating experience has demonstrated that the capability of the mechanical draft cooling towers is reduced by 20 percent or more when meteorological conditions result in a recirculation of the cooling tower vapor plume. This reduction in cooling tower capability results in an increase in the tower discharge water temperature of around 3.5°F above design conditions. The reduced tower capability coupled with extremely high ambient wet bulb temperature has required reduction in plant generation of 50 percent or more during periods of peak system demands.

In addition to these inherent operating problems, TVA recently experienced the partial collapse of the No. 5 tower at Browns Ferry making it unavailable for operation for an indefinite period of time. A similar failure of an Ecodyne tower at another power plant in Texas makes the continued structural integrity of the remaining cooling towers at Browns Ferry questionable without substantial modifications. Structural repair of the type needed cannot be made to a tower without removing it from service. Thus, we will experience additional constraints on our ability to operate the plant within the present temperature limit of 86°F and at any reasonable generation level until these problems are corrected. Thus, a temporary relaxation of the maximum temperature limit of 86°F to the proposed 90°F value is urgently needed.

TVA recognizes that prompt and effective actions must be taken to improve the cooling tower capability, and steps are already underway to do so. Immediate actions include (1) thoroughly inspecting and assessing the structural condition of the towers and initiate needed repairs; (2) increasing the pitch of the fan blades as much as possible to obtain more airflow, and (3) to investigate ways to prevent or significantly reduce the vapor entrainment problem.

TVA is evaluating several long-term modifications to the condenser cooling water system, including adding more heat removal capacity consisting of more cells or additional towers. Depending on the evaluation of reasonable alternatives, it is not anticipated that a permanent engineering solution to the cooling system problem will be completely implemented until about mid-1980.

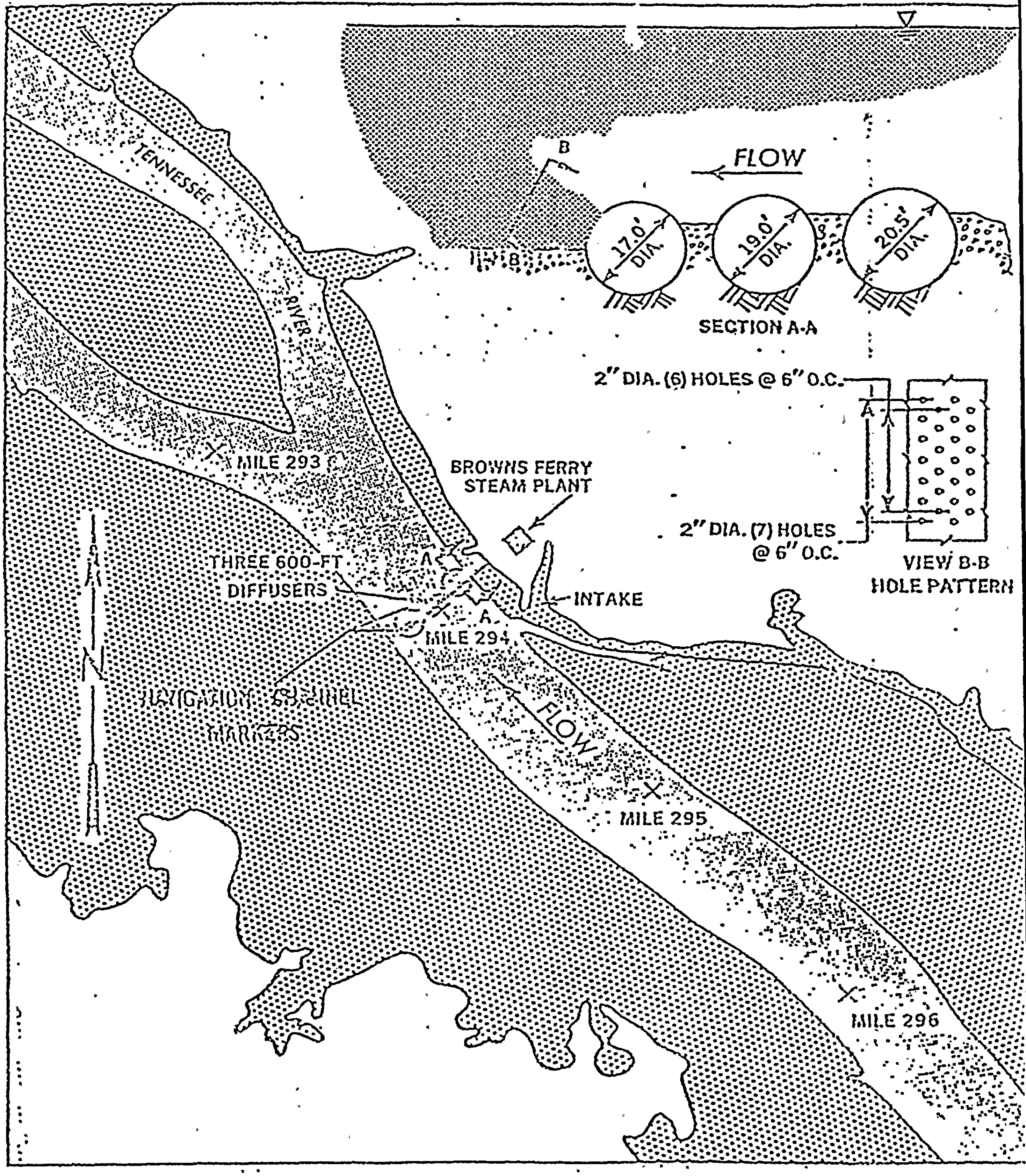
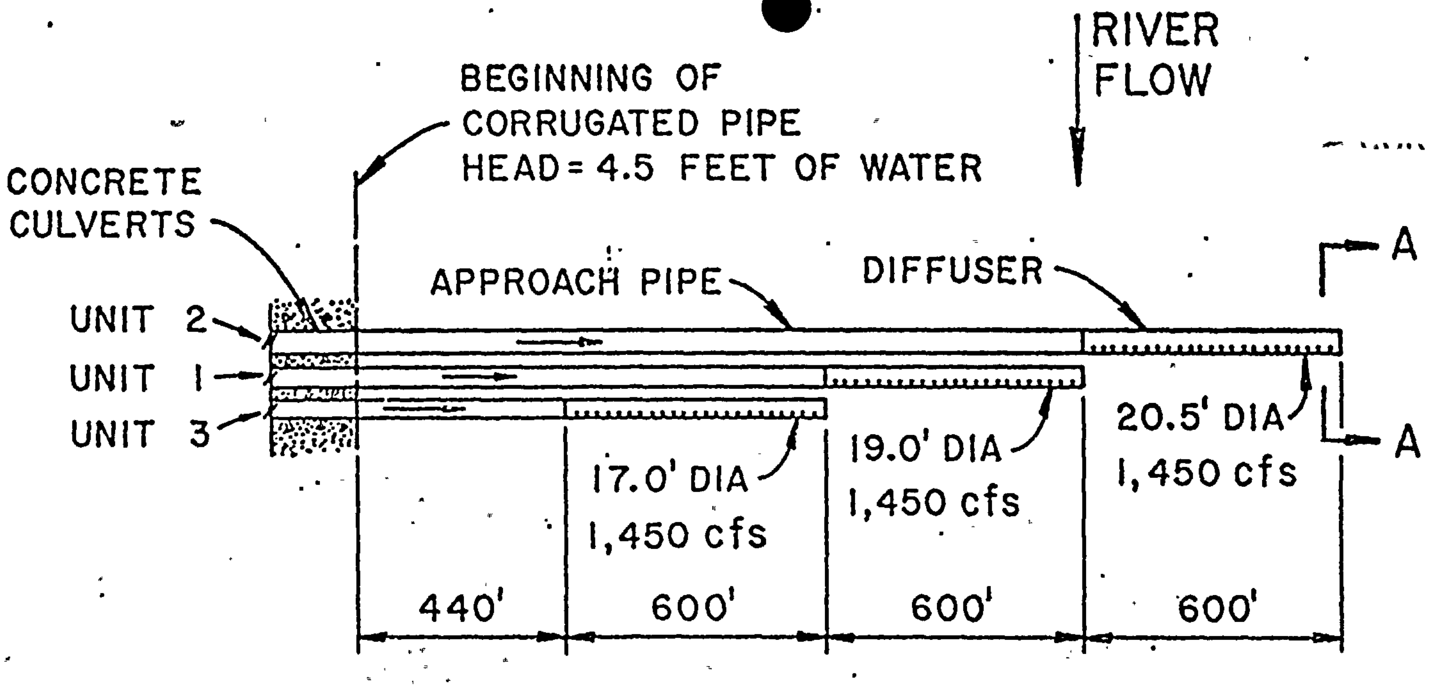
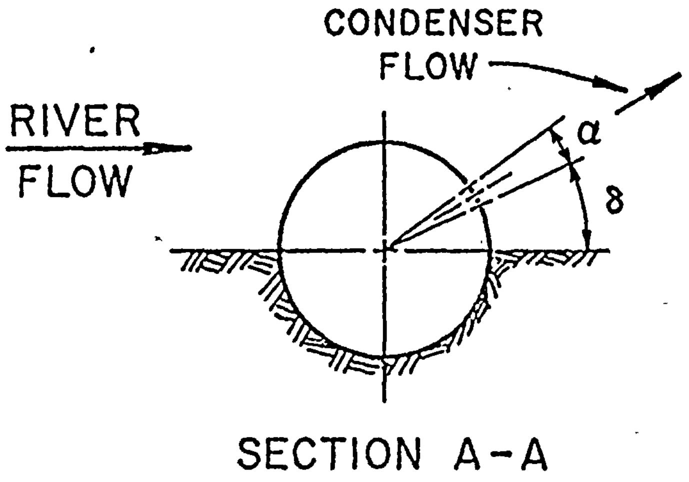


FIGURE 3.1-1

DIFFUSER SYSTEM AND CHANNEL MARKINGS



PLAN



SECTION A-A

ALTERNATIVE HOLE PATTERNS	
1" HOLES	2" HOLES
ALTERNATELY 25 AND 26 HOLES PER CORRUGATION	ALTERNATELY 6 AND 7 HOLES PER CORRUGATION

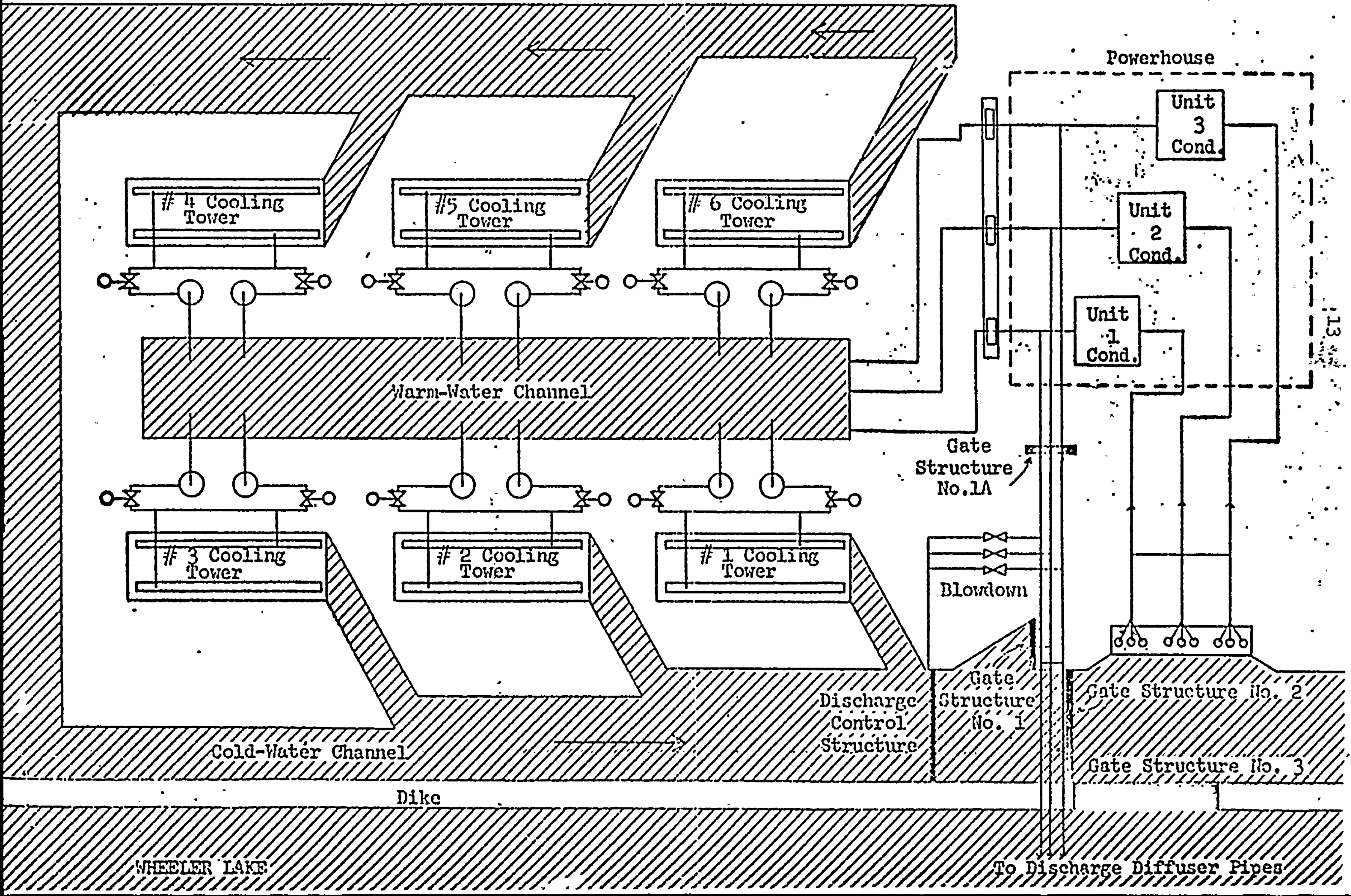
GALVANIZED STEEL PIPE
STRUCTURAL PLATE
#3 GAGE, 2"x6" CORRUGATION

2" HOLE SCHEME
ACCEPTED FOR CONSTRUCTION
$\alpha \approx 21°$ AND $\delta \approx 24°$

Figure 3.1-2
Diffuser System Design

BROWNS FERRY CONDENSER COOLING WATER SYSTEM

FIGURE 3.2-1



4.0 Thermal Regime of Wheeler Reservoir

4.1 General

Browns Ferry Nuclear Plant is located on Wheeler Reservoir, which is one of TVA's main stream reservoirs on the Tennesee River. The hydraulic regime in the reservoir is controlled by the operation of TVA's Guntersville Dam upstream of the plant and Wheeler Dam downstream. These projects are operated primarily for navigation, flood control, and power production.

4.2 Stratification

Wheeler Reservoir exhibits weak thermal stratification during the summer months due primarily to the relatively short transit time within the reservoir and the fact that the power intakes on the two dams withdraw water from the entire vertical depth of their respective reservoirs.

4.3 Natural Water Temperatures

It is very significant that natural water temperatures exceeding the current 86°F maximum have been observed in Wheeler Reservoir. In the operation of the Tennessee River hydroelectric projects, TVA has for years made weekly observations of the water temperatures in the releases from dams. Table 4.3-1 summarizes these observations for the period 1960 to 1976. Table 4.3-2 shows for the years 1966-1975 the month-by-month occurrences of the number of days the natural temperatures of the Wheeler releases equalled or exceeded 86°F.

In conjunction with the collection of preoperational data for the Browns Ferry site, water temperatures in Wheeler Reservoir have been monitored by permanent recording stations. The recorded temperatures range from about 40°F in the winter to a typical maximum of 85-90°F at the surface in the summer. The maximum top to bottom vertical temperature difference is about 5-8°F. Natural water temperatures above the maximum temperature standard of 86°F have been recorded over much of the reservoir depth. These data indicate that there is no significant change in the temperature of the inflow and outflow of Wheeler Reservoir. Thus, with the exception of the surface waters which are subject to diurnal temperature fluctuation resulting from meteorological conditions, the temperatures of the Wheeler Dam releases are almost identical to the average water temperatures at the Browns Ferry site.

The highest water temperatures at the plant site since the monitors have been installed were recorded during the summer of 1969 and illustrate the extent to which natural temperatures have exceeded the 86°F standard. Although all data have not been evaluated, the river temperatures recorded during the summer of 1977 are very similar to those recorded in 1969.

The monitor at Tennessee River mile (TRM) 293.6 about 0.4 mile downstream of the plant, has ten thermistors. One of these thermistors is mounted at an elevation of 550 feet (MSL) which, under normal Wheeler Reservoir operation, will vary from about three to six feet below the water surface during the summer months. In the application of temperature criteria adopted for the State of Alabama, the temperature has been measured at a depth of 5 feet in water 10 feet or greater in depth, which is the case for Wheeler Reservoir.

Table 4.3-3 shows the daily maximum and average temperatures recorded for this one thermistor during the summer of 1969.

4.4 Streamflow -

Since 1937, the U.S. Geological Survey has maintained a streamflow gaging station at Whitesburg, Alabama, about 39 miles above the Browns Ferry site.

The average daily streamflow at this station for 46 years of record is about 42,500 ft^3/s. At the Browns Ferry site the average annual streamflow is estimated to be about 45,000 ft^3/s. Based on the Whitesburg gage data for the period 1951 to 1970, Table 4.4-1 lists the percentage of days the mean daily flows at the Browns Ferry site could be below the indicated discharge.

The operation of Wheeler and Guntersville Dams results in wide fluctuations within the daily period represented by the mean daily streamflows. The hourly releases from Guntersville and Wheeler Dams for 10 years of record (1959-68) are illustrated by the flow duration curves of Figures 4.4-1 and 4.4-2. These hourly records show that the periods of low or no flow are only a matter of hours in duration. Therefore, the majority of the no or low flow occurrences can be eliminated by making adjustments in the daily operation of the Guntersville and Wheeler Dams. TVA has committed to make these operating adjustments as one method of complying with water quality standards.

Table 4.3-1

SUMMARY OF WEEKLY OBSERVED WATER TEMPERATURES IN THE RELEASES FROM GUNTERSVILLE AND WHEELER DAMS

1960 TO 1976

Year	Maximum Temperature °F		Minimum Temperature °F		Number of Days Natural Temperature Equalled or exceeded 86°F	
	Guntersville	Wheeler	Guntersville	Wheeler	Guntersville	Wheeler
1960	82.4	86.0	41.0	42.8	0	16
1961	82.4	82.4	39.2	41.0	0	0
1962	84.2	86.0	39.2	41.0	0	8
1963	82.4	84.2	39.2	39.2	0	0
1964	84.2	86.0	41.0	41.0	0	1
1965	84.2	86.0	42.8	44.6	0	1
1966	86.0	86.0	37.4	37.4	1	36
1967	80.6	80.6	42.8	44.6	0	0
1968	86.0	87.8	41.0	42.8	1	22
1969	88.7	87.8	41.0	41.0	15	30
1970	84.2	87.8	39.2	37.4	0	17
1971	84.2	86.0	41.0	41.0	0	2
1972	84.2	84.2	44.6	44.6	0	0
1973	84.2	86.0	42.8	41.0	0	7
1974	82.5	86.0	46.5	48.2	0	8
1975	84.2	84.2	44.6	48.2	0	0
1976	84.2	84.2	40.1	39.2	0	0

Table 4.3-2

NUMBER OF DAYS THE NATURAL TEMPERATURES OF THE WHEELER RELEASES EQUALED OR EXCEEDED 86°F

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
June	0	0	0	1	0	0	0	0	0	0
July	17	0	0	28	0	2	0	0	0	0
August	19	0	21	0	16	0	0	0	0	0
September	0	0	0	0	1	0	0	0	0	0
TOTAL	36	0	21	29	17	2	0	0	0	0

Table 4.3-3

DAILY RESERVOIR TEMPERATURES - WHEELER RESERVOIR

TRM-293.6 - Summer 1969

	Temperature Readings - Fehrenheit Sensor at Elevation 550 Feet	
Date	Maximum for Day	Average for Day
June 16	77.6	77.2
17	77.2	76.5
18	78.7	77.4
19	79.7	77.8
20	79.7	78.8
21	80.7	78.6
22	82.0	80.2
23	82.4	80.8
24	82.1	81.2
25	83.6	81.9
26	83.8	82.4
27	85.0	82.3
28	85.4	82.9
29	86.2	84.2
30	86.8	84.8
July 1	85.8	84.7
2	87.9	84.7
3	85.8	84.5
4	86.2	84.8
5	86.6	85.7
6	87.8	86.1
7	87.5	87.0
8	88.6	86.9
9	87.9	87.2
10	87.6	86.5
11	88.7	86.8
12	87.6	86.5
13	87.9	86.7
14	88.6	86.8
15	87.4	86.7
16	87.2	86.8
17	86.6	85.7
18	85.1	84.7
19	86.5	85.1
20	85.4	—
21	—	—
22	87.6	86.7
23	86.9	86.4
24	86.6	85.5
25	86.8	85.6
26	87.9	86.2
27	86.7	85.8

Table 4.3-3
(continued)

Date	Temperature Readings - Fahrenheit Sensor at Elevation 550 Feet Maximum for Day	Average for Day
July 28	85.9	85.1
29	85.1	84.5
30	85.8	84.4
31	84.9	84.4
Aug. 1	86.3	84.5
2	87.3	85.0
3	84.6	84.0
4	84.7	83.7
5	84.5	83.5
6	86.0	84.0
7	85.0	84.1
8	85.5	84.9
9	85.3	84.7
10	84.9	84.5
11	83.8	83.5
12	84.6	83.0
13	84.1	82.9
14	84.3	83.1
15	83.4	82.6

Table 4.4.1

Tennessee River Mean Daily Discharge at Browns Ferry	Percent of Days Mean Daily Discharge Is Lower
50,000 ft^3/s	76
45,000	67
40,000	56
33,000	35
30,000	27
25,000	17
20,000	10
15,000	6
10,000	3
5,000	1
1,000	0.3

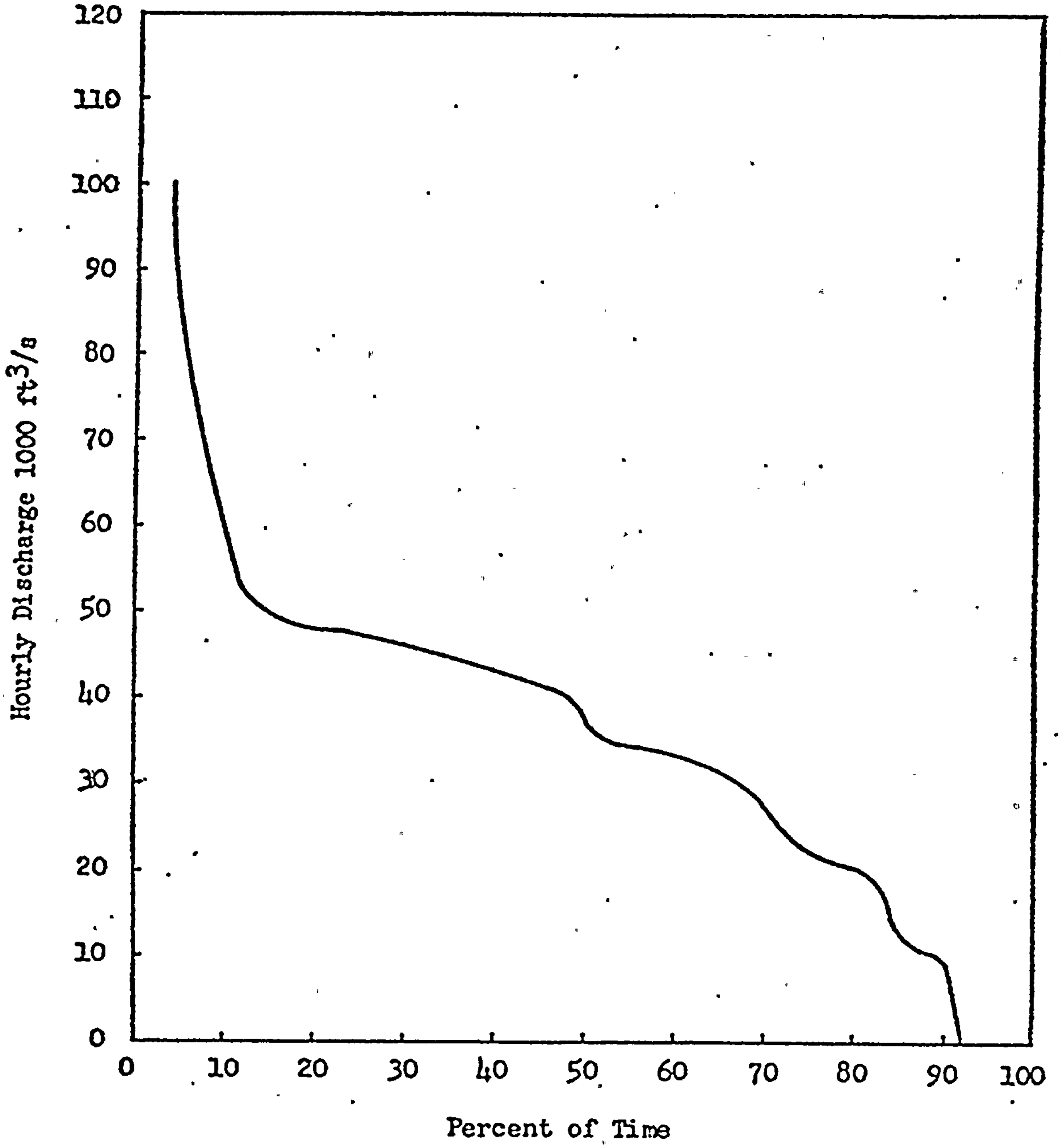


Figure 4.4-1
Guntersville Dam
Hourly Flow
10 Years of Record
1959 - 1968

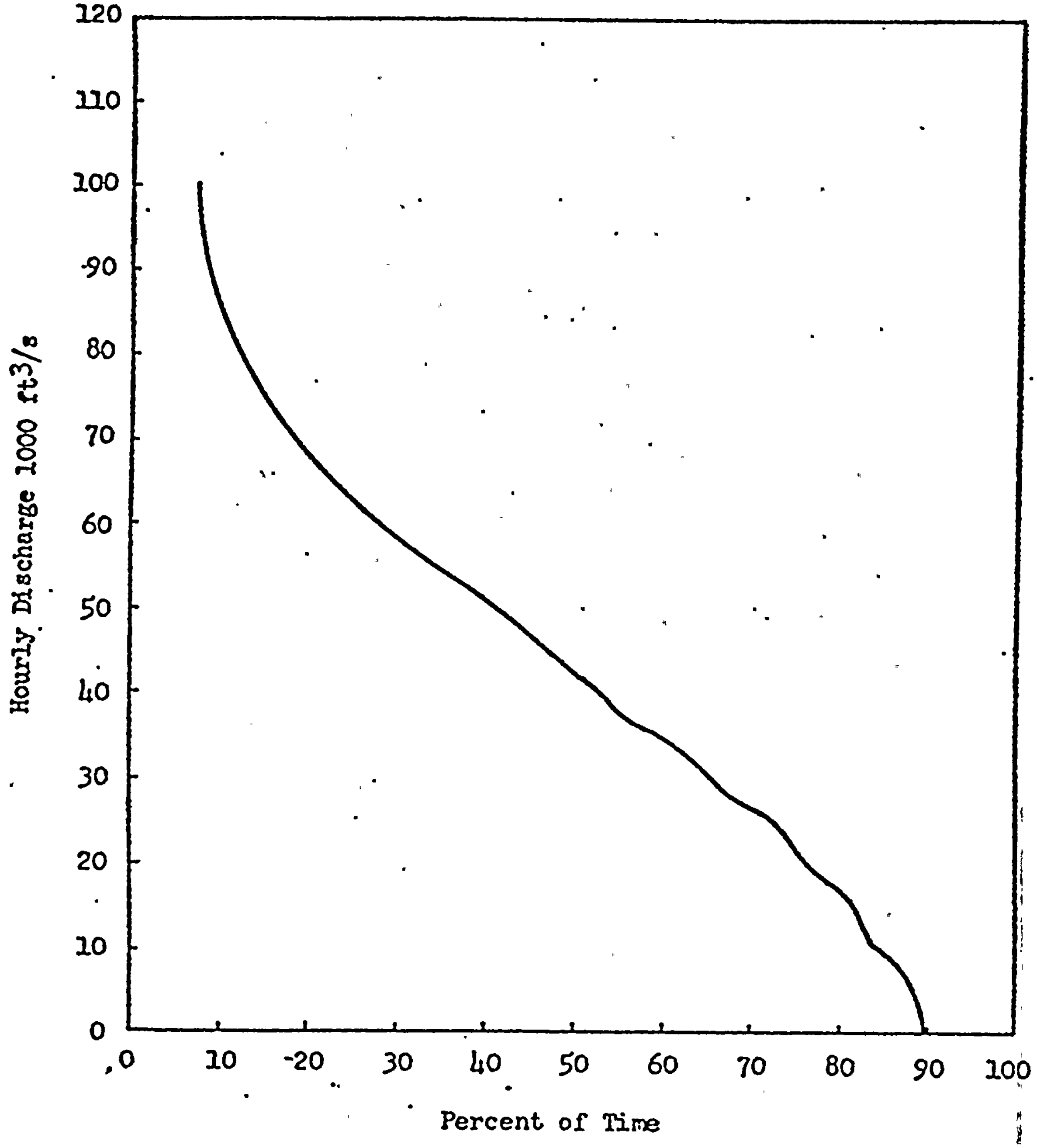


Figure 4.4-2
Wheeler Dam
Hourly Flow
10 Years of Record
1959 - 1968

5.0 Aquatic Ecology of Wheeler Reservoir

5.1 Fishery Resources

Wheeler Reservoir supports a warmwater fish fauna considered typical of large reservoirs in the southeastern United States. Table 5.1-1 summarizes the species which were recorded in the four-year preoperational monitoring survey of the area. In addition to the typical warmwater assemblage, three species thought to be more commonly associated with cool water reservoirs, lakes, and rivers have been recorded: walleye (Stizostedion v. vitreum), sauger (S. canadense), and smallmouth bass (Micropterus dolomieui). These latter species form the center of concern in terms of the aquatic thermal standards established for the Tennessee River. It is appropriate, therefore, to begin the discussion of the possible effects of plant operation under the proposed thermal criteria with a consideration of these species. In several instances, general reviews of the literature are used in order to reduce the number of specific citations; these reviews are identified with an asterisk in the Literature Cited Portion of Section 6.

Smallmouth bass (Micropterus dolomieui)--The distribution of smallmouth bass in North America describes a rough, inverted triangle bordered on the north by northern Minnesota and Quebec, by the western Appalachians on the east, and Missouri, Iowa, and the eastern Dakotas on the west. The Tennessee River system in Alabama forms the apex of the triangle (Trautman, 1957; Hubbs and Lagler, 1958). Smith-Vaniz (1968) indicates the Alabama distribution to be limited to the Tennessee River system. Dahlberg and Scott (1971a, b) report introductions of smallmouth in streams of the Appalachian foothills (Coosa, Savannah, and Chattahoochee river systems) in Georgia. Since the Coosa River contributes to the Mobile Bay drainage system (Smith-Vaniz, 1968), range expansion of the smallmouth in Alabama may occur. Other introductions outside

of its normal range in North America have occurred; for example, California (Emig, 1966), and are expected to continue because of the sport value of the species.

Smallmouth bass tend to inhabit cool, flowing streams of intermediate gradient (0.75 to 4.7 m/km; 4 to 25 ft./mile) and large lakes having some current, reefs or bars, and gravel or rocky shorelines (Trautman, 1957; Emig, 1966). Thermal preferences in the field have been reported from 21 to 26.7C; a final thermal preferendum of 28C was determined for young and yearling smallmouth (Ferguson, 1958).

Mean surface temperatures (July through September) for 18 bodies of water containing smallmouth populations ranged from 17.4 to 27.8C (Coble, 1967). More recent work has established that smallmouth bass can have higher thermal preferenda. The results of recent studies (Table 5.1-2) show that smallmouth acclimated to temperatures between 20 and 33C exhibit mean thermal preferenda of from 29 to 31C with ranges of from 25 to 35C. Reynolds and Casterlin's (1976) results also show that the mean day-night preferenda for smallmouth bass were slightly higher than for largemouth bass. Cherry et al. (1977) noted that smallmouth acclimated to 27 and 30C exhibited avoidance to temperatures of 33C while those acclimated to 33C avoided temperatures of 35C; they conclude that 35C represents the seven-day upper lethal temperature for the species. Dickson et al. (1976) report collecting smallmouth bass in a thermal discharge at 35C and Wrenn (1976) reports that sonic-tagged smallmouth remained up to three days in a heated discharge at temperatures from 31 to 33.4C.

Smallmouth bass are omnivorous throughout their life span, changing generally from a zooplankton-insect diet when young to an insect-macrocrustacean-fish diet as adults. Total annual growth has been correlated with mean surface temperatures from July through September (Coble, 1967); the data are sufficiently variable, however, to indicate possible relationships with other factors, i.e., water quality, food, area, parasitism (Emig, 1966; Coble, 1967).

Spawning activity has been reported to commence at from 10 to 24C for a variety of localities (Emig, 1966; Neves, 1975). Nest sites are at variable depths up to 3.6m and tend to be in areas sheltered from direct wind or wave action; gravel or rock substrates are preferred. Developmental periods range from 10 days at 13C to 2.5 days at 25.6C. Newly hatched young remain in or near the nest for several days. Parental care of schools of fry continues until the fish reach approximately 25 mm total length, at which time the young disperse among aquatic plants (Emig, 1966).

Walleye (Stizostedion v. vitreum)—The distribution of walleye in North America incorporates an area defined by the Mackenzie River, Great Slave Lake, and Peace River system of British Columbia eastward to Hudson Bay and Labrador, south on the Atlantic slope to central North Carolina, southwest through northern Georgia, Alabama, Mississippi and northern Arkansas, and northwest through eastern Kansas, Nebraska and the central and western Dakotas to Canada (Trautman, 1957; Hubbs and Lagler, 1958). Successful introductions have been made in reservoirs in Oklahoma (Grinstead, 1971), California (Goodson, 1966), and New Mexico (Jester, 1971). Smith-Vaniz (1968) reports the species for the Tennessee River system, Mobile Ray, and Escambia drainages in Alabama. Brown (1962) reports walleye present but not common throughout central and southern Alabama in the Alabama and Tombigbee river system.

Walleye have been successfully introduced in Lakes Lanier and Hartwell and unsuccessfully in Lake Sinclair in Georgia (Dahlberg and Scott, 1971b). Cook (1959) reports several collections from counties along the Pearl River and its tributaries in southern Mississippi and in the Mississippi River, but it has never been known to occur in large numbers in the state.

Walleye tend to inhabit large lakes and streams having relatively clear water. Sustained populations are found throughout the oligotrophic-eutrophic spectrum, but walleye never become abundant in heavily vegetated bodies of water (Niemuth, et al. 1962; Goodson, 1966). Ferguson (1958) reports sustained walleye populations occurring at August (presumably maximum) temperatures of 20 to 23C; Dendy (1945) reported a preferred summer maximum temperature of 25C and Goodson (1966) reports a temperature range of 0 to 32C for sustained populations. Regier, et al. (1969) report that some resident populations tolerate water temperatures up to 30C for extended periods. Smith and Koenst (1975) report that the optimum temperature range for growth of juvenile walleye extends from 19 to 25C and estimate that zero net growth occurs above 28C. Koenst and Smith (1976) report that, for juvenile walleye acclimated to 25.8C, 100 percent survived 96-hour exposure to 31C and 10 percent survived exposure to 32C; they estimate the upper lethal temperature (96-hour TL50) to 31.6C. Investigations presently underway at the TVA-EPA cooperative Browns Ferry Biothermal Research Project have shown continued survival and growth of juvenile walleye for 58 days at temperatures exceeding 28C and ranging up to 33C.

Walleye are generally piscivorous as adults; young walleye utilize plankton and aquatic insects for a short time, but in most cases shift rapidly to fish as a food source. Early growth and survival have been associated with the timing of the supply of forage fish (Jester, 1971) in New Mexico; however, Priegel (1970) did not find a similar relationship. Growth of walleye appears to be more rapid in the warmer waters of its occurrence (Goodson, 1966), but no specific temperature data are available.

Walleye spawn in a variety of habitats (Priegel, 1970); most spawning occurs in streams or along lake shores over rocks, gravel, and sand, but Priegel (1970) noted spawning in flooded marsh and bog vegetation. Peak spawning occurs at water temperatures of about 6 to 8C; temperature ranges reported from several studies and reviewed by Priegel (1970) are 3 to 14C.

Sauger (Stizostedion canadense)--Sauger have a more limited distribution than do walleye. Trautman (1957) and Hubbs and Lagler (1958) describe their distribution as occurring from the Hudson Bay drainage to New Brunswick, southward west of the Appalachians to West Virginia; to the Tennessee River in Alabama, to eastern Oklahoma and the Red River in Texas, to eastern Kansas, Nebraska, Wyoming, and southwestern Iowa and Montana. Smith-Vaniz (1968) reports the Alabama distribution is restricted to the Tennessee River system and Cook (1959) reports sauger in the Mississippi, Tennessee, and Pearl River watersheds in Mississippi. There are no Georgia records of native sauger, but it has been introduced in the Savannah and Chattahooche rivers of the Savannah and Apalachicola drainage systems (Dahlberg and Scott, 1971a, b).

The life history of the sauger is not well known, especially in terms of thermal preferences. Sauger are most commonly found in large lakes, rivers, and reservoirs. Dendy (1945) reported a thermal preference of 19.5C based on field studies in Norris Reservoir, Tennessee; Gammon (1970, 1973) reported a summer range of preferred temperatures of 22 to 28C in the Wabash River.

In the latter studies, sauger showed a clear avoidance of temperatures present in the mixing zone of a steam plant discharge (30 to 34C); the maximum temperature in which sauger were caught was 29C.

Koenst and Smith (1976) report that optimum growth of juvenile sauger occurred at 22C. For juveniles acclimated at 23.9 and 25.8C, 87.5 percent survived 96-hour exposure to 30C, but none survived exposure to 31C (although 12.5 percent of those acclimated to 19.9 and 22C did); the upper lethal temperature (96-hour TL50) was estimated to be 30.4C (Koenst and Smith, 1976). Yoder and Gamon (1976) noted that sauger avoided the heated effluent of a power plant (temperatures of approximately 33 to 37C) but were caught in large numbers in the discharge zone during the winter when effluent temperatures were 8 to 12C (vs 4C ambient). Teppen and Gamon (1976) noted declines in sauger abundance immediately below three power plants on the Wabash River.

Sauger are essentially piscivorous after their first year of life. Habitat preferences are poorly known, but sauger are generally regarded to be open-water species. In main stream reservoirs, sauger appear to be most common in the upper reaches including the tailwaters. Spawning occurs over gravel or rubble substrate in tailwaters, tributaries, and over reefs at water temperatures of 6 to 12C (Priegel, 1969).

5.1.1 Distribution and Occurrence of Smallmouth Bass, Walleye, and Sauger

Fish populations have been sampled quarterly since autumn, 1968, at three locations in the reservoir. Additionally, rotenone samples, larval fish samples, and creel censuses have been performed on an annual basis. In terms of thermal effects, only the area from the plant site (TRM 294) downstream to Wheeler Dam (TRM 275) is of concern. Table 5.1-3 summarizes catch statistics for the three species in gill nets fished immediately downstream from the plant diffuser discharge (Station 1, TRM 293). While walleye did not occur in this area, walleye were caught twice in samples taken directly across the reservoir from the plant site (Station 3); in autumn, 1970, one walleye was taken in 39 net-nights; in summer, 1972, two walleyes were taken in 34 net-nights of effort; in autumn, 1972, one walleye was taken in 40 net nights of effort. During the operational period, one walleye was taken at Station 1 in 1974 and one was taken at Station 3 in 1976 (Table 5.1-4).

Smallmouth occurred only in the autumn and spring quarters during the preoperational period; a similar pattern has been noted since plant startup Table 5.1-4. Sauger occurred more regularly, albeit at low numbers in the preoperational period (Table 5.1-3) and occurred most frequently in the autumn and spring quarters; their abundance and frequency of occurrence since commencement of plant operation has increased (Table 5.1-4). The pattern of increasing abundance at all stations (Table 5.1-4) agrees with creel census data (Table 5.1-9) and standing stock biomass data (Table 5.1-5) and indicates that the sauger population in Wheeler Reservoir has increased in recent years.

Standing stock data indicate that smallmouth bass reproduction (as estimated by numbers/ha of young fish in the samples) has decreased sharply since 1971 in two of three coves sampled consistently since 1969 (Table 5.1-6); this decrease appears to be translated into decreased angler harvest (see Table 5.1-10). The reason for the decline are not known; low levels of reproductive success at all three standard coves in 1973 may have resulted from spring floods. The long-term effects of flooding, e.g., siltation or other destruction of spawning habitat, would be expected to be more severe in the coves at TRM 286 and ERM 2.7; these coves would be more directly exposed to high river flows than would the cove at TRM 275, which is located on an embayment. In addition, the cove at TRM 286 is located in a county park; the decrease noted here may partly be due to increased boat traffic and other human activity.

Total, clupeid, and nonclupeid standing stock biomass (Tables 5.1-7 and 5.1-8) show a similar depression in 1973; however, these values have generally increased since 1973 while smallmouth young have increased only at TRM 275.

In contrast to smallmouth, standing stocks of sauger appear to have generally increased for all three age/size groups since 1971 (Table 5.1-5) except in the Elk River. This increase agrees with the increased catch by anglers (Table 5.1-11) and in gill net samples (Table5.1-4). Walleye have not been taken in cove samples in Wheeler Reservoir since 1954.

.1.2 Angler harvest of smallmouth bass, walleye, and sauger

Table 5.1-9 presents estimated angler harvest of sauger, based on a continuous, roving-clerk creel census. Sauger harvest in the areas censused (Figure 5.1-1) is largely concentrated above the plant (areas 1-1, and 1-2, 38 percent of total catch) and in the area below the plant (area 3-1, 31 percent). Area 2-1, which includes the plant and mixing zone, yielded 16 percent of the sauger catch. No census data are available for the tailwater fishery at Guntersville Dam, located approximately 30 river miles (48 km) upstream from the plant; the tailwater fishery is highly seasonal and limited to the spawning run (December-February).

The sauger fishery in the main pool of Wheeler Reservoir appears to be a recent development; prior to 1974, the creel census reported only harvests of 28 sauger in the spring of 1972 and 21 sauger in the autumn of 1970 (Table 5.1-11). Catches of sauger in Chickamauga (approximately 125 mi or 200 km upstream) have shown the same general increasing trend since 1972 as do those in Wheeler; the magnitude of the catch in Chickamauga is, however, significantly greater than for Wheeler (1974, 4,700 vs. 237; 1975, 3,500 vs. 388).

Walleye appear only once (1970--Table 5.1-11) in the Wheeler creel census and only rarely in the harvest from Chickamauga (68 in 1972; 137 in 1974). It appears that walleye are generally not actively sought, but rather are accidental captures.

Table 5.1-10 presents estimated harvest data for smallmouth bass. Of the smallmouth harvested, 45 percent were taken in area 3-2, 27 percent in area 4-1 (Elk River), 21 percent in area 3-1, and 7 percent in area 2-1. The concentration of harvest in the lower sections of the reservoir (and Elk River) reflects the distribution of preferred habitat of the species, e.g., rock bluffs, sunken logs, and gravel or rubble substrate.

Since 1970, the harvest of smallmouth has declined appreciably, except for an unusually high harvest in March, 1973 (Table 5.1-11). A similar decline has been noted for Chickamauga Reservoir where harvest has been estimated at 4,300, 100, 160, and 360 for the years 1972-1975, respectively. The reasons for the decline are not known. Plant operation does not appear to be a factor. For three comparable seasonal periods (summer, fall, and winter) in 1974-1975 and 1975-1976, the harvest for Wheeler was 556 during startup and operation of units 1 and 2 and 599 after plant shutdown (see Table 5.1-11).

Angler harvest (all species) from Wheeler Reservoir has been highly variable and has generally declined since 1972; a similar but more regular pattern of decline has been noted for Chickamauga:

ESTIMATED HARVEST--THOUSANDS

	1970	1971	1972	1973	1974	1975
Wheeler	153	392	550	340	195	286
Chickamauga			289	245	205	185

5.2 Plankton and Benthos

5.2.1 Sampling Program

5.2.1.1 Program Description

A nonfisheries biological monitoring program was initiated at the Browns Ferry Nuclear Plant in 1969. Data were and are being collected for the phytoplankton, zooplankton, and benthic macroinvertebrate communities once each quarter at the following locations: (1) Control Stations - TRM 307.52, TRM 301.06, TRM 295.87, and (2) Experimental Stations - TRM 293.70, TRM 291.76, TRM 288.78, TRM 283.94, and TRM 277.98.

5.2.1.2 Materials and Methods

The nonfisheries biological monitoring program is described in the Browns Ferry Nuclear Plant Environmental Technical Specifications. The monitoring program was designed to determine the effect of the thermal effluent on the reservoir standing crops of phytoplankton, zooplankton, and benthic macroinvertebrates by comparing population parameters at experimental stations with that for control stations.

5.2.1.3 Results and Discussions

The data compiled since 1969 has been summarized in the following reports:

* Tennessee Valley Authority. Water Quality and Biological Conditions in Wheeler Reservoir Before Operation of Browns Ferry Nuclear Plant - 1968-1973. Chattanooga, Tennessee, March 1974. Report No. M-WQ-74-1-BF-1.

○ Tennessee Valley Authority. *Water Quality and Biological Conditions in Wheeler Reservoir During Operation of Browns Ferry Nuclear Plant (Unit 1), August 17, 1973-February 17, 1974*. Chattanooga, Tennessee, April 1, 1974. Report No. M-WQ-74-2-BF-2.

○ Tennessee Valley Authority. *Water Quality and Biological Conditions in Wheeler Reservoir During Operation of Browns Ferry Nuclear Plant (Unit 1), February 18, 1974-* June 30, 1974. Chattanooga, Tennessee, August 15, 1974. Report No. M-WQ-74-3-BF-3.

○ Tennessee Valley Authority. *Water Quality and Biological Conditions in Wheeler Reservoir During Operation of Browns Ferry Nuclear Plant (Units 1 and 2), July 1, 1974-December 31, 1974*. Chattanooga, Tennessee, February 5, 1975. Report No. M-WQ-75-1-BF-4.

○ Tennessee Valley Authority. *Water Quality and Biological Conditions in Wheeler Reservoir During Operation of Browns Ferry Nuclear Plant (Units 1 and 2), January 1, 1975-June 30, 1975*. Chattanooga, Tennessee, August 5, 1975. Report No. M-WQ-75-2-BF-5.

○ Tennessee Valley Authority. *Water Quality and Biological Conditions in Wheeler Reservoir During Operation of Browns Ferry Nuclear Plant (Units 1 and 2), July 1, 1975-* December 31, 1975. Chattanooga, Tennessee, Feb. 12, 1976. Report No. M-WQ-76-1-BF-6.

° Tennessee Valley Authority. Water Quality and Biological Conditions in Wheeler Reservoir During Operation of Browns Ferry Nuclear Plant, January 1, 1976, December 31, 1976. Chattanooga, Tennessee, March 1977. Report No. M-EAC-77-01.

These data are summarized and discussed briefly for the three major aquatic communities (i.e. phytoplankton, zooplankton, and benthic macroinvertebrates).

Phytoplankton

The phytoplankton assemblage is diverse (Table 5.2-1) in Wheeler Reservoir with 27 Chrysophyta, 52 Chlorophyta, and 17 Cyanophyta taxa being documented. The percent composition of the three major phytoplankton groups during the summer quarter at the various stations is presented in Table 5.2-2. These data illustrate that blue-green algae (Cyanophyta) do become the dominant (50 percent of the standing crop) group of phytoplankton in Wheeler Reservoir. However, this dominance occurred both upstream and downstream of Browns Ferry Nuclear Plant and also occurred prior to commercial operation of the nuclear plant. Water temperatures at the 1-M depth for the sampling dates are presented in Table 5.2-3.

Estimates of the phytoplankton standing crop from 1969 through 1976 are presented in Table 5.2-4. The average standing crop estimates during the five-year preoperational phase indicate that the number of algae cells increases in the downstream reaches of Wheeler Reservoir. Likewise, the

data for the operational phase exhibits the same trend; however, the average standing crop estimates for this period are considerably higher than those values from the preoperational period. It should be noted that the estimates for the control stations were quite similar.

The biomass of the phytoplankton community was determined indirectly from the Chlorophyll a content of the cells (Table 5.2-5). As with the standing crop, estimates of the biomass increased in the lower reaches of Wheeler Reservoir. Chlorophyll a biomass levels, also, exhibited the same relationship between the preoperational and operational periods as did the standing crop estimates.

With both phytoplankton standing crop estimates and Chlorophyll a biomass values exhibiting the same trends, it is not surprising to note that primary productivity also followed the same general trend (Table 5.2-6). However, the magnitude of the variation between the preoperational and operational phases is not as large as with the standing crop or Chlorophyll a biomass.

Evaluation of the phytoplankton data indicates that there is a difference (because of the variability within the data set no statistically significant differences can be demonstrated) between the preoperational (1969-1973) and operational (1974-1976) years. There were no discernable alterations to the composition of the phytoplankton assemblage (i.e., blue-green algae did not tend to comprise a greater percentage of the flora and blue-greens were dominant, also, at one or more of the control stations). However, a consistent increase was documented in standing crop, Chlorophyll a biomass, and primary productivity estimates. These increases are not attributable to the thermal effluent from the Browns Ferry Nuclear Plant since they occurred during periods (summer 1975 and 1976) termed operational; when the plant was not actually operating (i.e., generating electricity and discharging heated water). The data for 1974 were intermediate to the preoperational and the 1975-1976 data; hence, the operation of one unit at Browns Ferry Nuclear Plant did not affect the phytoplankton community.

Zooplankton

The zooplankton assemblage is diverse (Table 5.2-7) in Wheeler Reservoir with 32 Cladocera, 24 Copepoda, and 47 Rotifera taxa represented. There is a distinct increase in the number of zooplankton per unit volume in the lower reaches of Wheeler Reservoir (Table 5.2-8). This increase parallels the pattern described for the phytoplankton in that the zooplankton populations for 1974 were intermediate to those of the preoperational and 1975-1976 levels. This suggests that one unit operation of Browns Ferry Nuclear Plant does not preclude the maintenance of a balanced and indigenous zooplankton community in Wheeler Reservoir.

Benthic Macroinvertebrates

The benthic macroinvertebrate community is not overly diverse (Table 5.2-9), but is characteristic of other mainstream Tennessee River impoundments. This type of fauna is typically associated with fine textured sediments with varying levels of organic detritus incorporated into the substrates. The macroinvertebrates have been grouped into four categories for discussion purposes (i.r., Hexagenia, Corbicula, Chironomid midges, and Oligochaetes).

The burrowing mayfly, Hexagenia bilineata, inhabits soft sediments. This type of habitat is not usually encountered at TRM 301.06 and TRM 307.52 (Table 5.2-10); hence, the reduced population levels reflect lack of habitat. The largest populations (based on average population estimates) were documented immediately downstream of the Browns Ferry Nuclear Plant thermal discharge. This population distribution was noted for both the preoperational and the operational phases.

Concern has been expressed about the potential effects of thermal plume entrainment on drifting aquatic macroinvertebrates and the eggs of aquatic insects, especially H. bilenata. Plume drift studies at Cumberland Steam Plant on Lake Barkley demonstrated that nymphs of H. bilineata could survive drifting for prolonged periods (up to 4.5 hours) at temperatures of 34.8°C (94.6°F) and higher. Recent laboratory studies have documented the H. bilineata eggs will develop and hatch at 34°C (93.2°F)

(Tennessen, Personal communication). From these data and the population characteristics it can be concluded that the thermal effluent from Browns Ferry does not affect the H. bilineata population.

Corbicula manilensis, the Asiatic clam, with the exception of a short initial semiplanktonic stage is fairly sedentary and provides an avenue for studying long-term effects. The maximum populations of C. manilensis were documented within the immediate vicinity of the Browns Ferry Nuclear Plant (Table 5.2-11). This distributional pattern closely parallels that of H. bilineata. Since C. manilensis exhibits a contagious distribution the variations between the preoperational and operational phases hold no significance. These data indicate that the thermal effluent from Browns Ferry is not affecting the C. manilensis population.

Chironomid midges, depending upon the species, may have two or more complete life cycles during a summer period. Hence, chironomid populations are subject to marked natural variations. There is a very similar population distribution between the preoperational and the operational phases of the monitoring program (Table 5.2-12). As with the two previous benthic macroinvertebrate populations, the data indicate that the thermal effluent from Browns Ferry Nuclear Plant is not affecting the chironomid midge population.

Aquatic oligochaetes, depending upon the taxon and the abundance, can be classified as nuisance species and/or as indicators of organic pollution. Even though the population numbers have increased (Table 5.2-13) since commercial operation was initiated, the continued abundance of other species and the fact that only a few hundred feet of the bottom habitat is actually contacted by the thermal effluent suggests that the increase occurred coincidentally with the start of commercial operation. Hence, it can be deduced from these data that the thermal effluent from Browns Ferry Nuclear Plant is not affecting the oligochaetes populations.

The available benthic macroinvertebrate data suggest that the operation of the Browns Ferry Nuclear Plant during 1974 did not affect the maintenance of a balanced and indigenous benthic macroinvertebrate community.

Table 5.1-1

Common and Scientific Names* of Fishes taken in Preoperational Sampling, Wheeler Reservoir, 1969-1972.

Common Name	Scientific Name	Group**	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Paddlefish	*Polyodon spathula*	R		X	X		
Spotted gar	*Lepisosteus oculatus*	R	X	X	X		
Longnose gar	*Lepisosteus osseus*	R	X	X	X	X	X
Shortnose gar	*Lepisosteus platostomus*	R	X		X		
Skipjack herring	*Alosa chrysochloris*	R	X	X	X	X	X
Gizzard shad	*Dorosoma cepedianum*	F	X	X	X		X
Threadfin shad	*Dorosoma petenense*	F	X	X	X	X	X
Mooneye	*Hiodon tergisus*	R	X	X	X		X
Stoneroller	*Campostoma anomalum*	F	X				
Goldfish	*Carassius auratus*	R		X	X		
Carp	*Cyprinus carpio*	R	X	X	X	X	X
Bigeyed chub	*Hybopsis amblops*	F	X				
Silver chub	*Hybopsis storeriana*	F					X
Golden shiner	*Notemigonas crysoleucas*	F	X	X	X		

*Taken from *Common and Scientific Names of Fishes*, American Fisheries Society Special Publication No. 6 Third Edition, 1970.

**Indicates forage, rough, or game as arbitrarily indicated for TVA waters.

Table 5.1-1 (continued) (page 2 of 4 pages)

Common and Scientific Names of Fishes taken in Preoperational Sampling, Wheeler Reservoir, 1969-1972.

Common Name	Scientific Name	Group	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Emerald shiner	*Notropis atherinoides*	F	X				X
Spotfin shiner	*Notropis spilopterus*	F	X				X
Bluntnose minnow	*Pimephales notatus*	F	X				
Bullhead minnow	*Pimephales vigilax*	F					X
River carpsucker	*Carpiodes carpio*	R		X	X		
Creek chubsucker	*Erimyzon oblongus*	F	X				
Northern hog sucker	*Hypentelium nigricans*	R	X	X	X		
Smallmouth buffalo	*Ictiobus bubalus*	R	X	X	X	X	X*
Bigmouth buffalo	*Ictiobus cyprinellus*	R	X	X			
Black buffalo	*Ictiobus niger*	R				X	
Spotted sucker	*Minytrema melanops*	R	X	X	X	X	
Silver redhorse	*Moxostoma anisurum*	R			X		
River redhorse	*Moxostoma carinatum*	R	X	X	X		
Black redhorse	*Moxostoma duquesnei*	R	X		X		
Golden redhorse	*Moxostoma erythrurum*	R	X	X	X	X	

**Ictiobus* sp. - larval fish; species not known.

Table 5.1-1 (continued) (page 3 of 4 pages)

Common and Scientific Names of Fishes taken in Preoperational Sampling, Wheeler Reservoir, 1969-1972.

Common Name	Scientific Name	Group	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Shorthead redhorse	*Moxostoma macrolepidotum*	R	X		X		
Blue catfish	*Ictalurus furcatus*	R		X	X	X	X
Black bullhead	*Ictalurus melas*	R	X	X	X		
Yellow bullhead	*Ictalurus natalis*	R		X		X	
Brown bullhead	*Ictalurus nebulosus*	R		X	X		
Channel catfish	*Ictalurus punctatus*	R	X	X	X	X	X
Madtom	*Noturus* sp.	F	X				
Flathead catfish	*Pylodictis olivaris*	R	X	X	X	X	X
Blackstripe topminnow	*Fundulus notatus*	F	X				
Mosquitofish	*Gambusia affinis*	F	X				
Brook Silverside	*Labidesthes sicculus*	F	X				X
White bass	*Morone chrysops*	G	X	X	X	X	X
Yellow bass	*Morone mississippiensis*	G	X	X	X	X	X
Rock bass	*Ambloplites rupestris*	G	X			X	
Green sunfish	*Lepomis cyanellus*	G	X			X	

Table 5.1-1 (continued) (page 4 of 4 pages)

Common and Scientific Names of Fishes taken in Preoperational Sampling, Wheeler Reservoir, 1969-1972.

Common Name	Scientific Name	Group	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Warmouth	*Lepomis gulosus*	G	X	X	X	X	
Orangespotted sunfish	*Lepomis humilis*	F	X				
Bluegill	*Lepomis macrochirus*	G	X	X	X	X	X
Longear sunfish	*Lepomis megalotis*	G	X	X	X	X	X
Redear sunfish	*Lepomis microlophus*	G	X	X	X	X	
Smallmouth bass	*Micropterus dolomieui*	G	X	X	X	X	X
Spotted bass	*Micropterus punctulatus*	G	X	X	X	X	
Largemouth bass	*Micropterus salmoides*	G	X	X	X	X	X
White crappie	*Pomoxis annularis*	G	X	X	X	X	X
Black crappie	*Pomoxis nigromaculatus*	G	X	X	X	X	
Darter	*Etheostoma* sp.	F					X
Logperch	*Percina caprodes*	F	X				X
Sauger	*Stizostedion canadense*	G	X	X	X	X	
Walleye	*Stizostedion vitreum vitreum*	G		X	X	X	
Freshwater drum	*Aplodinotus grunniens*	R	X	X	X	X	X

Table 5.1-2 Thermal preferenda of smallmouth bass obtained from three recent investigations.

Acclimation temperature, C	20-24	27	30	33
Preferred temperature				
Mean	30.4 day (1) 29.8 night (1)	30.1 (2) 29.7 (3)	31.3 (2) 30.9 (3)	29.4 (3)
Range	26.7-34.4 day (1) 25.6-33.9 night (1)			
95% confidence limits		28.3-32.2 (2) 26.7-30.6 (3)	29.9-35.1 (2) 27.7-32.6 (3)	28.5-34.8 (3)

References: (1) Reynolds & Casterlin, 1976; (2) Cherry et al., 1975; and (3) Cherry et al., 1977.

Tab[illegible]6.1-3 Summary of catch (N) and catch per unit o[illegible]ffort (c/f) for smallmouth bass, walleye, and sauger during preoperational monitoring, Browns Ferry Nuclear Plant. Data are from gill net catches at Station 1, TRM 293.

Year	Species[1]	Autumn		Winter		Spring		Summer	
		N	c/f	N	c/f	N	c/f	N	c/f
1968-69	SMB	-	-	-	-	-	-	-	-
	W	-	-	-	-	-	-	-	-
	S	6	0.20	2	0.05	5	0.13	3	0.08
1969-70	SMB	4	0.10	-	-	1	0.03	-	-
	W	-	-	-	-	-	-	-	-
	S	8	0.20	-	-	3	0.08	4	0.10
1970-71	SMB	3	0.08	-	-	-	-	-	-
	W	-	-	-	-	-	-	-	-
	S	2	0.05	4	0.10	-	-	-	-
1971-72	SMB	-	-	-	-	2	0.05	-	-
	W	-	-	-	-	-	-	-	-
	S	2	0.05	4	0.10	-	-	-	-
1972-73	SMB	-	-	-	-	-	-	-	-
	W	No Data	-	-	-	-	-	-	-
	S	-	-	-	-	-	-	1	0.03
1973-74	SMB	2	0.05	-	-	1	0.03	-	-
	W	-	-	-	-	-	-	-	-
	S	7	0.18	-	-	2	0.05	-	-

[1] SMB = smallmouth bass, Micropterus dolomieui
W = walleye, Stizostedion v. vitreum
S = sauger, S. canadense

Table 5-1-4 Catch per unit of effort for smallmouth bas[illegible]SMB), sauger (S), and walleye (W), and total fi[illegible] catch from gill nets during the operational period, Browns Ferry Nuclear Plant.

Winter						Summer					
Station	Year	SMB	S	W	Total	Station	Year	SMB	S	W	Total
1	74		-		418	1	74	-	0.05		606
	75		-		308		75	-	0.11		735
	76		0.65		253		76	-	0.28		897
2	74		0.08		231	2	74	-	-		85
	75		No Samples		-		75	-	0.08		114
	76		0.93		433		76	0.03	0.36		179
3	74		0.05		292	3	74	-	0.03		643
	75		0.49		414		75	-	0.18		1,111
	76		0.05		151		76	-	0.65		990

Spring						Autumn					
Station	Year	SMB	S	W	Total	Station	Year	SMB	S	W	Total
1	74	0.03	0.05		985	1	74	0.05	0.25	-	342
	75	-	0.11		997		75	-	0.63	-	268
	76	-	0.78		1,344		76	-	2.08	0.03	486
2	74	-	0.03		164	2	74		0.28	-	129
	75	-	0.18		405		75		0.98	-	273
	76	-	0.35		835		76		1.18	-	323
3	74	-	0.03		686	3	74		0.70	0.03	822
	75	-	0.40		423		75		0.05	-	475
	76	-	1.23		829		76		3.45	-	610

1/ Station 1 - TRM 293
2 - TRM 299
3 - TRM 294

Table 5.1-5 Numbers (N) and biomass (kg) of sauger and walleye per hectare taken in cove-rotenone samples, Wheeler Reservoir. YOY = young of year (<200 mm TL); I = intermediate (200-300 mm); H = harvestable (>300 mm). Coves at TRM 275, 286, and ERM (Elk River) 2.7 are standard sampling coves for preoperational and operational monitoring.

Location	Year	Sauger - YOY		I		H	
		N	kg	N	kg	N	kg
TRM 275*	1961	-	-	3	0.14	-	-
	1970	5	0.13	-	-	-	-
	1971	-	-	1	0.29	-	-
	1972	5	0.35	-	-	-	-
	1973	16	0.60	-	-	-	-
	1974	5	0.15	-	-	1	0.21
	1975	14	0.37	5	0.62	1	0.11
	1976	6	0.31	5	0.88	-	-
TRM 278	1950	3	0.13	3	0.27	-	-
	1951	9	0.34	1	0.04	-	-
	1952	-	-	3	0.49	1	0.32
	1953	2	0.11	1	0.13	1	0.38
	1954	2	0.09	14	1.69	4	1.66
TRM 279	1956	-	-	2	0.32	-	-
TRM 280	1976	2	0.12	14	2.05	-	-
TRM 286	1969	1	0.03	-	-	-	-
	1970	18	0.69	-	-	-	-
	1971	-	-	-	-	-	-
	1972	1	0.03	1	0.05	-	-
	1973	9	0.30	-	-	1	0.17
	1974	8	0.16	1	0.12	1	0.28
	1975	27	0.74	10	1.56	-	-
	1976	21	0.99	24	2.48	7	2.45
TRM 294	1973	5	0.18	-	-	-	-

Table 5.1-5 (continued)

		Sauger - YOY		I		H	
Location	Year	N	kg	N	kg	N	kg
ERM 2.7*	1974	5	0.17	-	-	-	-
	1975	3	0.06	5	0.59	-	-
	1976	-	-	8	0.77	2	0.60
ERM 7.2	1955	5	0.20	3	0.25	-	-
	1956	-	-	3	0.41	-	-
		Walleye - YOY		I		H	
		N	kg	N	kg	N	kg
TRM 278	1951	-	-	1	0.08	-	-
	1952	-	-	-	-	-	-
	1953	-	-	-	-	-	-
	1954	-	-	3	0.34	-	-

*No sauger taken in 1969 at TRM 275 and in 1969 through 1973 at ERM 2.7.

Table 5.1-6 Number (N) and biomass (kg) of smallmouth bass per hectare taken in cove-rotenone samples, Wheeler Reservoir. YOY = young of year (<125 mm TL); I = intermediate (125-200 mm); H = harvestable (>200 mm). Coves at TRM 275, 286, and ERM (Elk River) 2.7 are standard sampling coves for preoperational and operational monitoring.

Location	Year	YOY		I		H	
		N	kg	N	kg	N	kg
TRM 275	1961	108	0.41	23	1.70	-	-
	1969	112	0.29	45	2.91	21	4.63
	1970	95	0.36	19	1.02	12	4.66
	1971	85	0.86	32	1.35	32	18.69
	1972	80	0.64	31	2.56	17	3.39
	1973	36	0.41	7	0.57	8	1.34
	1974	146	0.87	11	0.69	6	0.85
	1975	84	0.68	11	0.67	3	0.87
	1976	108	1.46	19	0.91	24	3.35
TRM 278	1949	47	0.39	13	0.46	3	0.78
	1950	28	0.30	6	0.19	7	3.12
	1951	14	0.11	2	0.05	6	4.51
	1952	42	0.43	44	2.01	2	0.37
	1953	27	0.34	16	0.65	12	2.18
	1954	18	0.23	44	1.62	9	2.00
TRM 279	1956	16	0.20	28	0.95	4	0.76
TRM 286	1969	149	0.32	58	0.53	29	1.03
	1970	86	0.15	13	0.55	2	0.38
	1971	135	1.13	83	2.36	5	0.71
	1972	8	0.05	1	0.09	1	0.18
	1973	1	0.01	-	-	-	-
	1974	1	0.01	-	-	-	-
	1975	3	0.04	-	-	-	-
	1976	7	0.10	1	0.03	7	1.13
TRM 293	1969	27	0.38	26	0.54	9	2.93
TRM 294	1973	-	-	-	-	24	4.42

Table 5.1-6 (Continued)

Location	Year	YOY		I		H	
		N	kg	N	kg	N	kg
ERM 27 (Elk River)	1969	25	0.26	2	0.04	13	1.98
	1970	20	0.21	2	0.23	-	-
	1971	141	1.31	38	1.01	6	0.99
	1972	9	0.10	9	0.75	11	1.61
	1973	-	-	-	-	-	-
	1974	16	0.13	-	-	-	-
	1975	9	0.10	3	0.18	3	0.35
	1976	—	—	—	—	—	—

Table 5.1-7 Total clupeid and nonclupeid standing stock biomass (kg/ha) estimated by cove-rotenone samples, Wheeler Reservoir.

Location	Year	Total	Clupeid	Nonclupeid
TRM 275	1961	190	16	174
	1969	965	588	377
	1970	1,107	574	533
	1971	727	258	469
	1972	1,181	830	351
	1973	280	123	157
	1974	208	110	98
	1975	266	73	193
	1976	460	94	366
TRM 278	1949	203	89	114
	1950	296	230	66
	1951	115	28	88
	1952	218	97	121
	1953	262	98	164
	1954	330	115	215
TRM 279	1956	203	172	31
TRM 280	1976	733	343	390
TRM 286	1969	441	155	286
	1970	759	496	263
	1971	569	284	285
	1972	561	284	277
	1973	292	80	212
	1974	505	447	58
	1975	287	153	134
	1976	1,635	1,400	235
TRM 293	1969	1,534	1,139	395
TRM 294	1973	333	63	270
TRM 339.2	1961	242	28	214
ERM 2.7 (Elk River)	1969	1,091	401	690
	1970	599	71	528
	1971	543	108	435
	1972	457	184	273
	1973	364	73	291
	1974	381	93	288
	1975	405	54	351
	1976	456	60	396

Table 5.1-7 (Continued)

Location	Year	Total	Clupeid	Nonclupeid
ERM 7.2	1955	369	110	259
	1956	664	413	251
	1957	697	330	367
	1958	745	259	486
	1959	642	315	327
	1960	1,149	604	545
	1961	388	44	345

Table 5.1-8 Means and standard error (SE) of total, clupeid and nonclupeid standing stock biomass (kg/ha) estimated by cove-rotenone samples, Wheeler Reservoir, 1949-1961 and 1969-1976. N = number of coves sampled.

Year	N	Total	SE	Clupeid	SE	Nonclupeid	SE
1949	1	203	-	89	-	114	-
1950	1	296	-	230	-	66	-
1951	1	115	-	28	-	88	-
1952	1	219	-	97	-	121	-
1953	1	262	-	98	-	164	-
1954	1	330	-	115	-	215	-
1955	1	369	-	110	-	259	-
1956	2	434	230	293	120	141	110
1957	1	697	-	330	-	367	-
1958	1	745	-	259	-	486	-
1959	1	642	-	315	-	327	-
1960	1	1,149	-	604	-	545	-
1961	3	273	59	30	8	244	51
1969	4	1,008	225	571	209	437	87
1970	3	822	150	380	156	441	89
1971	3	613	58	217	55	396	57
1972	3	733	226	433	201	300	25
1973	4	299	34	81	10	218	43
1974	3	365	86	217	115	148	71
1975	3	319	43	93	30	226	64
1976	4	821	279	474	315	347	38

Table 5.1-9 Estimated sauger sport fishing harvest by area, Wheeler Reservoir, April 1973 through June 1976.

Season		Areas 1-1 and 1-2		Area 2-1		Area 3-1		Area 3-2		Area 4-1		Totals	
		No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.
1973	Apr - June	-	-	-	-	-	-	-	-	-	-	-	-
	July - Aug	-	-	-	-	-	-	-	-	-	-	-	-
	Sept - Dec	-	-	-	-	-	-	-	-	-	-	-	-
1974	Jan - Mar	-	-	-	-	-	-	-	-	-	-	-	-
	Apr - June	-	-	-	-	-	-	-	-	-	-	-	-
	July - Aug[1]	39	31	18	13	82	62	14	11	-	-	153	117
	Sept - Dec	84	42	-	-	-	-	-	-	-	-	84	42
1975	Jan - Mar[2]	-	-	-	-	-	-	-	-	-	-	-	-
	Apr - June[3]	91	54	28	19	88	71	51	10	78	102	336	256
	July - Aug[3]	-	-	-	-	-	-	-	-	-	-	-	-
	Sept - Dec[3]	52	42	-	-	-	-	-	-	-	-	52	42
1976	Jan - Mar[3]	-	-	-	-	-	-	-	-	-	-	-	-
	Apr - June[3]	77	115	99	107	110	27	-	-	-	-	286	249

1. Startup, Unit 1.
2. Startup, Unit 2.
3. Plant not operating.

Table 5.1-10 Estimated smallmouth fishing harvest by area, Wheeler Reservoir, April 1973 through June 1976.

Season		Areas 1-1 and 1-2		Area 2-1		Area 3-1		Area 3-2		Area 4-1		Totals	
		No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.
1973	Apr - June	-	-	52	-[1]	620	457	429	149	34	24	1,135	630
	July - Aug	-	-	139	93	69	53	310	246	98	68	616	460
	Sept - Dec	-	-	-	-	-	-	-	-	-	-	-	-
1974	Jan - Mar	-	-	-	-	-	-	34	60	51	56	85	116
	Apr - June	-	-	-	-	-	-	333	639	24	62	357	701
	July - Aug[2]	-	-	-	-	-	-	47	88	65	80	112	168
	Sept - Dec	-	-	9	9	36	62	32	45	37	52	114	168
1975	Jan - Mar[3]	-	-	-	-	-	-	209	197	121	60	330	257
	Apr - June[4]	-	-	77	54	101	60	90	36	126	75	394	225
	July - Aug[4]	28	17	-	-	57	40	26	118	240	96	351	271
	Sept - Dec[4]	-	-	-	-	-	-	68	37	-	-	68	37
1976	Jan - Mar[4]	10	10	10	5	-	-	20	20	140	182	180	217
	Apr - June[4]	-	-	23	36	31	31	338	509	219	311	611	887

1. Missing data.
2. Startup, Unit 1.
3. Startup, Unit 2.
4. Plant not operating.

Table 5. 11 Estimated smallmouth bass, sauger, and walleye sport-fishing harvest, Wheeler Reservoir, July 1970 through June 1976.

Season		Smallmouth Bass		Sauger		Walleye	
		No.	lb.	No.	lb.	No.	lb.
1970	S	6,424	4,537	–	–	–	–
	F	4,674	4,700	21	8	48	37
1971	W	101	133	–	–	–	–
	S	2,505	2,580	–	–	–	–
	S	2,614	2,579	–	–	–	–
	F	268	281	–	–	–	–
1972	W	638	493	–	–	–	–
	S	2,279	1,937	28	28	–	–
	S	850	852	–	–	–	–
	F	156	85	–	–	–	–
1973	W[1]	5,304	2,061	–	–	–	–
	S	1,135	630	–	–	–	–
	S	616	460	–	–	–	–
	F	–	–	–	–	–	–
1974	W	85	116	–	–	–	–
	S	357	701	–	–	–	–
	S[2]	112	168	153	117	–	–
	F	114	168	84	42	–	–
1975	W[3]	330	257	–	–	–	–
	S[4]	394	225	336	256	–	–
	S[4]	351	271	–	–	–	–
	F[4]	68	37	52	42	–	–
1976	W[4]	180	217	–	–	–	–
	S[4]	611	887	286	249	–	–
Total		30,166	24,375	960	742	48	37

---

1. Ninety-eight percent of the smallmouth caught during the season were taken in March.
2. Startup, Unit 1.
3. Startup, Unit 2.
4. Plant not operating.

Table 5.2-1

LIST OF PHYTOPLANKTON GENERA COLLECTED IN WHEELER RESERVOIR

FROM 1969-1976 DURING THE SUMMER SEASON

CHRYSOPHYTA

- Actinella
- Achnanthes
- Asterionella
- Attheya
- Caloneis
- Chaetoceros
- Cocconeis
- Cyclotella
- Cymbella
- Denticula
- Diatoma
- Dinobryon
- Eunotia
- Fragilaria
- Gomphonema
- Gyrosigma
- Mallomonas
- Melosira
- Navicula
- Nitzschia
- Ophiocytium
- Pinnularia
- Pyrobotrys
- Rhizosolenia
- Stephanodiscus
- Surirella
- Synedra

CHLOROPHYTA

- Actinastrum
- Ankistrudesmus
- Arthrodesmus
- Acanthosphaeria
- Botryococcus
- Carteria
- Chlamydomonas
- Chlorella
- Chodatella
- Chlorococcum
- Closteridium
- Closteriopsis
- Coelastrum
- Cosmarium
- Crucigenia
- Cryptomonas
- Dactylococcus
- Dictyosphaerium
- Elkatothrix
- Euastrum
- Eudurnia
- Gloedactinium
- Gloeocystis
- Golenkinia
- Gonium
- Kirchneriella
- Micractinium
- Oocystis
- Pandornia
- Pediastrum
- Planktosphaeria
- Platydornia
- Pleodornia
- Polyedriopsis
- Protococcus
- Protoderma
- Pteromonas
- Quadrigula
- Scenedesmus
- Selenastrum
- Schroederia
- Staurastrum
- Sphaerocystis
- Tetradesmus
- Tetraedron
- Tetrallantos
- Tetraspora
- Tetrastrum
- Treubaria
- Trochiscia
- Ulothrix
- Vorticella

CYANOPHYTA

- Anacystis
- Anabaena
- Anabaenopsis
- Aphandcapsa
- Aphanizomenon
- Arthrospira
- Chroococcus
- Coelosphaerium
- Cylindrospermum
- Dactylococcopsis
- Gomphosphaeria
- Merismopedia
- Myxosarcina
- Oscillatoria
- Phormidium
- Raphidiopsis
- Spirulina

Table 5.2-2

PERCENTAGE DIVERSITY FOR MAJOR GROUPS OF PHYTOPLANKTON BY RIVER MILE AND YEAR - 1969-1976 (SUMMER) - BROWNS FERRY NUCLEAR PLANT

		Major Group Percentage Present									
		Preoperational						Operational			
TRM	Major Groups	1969	1970	1971	1972	1973	$\bar{x}$	1974	1975	1976	x
277.98	Chrysophyta	14	73	31	61	32	42	32	18	29	26
	Chlorophyta	30	15	9	22	37	23	49	25	26	33
	Cyanophyta	56	12	60	17	31	35	16	56	44	39
283.94	Chrysophyta	12	57	41	64	31	41	30	26	37	31
	Chlorophyta	36	18	10	19	34	23	47	40	24	37
	Cyanophyta	52	25	49	17	35	35	20	34	39	31
288.78	Chrysophyta	8	64	42	71	33	44	43	33	35	37
	Chlorophyta	37	14	6	17	25	20	26	26	18	23
	Cyanophyta	55	22	52	11	32	34	15	39	47	34
291.76	Chrysophyta	10	56	40	68	22	39	53	22	41	39
	Chlorophyta	25	20	6	21	32	21	27	28	21	25
	Cyanophyta	65	24	54	11	46	40	15	49	37	34
293.70	Chrysophyta	20	75	40	55	19	42	44	28	43	38
	Chlorophyta	18	11	6	31	32	20	35	29	27	30
	Cyanophyta	62	14	54	14	49	39	17	41	29	29
295.87[a]	Chrysophyta	8	76	54	51	17	41	30	14	41	28
	Chlorophyta	34	7	7	35	30	23	47	25	18	30
	Cyanophyta	58	17	39	14	53	36	16	60	40	39
301.06[a]	Chrysophyta	14	39	45	58	13	34	30	30	40	33
	Chlorophyta	27	19	6	24	28	21	39	28	28	32
	Cyanophyta	59	42	49	18	59	45	26	40	31	32
307.52[a]	Chrysophyta	12	89	63	67	9	48	11	19	59	30
	Chlorophyta	83	6	8	22	37	31	40	35	35	37
	Cyanophyta	5	5	29	11	54	21	37	45	5	29

a = Control stations

Table 5.2-3

WHEELER RESERVOIR TEMPERATURE AT THE TIME BIOLOGICAL SAMPLES WERE TAKEN DURING THE SUMMER (1972-1976)

(°F AT 1-METER DEPTH)

	Date				
TRM	7/5/72	7/9/73	7/8/74	7/7/75	7/1/76
277.98	79.0	84.1	82.1	83.1	80.2
283.94	79.0	84.2	82.4	82.3	80.2
288.78	78.5	82.8	79.6	81.2	79.9
291.76	78.3	81.7	80.4	80.6	79.0
293.70	78.4	82.2	81.3	80.8	78.6
295.87	78.0	81.7	78.9	80.3	78.6
301.06	78.1	81.3	79.5	80.3	78.7
307.52	78.1	81.4	78.6	79.9	78.3

Table 5.2-4

PHYTOPLANKTON POPULATION BY STATION - (SUMMER - 1969-1976)

BROWNS FERRY NUCLEAR PLANT

TRM	Preoperational	Operational 1974	Operational 1975	Operational 1976	$\bar{x}$
	Phytoplankters/l. (Mean Values x 10^6)				
277.98	3.2	4.0	6.7	5.8	5.5
283.94	2.7	4.0	3.5	7.3	4.9
288.78	3.1	3.0	1.5	6.4	3.6
291.76	1.9	2.2	1.5	2.5	2.1
293.70	1.3	1.5	0.8	3.8	2.0
295.87[a]	1.6	1.0	1.3	1.1	1.1
301.06[a]	1.2	1.2	0.8	0.9	1.0
307.52[a]	1.2	0.5	0.3	0.2	0.3

a. Control stations

Table 5.2-5

CHLOROPHYLL CONCENTRATIONS BY STATION, 1969-1976 (SUMMER)

BROWNS FERRY NUCLEAR PLANT

	Surface Phytoplankton Chlorophyll a (mg Chl a/m^3) (Mean Values)				
		Operational			
TRM	Preoperational	1974	1975	1976	$\overline{x}$
277.98	6.76	16.22	10.56	14.66	13.81
283.94	5.72	16.08	13.05	15.60	14.91
288.78	4.26	9.01	4.85	17.01	13.29
291.76	4.21	6.59	3.70	5.24	5.18
293.70	4.53	1.68	2.15	8.74	4.19
295.87[a]	3.77	4.04	1.98	0.81	3.62
301.06[a]	2.43	0.43	1.81	1.48	1.24
307.52[a]	1.88	0.43	1.46	1.09	1.00

a. Control stations

Table 5.2-6

DAILY PRIMARY PRODUCTIVITY (C-14) ESTIMATES BY STATION 1972-1976 (SUMMER)--BROWNS FERRY NUCLEAR PLANT

	mg C/ m^2/day						
	Preoperational			Operational			
TRM	1972	1973	$\bar{x}$	1974	1975	1976	$\bar{x}$
277.98	2,202	1,899	2,050	3,784	1,661	2,072	2,506
283.94	2,720	2,539	2,630	5,496	1,935	2,705	3,379
288.78	1,167	452	810	2,957	887	3,808	2,551
291.76	1,143	227	685	2,491	691	1,271	1,484
293.70	587	157	372	1,872	374	1,926	1,391
295.87[a]	511	220	366	2,129	419	888	1,145
301.06[a]	445	52	249	1,789	294	515	866
307.52[a]	350	89	220	425	127	156	236

a. Control stations

Table. 5.2-7

OCCURRENCE OF ZOOPLANKTON SPECIES, BROWNS FERRY NUCLEAR PLANT

	Tennessee River Mile							
	278	284	289	292	294	296	301	308
Cladocera								
Alona sp.	1	2	0	3	3	0	0	0
Alona costata Sars	3	0	0	3	3	0	0	0
Alona gutta	0	0	3	0	0	0	0	0
Alona quadrangularis Leydig	2	0	1	1	3	2	1	2
Alonella sp.	0	0	3	0	3	0	0	0
Bosmina longirostris (O. F. Muller)	1	1	1	1	1	1	1	1
Camptocercus rectirostris Schodler	0	0	3	0	3	0	2	1
Ceriodaphnia lacustris Birge	1	1	3	3	1	3	3	3
Ceriodaphnia quadrangula (O. F. Muller)	0	1	1	1	3	3	0	0
Ceriodaphnia reticulata	3	0	0	3	0	0	0	0
Chydorus sp.	3	1	3	1	1	1	1	1
Daphnia parvula Fordyce	1	1	1	3	1	3	0	3
Daphnia pulex Leydia	0	0	3	0	3	0	0	0
Daphnia retrocurva Forbes	1	1	1	1	1	1	1	1
Daphnia galeata (Mendotae)	3	0	0	3	0	0	3	3
Diaphanosoma leuchtenbergianum Fischer	1	1	1	1	1	1	1	1
Eurycercus sp.	0	0	0	2	1	0	0	2
Gastropus sp.	0	0	0	0	0	0	0	3
Holopedium gibberum Zaddach	1	1	1	1	1	1	2	1
Ilyocryptus spinifer Herrick	1	1	1	3	1	1	1	2
Latona setifera	0	0	0	0	3	0	0	0
Leptodora kindtii (Focke)	1	1	1	1	1	1	1	1
Leydigia quadrangularis (Leydia)	3	3	0	1	0	3	0	0
Moina micrura Kurz	3	3	3	3	0	3	2	1
Moina minuta Hansen	3	3	3	3	3	3	3	0
Pleuroxus denticulatus Birge	3	0	0	1	3	2	0	1
Pleuroxus hamulatus Birge	3	0	0	3	3	3	0	0
Scapholebris Kingi Sars	0	0	0	0	0	0	0	1
Sida crystallina (O. F. Muller)	3	3	1	1	1	1	1	1
Simocephalus (immature)	2	1	1	2	1		2	1
Simocephalus serrulatus	3	3	3	0	3	3	3	0
Simocephalus vetulus Schodler	0	0	2	0	0	0	2	0
Copepoda								
Argulus sp.	0	0	3	0	0	0	0	0
Attheyella illinoisensis (S. A. Forbes)	0	3	0	0	0	0	0	0
Canthocamptus robertcokeri M. S. Wilson	0	3	3	3	3	3	0	3
Canthocamptus staphylinoides Pearse	2	0	0	0	0	2	0	3
Cyclops bicuspidatus thomasi S. A. Forbes	1	1	1	1	1	1	1	1
Cyclops varicans rubellus Lilljeborg	0	3	0	0	3	3	3	3
Cyclops vernalis Fischer	1	1	1	1	1	1	1	1
Diaptomus birgei Marsh	2	0	0	0	0	0	0	0
Diaptomus mississippiensis Marsh	0	0	0	0	0	0	0	2
Diaptomus pallidus Herrick	1	1	1	1	1	1	1	1
Diaptomus reighardi Marsh	1	1	1	1	1	1	1	1

TAble 5.2-7.(continued)

	Tennessee River Mile							
	278	284	289	292	294	296	301	308
Diaptomus sanguineus S. A. Forbes	3	1	0	2	3	3	1	0
Epischura fluviatilis	0	0	0	0	0	0	0	3
Ergasilus sp.	1	1	1	1	1	1	1	1
Eucyclops agilis (Koch)	1	1	1	1	1	1	1	1
Eucyclops speratus (Lilljeborg)	0	0	3	0	3	0	0	0
Macrocyclops albidus (Jurine)	3	0	0	0	0	0	1	0
Mesocyclops edax (S. A. Forbes)	1	1	1	1	1	1	1	1
Nitocra lacustris Fischer	3	1	2	1	1	1	1	3
Osphranticum laborectum	0	3	0	0	0	0	0	0
Paracyclops fimbriatus Fischer	3	3	0	0	0	3	0	0
Paracyclops fimbriatus poppei Rehberg	0	0	0	0	0	2	0	0
Parastenocaris sp.	0	0	0	0	3	0	0	0
Tropocyclops prasinus (Fischer)	1	1	1	3	3	1	1	1
Rotifera								
Asplanchna sp.[a]	1	1	1	1	1	1	1	1
Asplanchna herricki	3	0	3	3	0	3	0	3
Brachionus angularis Gosse	1	1	1	1	1	1	1	1
Brachionus bennini (Leisslung)	0	0	0	2	0	0	0	0
Brachionus bidentata Anderson	2	3	1	3	1	1	1	1
Brachionus budapestinensis Daday	1	1	1	1	1	1	1	1
Brachionus calcyciflorus Pallas	1	1	1	1	1	1	1	1
Brachionus caudatus Barrois & Daday	1	1	1	1	1	1	1	1
Brachionus havanaensis Rousselet	2	1	3	1	1	3	3	1
Brachionus quadridentatus Herman	3	1	3	3	1	1	3	1
Brachionus rubens Ehrenburg	2	0	0	0	0	0	0	0
Brachionus urcerolaris Muller	3	0	3	0	0	3	3	3
Cephalodella sp.	3	3	3	3	3	1	3	3
Collotheca pelagica	3	3	3	3	1	3	1	1
Conochiloides sp.	1	1	1	1	1	1	1	1
Conochilus hippocrepis (Schrank)	0	0	0	0	2	3	2	2
Conochilus unicornis Burckhardt	1	1	1	1	1	1	1	1
Dissotrocha sp.	0	0	0	0	0	0	0	3
Epiphanes macroura Barrois & Daday	3	3	3	3	3	3	3	3
Euchlanis sp.	3	1	1	1	3	3	3	1
Filinia sp.[b]	1	3	1	3	3	3	1	1
Hexarthra sp.[c]	1	1	3	3	1	0	0	2
Kellicottia bostoniensis (Rousselet)	1	1	1	1	3	1	1	1
Keratella americana (Ahlstrom)[d]	3	3	0	3	3	0	3	3
Keratella cochlearis (Gosse)	1	1	1	1	1	1	1	1
Keratella crassa Ahlstrom	1	1	1	1	1	1	1	1
Keratella earlinae Ahlstrom	3	3	1	3	1	1	1	1
Keratella quadrata	0	0	0	0	3	0	0	0
Keratella valga (Ehrenberg)	0	0	2	0	0	0	0	3
Lecane sp.[e]	0	3	3	0	0	3	3	0
Lepadella sp.	0	0	0	2	0	0	2	3
Macrochaetus sp.	3	0	0	0	0	3	0	0
Monostyla sp.	3	0	1	0	2	3	1	3

Table 5.2-7 (continued)

	Tennessee River Mile							
	278	284	289	292	294	296	301	308
Monostyla crenata Harring	0	0	0	0	0	0	0	3
Monostyla quadridentata Ehrenberg	0	0	0	0	0	0	0	2
Notholca sp.	0	3	3	3	3	1	3	0
Platyias patulus (Muller)	1	1	3	0	1	3	1	1
Platyias quadricornis (Ehrenberg)	1	0	0	0	3	0	0	0
Ploesoma sp.[f]	1	1	1	1	1	1	3	1
Polyarthra sp.	1	1	1	1	1	1	1	1
Pompholyx sulcata Hudson	0	0	0	0	0	0	0	3
Ptygura sp.	0	3	0	0	0	0	0	0
Rotaria neptunia	3	3	3	3	3	3	3	3
Synchaeta sp.[g]	1	1	1	1	1	1	1	1
Testudinella sp.	0	3	0	0	0	0	0	0
Trichocerca sp.	1	1	1	1	1	1	1	1
Trichotria sp.	3	3	3	3	1	3	3	1

---

0. Organism not identified at TRM indicated.
1. Organism identified at TRM indicated in both preoperational and operational monitoring.
2. Organism identified at TRM indicated in only preoperational monitoring.
3. Organism identified at TRM indicated in only operational monitoring.

---

[a] Includes *Asplanchna priodonta* Gosse, *Asplanchna amphora* Western, and *Asplanchna herricki*.

[b] Includes *Filinia maior* (Celditz) and *Filinia longiseta*.

[c] Includes *Hexarthra intermedia* Wisniewski and *Hexarthra mira* (Hudson).

[d] Formerly *Keratella gracilenta* Ahlstrom.

[e] Includes *Lecane leontina*.

[f] Includes *Ploesoma hudsoni* (Imhof) and *Ploesoma trucantum* (Levander).

[g] Includes *Synchaeta stylata* Wierzejsky.

Table 5.2-8

ZOOPLANKTON POPULATION BY STATION (SUMMER 1973-1976)

BROWNS FERRY NUCLEAR PLANT

	Zooplankton / m^3 (10^4)				
	Preoperational[a]	Operational			
TRM	1973	1974	1975	1976	$\bar{x}$
277.98	19.1	20.8	18.5	35.5	24.9
283.94	10.1	20.4	21.3	11.5	17.7
288.78	2.7	8.0	2.3	11.4	7.2
291.76	1.1	5.4	2.9	3.9	4.1
293.70	2.3	4.0	3.2	9.5	5.6
295.87[b]	0.9	3.3	1.2	9.5	4.7
301.06[b]	0.5	1.9	1.4	8.1	3.8
307.52[b]	1.8	1.1	1.3	8.3	3.6

a. Zooplankton collection methodology was change in 1973 to a bottom to surface vertical tow of a 1/2-m tow net, hence only 1973 preoperational date can be compared to the operational data.

b. Control Station

Table 5.2-9

BENTHIC MACROINVERTEBRATE TAXA COLLECTED IN WHEELER RESERVOIR

BROWNS FERRY NUCLEAR PLANT

- Annelida
  - Clitellata (Oligochaetes)
    - *Branchiura sowerbyi* Beddard
    - *Limnodrilus claparedianus* Ratzel

- Arthropoda
  - Insecta
    - Diptera (Chironomid midges)
      - *Chironomus tentans* Fabricius
      - *Coelotanypus* spp.
      - *Cryptochironomus* spp.
      - *Pentaneura* spp.
      - *Procladius* spp.
      - *Smittia* spp.
      - *Xenochironomus festivus* (Say)

    - Ephemeroptera (mayflies)
      - *Hexagenia bilineata* (Say)

- Mollusca
  - Pelecypoda
    - Heterodonta
      - *Corbicula manilensis* Phillipi

Table 5.2-10

HEXAGENIA POPULATIONS BY STATIONS (SUMMER)

BROWNS FERRY NUCLEAR PLANT

	Hexagenia/m^2 (Mean Values)				
		Operational			
TRM	Preoperational	1974	1975	1976	$\bar{x}$
277.98	9	22	121	26	56
283.94	20	40	83	423	182
288.78	44	179	300	310	263
291.76	91	173	266	312	250
293.70	72	269	167	151	196
295.87[a]	13	185	183	177	182
301.06[a]	15	0	4	24	9
307.52[a]	0	0	4	0	1

---

[a] Control Stations

Table 5.2-11

CORBICULA POPULATIONS BY STATIONS

BROWNS FERRY NUCLEAR PLANT

	Corbicula/m² (Mean Values)					
	Preoperational		Operational			
TRM	All Seasons	Summer	Summer 1974	Summer 1975	Summer 1976	$\bar{x}$
277.98	83	91	92	173	97	121
283.94	119	220	133	48	159	113
288.78	209	224	453	195	387	345
291.76	187	169	318	139	264	240
293.70	149	154	288	185	240	238
295.87[a]	108	136	223	131	153	169
301.06[a]	46	63	26	97	56	60
307.52[a]	64	62	36	52	71	53

[a] Control Stations

Table 5.2-12

CHIRONOMIDAE POPULATIONS BY STATIONS (SUMMER)

BROWNS FERRY NUCLEAR PLANT

	Chironomidae/m^2 (Mean Values)				
		Operational			
TRM	Preoperational	1974	1975	1976	$\bar{x}$
277.98	97	110	147	83	113
283.94	116	110	92	70	91
288.78	75	74	150	90	105
291.76	68	58	92	121	90
293.70	52	104	36	102	81
295.87[a]	34	60	18	80	41
301.06[a]	44	2	2	36	13
307.52[a]	43	6	68	12	42

a. Control stations

Table 5.2-13

OLIGOCHAETA POPULATIONS BY STATION (SUMMER)

BROWNS FERRY NUCLEAR PLANT

TRM	Oligochaeta/m^2 (Mean Values)				
		Operational			
	Preoperational	1974	1975	1976	$\bar{x}$
277.98	115	346	516	276	379
283.94	115	320	409	604	444
288.78	182	545	457	493	498
291.76	130	442	409	389	413
293.70	178	527	316	62	302
295.87[a]	97	233	147	199	193
301.06[a]	99	134	89	224	149
307.52[a]	27	66	38	40	48

---

[a] Control stations

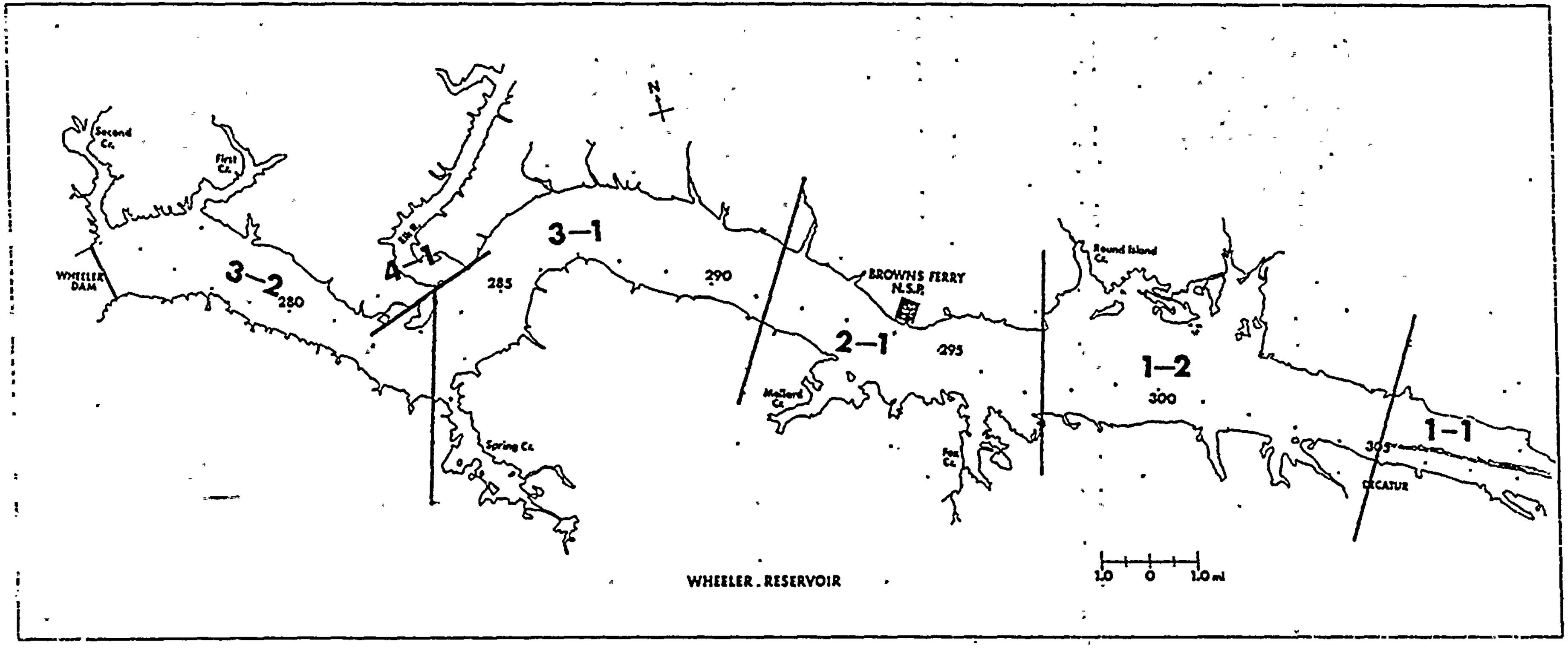


Figure 5.1-1 Definition of areas sampled in creel census, Wheeler Reservoir.

6.0 Effects of Operation at 90°F (32.2°C) Maximum

6.1 Fishery Resources

The effect of discharging heated water to a maximum of 32.2°C will be the avoidance of the mixing zone and the warmest regions of the thermal plume by the more thermally-sensitive species during the periods of highest ambient temperature. Wrenn (1975) noted that skipjack herring, sauger and walleye avoided the heated effluent of Colbert Steam Plant (Pickwick Reservoir) at temperatures greater than 30°C, while gar, gizzard shad, threadfin shad, carp, bluegill, largemouth bass and channel catfish were commonly collected in the discharge at maximum summer temperatures (33°-35°C). These results are in general agreement (discounting differences in thermal history, i.e., seasonal acclimation) with those from studies of other steam plants (e.g., Gammon, 1973; Teppen and Gammon, 1976; Yoder and Gammon, 1976) in that many species adjust their distribution relative to the thermal discharge on a seasonal basis. The discharge diffusers at Browns Ferry are located such that there is no possibility of fish becoming trapped in areas of adverse temperatures.

Results of operational monitoring through 1976 (Tables 6.1-1-6.1-4) indicate that, while catch totals occasionally fall outside the ranges (mean ± 1 standard error) defined by preoperational sampling, the occurrences cannot conclusively be attributed to plant operation. For example, in winter samples (Table 6.1-1), only catches at Station 2 (above the plant at TRM 299) varied outside the preoperational range; winter samples included one set (1975) under full operating conditions i.e., thermal discharge. Summer operational catches (Table 6.1-3) included a thermal-dishcarge period (1974); the catch at Station 1, the thermally-influenced area at TRM 293 in 1974, was below the

preoperational range as would be expected; so, however, was the catch at Station 2.

6.1.1 Thermal Blockage of Fish Migrations

One of the possible impacts of the discharge of a thermal effluent is that of establishing a thermally-enriched zone which could act as a barrier to migrating fish species. Three species present in Wheeler Reservoir are considered likely to make upstream spawning migrations: sauger, walleye, and white bass. Migrations of sauger occur from November through April in TVA reservoirs and white bass migrations usually occur from February through April; migrations of the rarely-occurring walleye have not been documented.

During TVA's recent 316(a) studies of two steam plants, Bull Run and Cumberland (reports submitted to EPA in 1976), the ability of sauger and white bass to negotiate a thermal discharge during their spawning migrations was investigated. Both of these plants have relatively large thermal plumes relative to the dimensions of the receiving waters.

The Bull Run study was performed during December-April 1975 and January-March 1976. In the first period phase 203 sauger were tagged and released at least four miles below the plant. Of the 30 sauger which were later recaptured, 11 were caught in the discharge basin and four were taken above the plant. None of these fish were recaptured above the plant before the plant experienced a shutdown, but six of the fish did move into the discharge basin and were recaptured while the plant was operating. During 1976, 56 sauger were tagged and released below Bull Run Steam Plant. Three of these sauger were later recaptured above the plant before a shutdown occurred. The coldest temperatures in four years were experienced at this time, and the plant was required to operate near maximum capacity.

It was apparent from this two-year study that the heated discharge from Bull Run Steam Plant posed no significant problem to sauger migrations in Melton Hill Reservoir. Data collected during 1975 indicated that sauger moved into and remained in the discharge while the plant was operating. Studies conducted during 1976 indicated that the tagged fish apparently had little difficulty continuing their movement past the thermal plume to the colder upper reaches of the reservoir and then returning downstream.

Near the Cumberland Steam Plant 252 sauger were tagged and released below the plant during the period from December 1974 to January 1975. Nine of the 19 recaptured fish had moved past the plant when at least one of two units were operating. In April 1976, 88 White bass were tagged and released below Cumberland's thermal effluent. Six of these fish were subsequently recaptured upstream of the plant in the vicinity of Cheatham Dam before a shutdown occurred.

The observations from both steam plants studies demonstrate that sauger and white bass can move upstream past, under or through a thermal plume during their spawning migrations. Walleye would also be expected to exhibit the same unrestricted movement past a heated water discharge. Based on these observations, plus the fact that worst-case thermal conditions occur in the summer, several months after spawning migrations have been concluded, it is believed that no thermal barrier to migration will occur with a 90°F maximum temperature limitation.

6.1.2 Summary

1. Wheeler Reservoir supports a fish fauna typical of southeastern reservoirs; the assemblage of 59 species taken during preoperational monitoring (Table 5.1-1) is largely dominated by clupeids, ictalurids, centrarachids and one sciaenid.

2. Three species have been identified by EPA and the State of Alabama as coolwater species; sauger, walleye and smallmouth bass. The apparent thermal requirements of these species serve as the basis for the present thermal standards applied to the Tennessee River.

3. The distribution of these three species, as indicated by netting and creel census results, in such that they are not abundant in the area likely to be affected by the thermal plume. Sauger are largely concentrated above the plant; smallmouth bass are concentrated in areas 10 km (6 mi) or more below the plant and in the Elk River. Walleye are seldom captured by any method, do not contribute significantly to the angler harvest and thus apparently are not an important component of the total fish community of Wheeler Reservoir.

4. Abundance of smallmouth bass, as indicated by creel census, netting and standing stock estimates, appears to be declining while sauger abundance is increasing. Neither phenomenon is attributable to plant operation.

5. Recent laboratory and field investigations indicate that earlier definitions of thermal preferenda and upper lethal temperatures, for the three species of concern, require revision upwards. The classification of smallmouth bass as a "coolwater" species appears

to be untenable; in terms of thermal requirements, it does not differ significantly from largemouth bass under similar conditions of acclimation. While sauger and walleye appear to have lower thermal preferenda and upper lethal temperature limits than do smallmouth, recent results suggest that short-term exposures to temperatures of 30°-32°C would not cause mortality.

6. Sauger, smallmouth and walleye are capable of avoiding water temperatures above their preferenda; none of the three is limited by habitat requirements to the area of the mixing zone and thermal plume.

7. No migrating species will be affected by thermal blockage.

8. Operation of Browns Ferry Nuclear Plant under thermal standards of 32.2C maximum temperature may affect the seasonal distribution of some species, but such operation will not result in any significant adverse impact upon the fisheries resources of Wheeler Reservoir.

6.2 Plankton and Benthos

Evaluation of the temporary thermal limits is based on the following assumptions:

- The commercial operation of the Browns Ferry Nuclear Plant is with Helper Mode cooling during periods when ambient temperatures approach or exceed 86°F.
- The frequency analysis presented in Section 7, Figure 7.2-2, approximates the conditions that will exist in the future.
- The frequency and duration of the mixed river temperature do not exceed those presented in Table 7.3-1.
- The maximum temperature discharged via the Helper Mode during a worse case situation cannot exceed 94°F.
- The maximum mixed temperature will not exceed 90°F.

Primary concern in the evaluation is for the effects upon the plankton communities (i.e., phytoplankton and zooplankton). As previously discussed in the benthic macroinvertebrate section, this community is not significantly affected since the thermal effluent contacts only a very small area immediately downstream from the diffuser.

The literature contains little specific information on the _in situ_ effects of elevated temperature on zooplankton. Anraku (1974) recognized that increased temperatures could induce changes in zooplankton species composition that may affect the feeding of their predators, especially that of the early development stage of fish, and that increased temperatures could also alter patterns of energy flow. Coker (1934) found that there appears to be a physiological difference between copepods reared at low temperatures and those reared at high temperatures.

The frequency and duration of elevated temperatures (Figure 7.2-2 and Table 7.3-1) over ambient conditions under helper mode operation are deduced not to be of sufficient magnitude to significantly affect the zooplankton community. Thus, the operation of the Browns Ferry Nuclear Plant in the Helper Mode of cooling to achieve the proposed thermal limit should not prevent the maintenance of a balanced and indigenous zooplankton community in Wheeler Reservoir. However, operation under open cycle to achieve the limit would greatly increase the frequency and duration of temperatures at the proposed maximum limit. The extended duration and frequency experienced via open mode cooling (Figure 7.2-2 and Table 7.3-1) could affect the zooplankton communities of Wheeler Reservoir.

The phytoplankton community because of the potential for nuisance forms to dominate, and the general nonmotile nature of the organisms, is the principal community in the evaluation of the temporary thermal limit. Under natural conditions, one of the main factors in seasonal succession and abundance of species is the different temperature optima of species (Patrick 1974, Hutchinson 1967). As the temperature increases or decreases, species replacement takes place. Temperatures in natural situations in which algal groups exhibit best growth are: diatoms, 18° to 30° C; greens 30° to 35° C; blue-greens, 35° to 40° C (Foerster, et al, 1974); Cairns, 1955; Patrick 1974; Allen Creek Nuclear Generating Station EIS, 1974). Reid (1961), however, states that blue-greens can predominate in southern temperate aquatic communities when water temperatures exceed 19° C. The seasonal change in floral composition and the dominance of blue-green algae both occur naturally in Wheeler Reservoir, both upstream and downstream from the Browns Ferry Nuclear Plant.

Experimental results (Patrick, 1974) indicate that small heat shocks for very short periods of time may have only temporary adverse effects on some species of algae. Since the frequency and duration of elevated temperatures (Figure 7.2-2 and Table 7.3-1) over ambient conditions are expected to be relatively infrequent and predominantly of short duration with helper mode operation, it is deduced that the operation of the Browns Ferry Nuclear Plant in Helper Mode to achieve the proposed thermal limit should not prevent the maintenance of a balanced and indigenous phytoplankton community in Wheeler Reservoir. However, operation under open cycle to achieve the limit would greatly increase the frequency and duration of temperatures at the proposed maximum limit. The extended duration and frequency experienced via open mode (Figure 7.2.2 and Table 7.3-1) could affect the zooplankton communities of Wheeler Reservoir.

FISHERY LITERATURE CITED

Brown, B. E. 1962. Occurrence of the walleye, Stizostedion vitreum, in Alabama south of the Tennessee Valley. Copeia 1962(2):469-471.

Cherry, D. S., K. L. Dickson, and J. Cairns, Jr. 1975. Temperatures selected and avoided by fish at various acclimation temperatures. J. Fish. Res. Board Can. 32:485-491.

____________, K. L. Dickson, J. Cairns, Jr., and J. R. Stauffer. 1977. Preferred, avoided and lethal temperatures of fish during rising temperature conditions. J. Fish Res. Board Can. 34:239-246.

Coble, D. W. 1967. Relationship of temperature to total annual growth in adult smallmouth bass. J. Fish Res. Bd. Canada 24:87-99.

Cook, F. A. 1959. Freshwater Fishes in Mississippi. Miss. Game and Fish Comm., 239 p.

Dahlberg, M. D., and D. C. Scott. 1971a. The freshwater fishes of Georgia. Bull. Georgia Acad. Science 29:1-64.

________________. 1971b. Introductions of freshwater fishes in Georgia. Bull. Georgia Acad. Science 29:245-252.

Dendy, J. S. 1945. Fish distribution, Norris Reservoir, Tennessee, 1943. II. Depth distribution of fish in relation to environmental factors, Norris Reservoir. Journ. Tenn. Acad. Science 20(1):114-135.

Dickson, K. L., J. Cairns, Jr., D. S. Cherry, and J. R. Stauffer. 1976. An analysis of the applicability of EPA's draft water-temperature criteria: a site-specific case-history evaluation. p. 316-236 In: G. W. Esch and R. W. McFarlane (eds). Thermal Ecology II, ERDA Symposium Series (CONF-750425). Augusta, GA. 1975.

*Emig, J. W. 1966. Smallmouth bass. p. 354-365 In: A. Calhoun (ed.) Inland Fisheries Management. Dept. Fish and Game, State of California.

*Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Canada 15:607-624.

Gammon, Jr. R. 1970. Aquatic life survey of the Wabash River with special reference to effects of thermal efflunets on populations of macroinvertebrates and fish. Report to Public Service Indiana. 65 p. mimeo.

_________. 1973. The response of fish populations in the Wabash River to heated effluents. P. 513-52 Oak Ridge, TN In: D. J. Nelson (ad). Proc. 3rd Nat'l. Symposium on Radioecology, USAEC (Conf-710501-)

*Goodson, L. F., Jr. 1966. Walleye. p. 423-425 In: A. Calhoun (ed.) Inland Fisheries Management. Dept. Fish and Game, State of California.

Grinstead, B. G. 1971. Reproduction and some aspects of the life history of walleye, *Stizostedion vitreum* (Mitchell) in Canton Reservoir in Oklahoma. p. 41-51 *In*: G. E. Hall (ed.) *Reservoir Fisheries and Limnology* Amer. Fish. Soc. Spec. Pub. No. 8.

Hubbs, C. L. and K. F. Lagler. 1958. *Fishes of the Great Lakes Region*, Bull. 26, Cranbrook Institute of Science. 213 p.

Jester, D. B. 1971. Effects of commercial fishing, species introductions and drawdown control on fish populations in Elephant Butte Reservoir, New Mexico. p. 265-286 *In*: G. E. Hall (ed.) *Reservoir Fisheries and Limnology*. Amer. Fish Soc. Spec. Pub. No. 8.

Koenst, W. M. and L. L. Smith, Jr., 1976. Thermal requirements of early life history states of walleye, *Stizostedion vitreum vitreum* and sauger, *Stizostedion canadense*. J. Fish. Res. Board Can. 33:1130-1138.

Neves, R. J. 1975. Factors affecting fry production of smallmouth bass (*Micropterus dolomieui*) in South Branch Lake, Maine. Trans. Amer. Fish. Soc. 104:83-87.

Niemuth, W., W. Churchill, and T. Wirth. 1962. The walleye, its life, history, ecology, and management. Pub. No. 227. Wis. Cons. Dept. 14 p.

*Priegel, G. R. 1969. The Lake Winnebago sauger. Age, growth, reproduction, food habits, and early life history. Tech. Bull. No. 43., Dept. Nat. Resources, State of Wisconsin, 63 p.

*_______________. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Tech. Bull. No. 45, Dept. Nat. Resources, State of Wisconsin, 105 p.

Regier, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fish. Comm. Tech. Rep. 15. 101 p.

Reynolds, W. W. and M. E. Casterlin. 1976. Thermal preferenda and behavioral thermoregulation in three centrarchid fishes. p. 185-190 *In*: G. W. Esch and R. W. McFarlane (eds). Thermal Ecology II, ERDA Symposium Series (CONF-750425). Augusta, GA. 1975.

*Smith, L. L., Jr., and W. M. Koenst. 1975. Temperature effects on eggs and fry of percoid fishes. Ecological Research Series, EPA-660/3-75-017. U.S. Environmental Protection Agency. 91 p.

Smith-Vaniz, W. F. 1968. *Freshwater Fishes of Alabama*. Agr. Exp. Sta., Auburn Univ., 211 p.

Teppen, T. C. and J. R. Gammon. 1976. Distribution and abundance of fish populations in the middle Wabash River. p. 272-283 *In*: G. W. Esch and R. W. McFarlane (eds). Thermal Ecology II, ERDA Symposium Series (CONF-750425). Augusta, GA. 1975.

Trautman, M. B. 1975. The Fishes of Ohio. The Ohio State University Press, 683 p.

Wrenn, W. B. 1975. Seasonal occurrance and diversity of fish in a heated discharge channel, Tennessee River. Proc 29th Ann. Conf. S.E. Assoc. Game and Fish Comm: 235-247.

______________, 1976. Temperature preference and movement of fish in relation to a long, heated discharge channel. p. 191-194 In: G. W. Esch and R. W. McFarlane (eds). Thermal Ecology II, ERDA Symposium Series (CONF-750425). Augusta, GA. 1975.

Yoder, C. O. and J. R. Gammon. 1976. Seasonal distribution and abundance of Ohio River fishes at the J. M. Stuart electric generating station. p. 284-295 In: G. W. Esch and R. W. McFarlane (eds). Thermal Ecology II, ERDA Symposium Series (CONF-750425). Augusta, GA. 1975.

PLANKTON & BENTHOS LITERATURE CITED

Allen Creek Nuclear Generating Station. 1974. Final Environmental Statement for Units 1 and 2. Houston Lighting and Power Company. Section 5.5.2.1.1.

Anraku, M. 1974. "Review, Warm Water Effluents and Plankton." Bull. Plantkton Society of Japan. 21(1):1-31.

Cairns, J. 1955. "The Effects of Increased Temperatures Upon Aquatic Organisms." Pardue University Eng. Bull. 40.346.

Coker, R. E. 1934. "Reaction of Some Freshwater Copepods to High Temperatures." J. Elisha Mitchell Scientific Soc. 50:143-159.

Foerster, J. W., F. K. Trainor, and J. D. Buck. 1974. "Thermal Effects on the Connecticut River: Phycology and Chemistry." J. Water Poll. Contr. Fed., 46(9):2138-2152.

Hutchinson, G. E. 1967. A Treatise on Limnology. Volume II Introduction to Lake Biology and the Limnoplankton. John Wiley & Sons, Inc., New York, 1115 pp.

Patrick, R. 1974. "Effects of Abnormal Temperatures on Algal Comminities." In: Thermal Ecology. Edited by J. W. Gibbons and R. R. Sharitz, U.S. Atomic Energy Commission, pp. 335-349.

Reid, G. K. 1961. Ecology of Inland Waters and Estuaries. Van Nostrand Reinhold Co., New York, 375 pp.

Tennessen, K. J. Biologist TVA Water Quality and Ecology Branch, Muscle Shoals, Alabama. Personal communications.

Table 6.1-1

SUMMARY OF WINTER QUARTER GILL NET SAMPLING PREOPERATIONAL (1969-1973) AND OPERATIONAL (1974-1976)

STATION	$\bar{x}$N	c/f SE	$\bar{x}$ wt	SE			N	c/f	wt. kg.	c/f
1 - preoperational (means)	10.046	4.632	3.502	1.915	1 - operational	1974	418	10.450	165.53	4.138
						1975	308	8.105	137.46	3.617
						1976	253	6.325	90.09	2.252
2 - preoperational (means)	10.087	1.168	3.848	.607	2 - operational	1974	231	6.417	96.03	2.668
						1975	NO SAMPLE			
						1976	151	3.775	47.15	1.179
3 - preoperational (means)	8.138	4.063	3.089	1.548	3 - operational	1974	292	7.300	124.41	3.110
						1975	414	10.615	161.95	4.153
						1976	433	10.825	134.62	3.364

Table 6.1-2

SUMMARY OF SPRING QUARTER GILL NET SAMPLING PREOPERATIONAL (1969-1973) AND OPERATIONAL (1974-1976)

STATION	$\bar{x}$N	SE	c/f $\bar{x}$ wt	SE			N	c/f	wt. kg.	c/f
1 - preoperational (means)	18.827	3.919	6.049	.800	1 - operational	1974	985	24.625	269.18	6.730
						1975	997	26.237	285.57	7.515
						1976	897	22.425	240.70	6.017
2 - preoperational (means)	11.815	3.810	3.613	.977	2 - operational	1974	164	4.100	92.37	2.309
						1975	405	10.125	87.35	2.184
						1976	179	5.424	82.26	2.493
3 - preoperational (means)	22.977	16.520	5.878	3.438	3 - operational	1974	686	22.867	158.61	5.287
						1975	423	10.575	96.33	2.408
						1976	990	24.750	272.47	6.812

Table 6-1-3

SUMMARY OF SUMMER QUARTER GILL NET SAMPLING PREOPERATIONAL (1968-1972) AND OPERATIONAL (1974-1976)

	c/f									
STATION	$\bar{x}$N	SE	$\bar{x}$ wt	SE			N	c/f	wt. kg.	c/f
1 - preoperational (means)	29.42	6.34	8.29	1.90	1 - operational	1974	316	7.90	101.75	2.54
						1975	735	19.34	164.56	4.33
						1976	897	22.43	240.70	6.02
2 - preoperational (means)	23.18	14.64	3.44	1.27	2 - operational	1974	85	2.83	64.82	2.16
						1975	114	2.85	45.46	1.14
						1976	179	5.42	82.26	2.49
3 - preoperational (means)	41.90	11.15	9.77	3.25	3 - operational	1974	643	16.08	174.92	4.37
						1975	1,111	27.78	178.01	4.45
						1976	990	24.75	272.47	6.81

Table 6.1-4

SUMMARY OF FALL QUARTER GILL NET SAMPLING PREOPERATIONAL (1969-1972) AND OPERATIONAL (1973-1976)

STATION	x̄N	SE	c/f x̄ wt	SE			N	c/f	wt. kg.	c/f
1 - preoperational (means)	9.88	1.53	2.80	0.37	1 - operational	1973	476	11.90	166.22	4.16
						1974	252	8.55	138.97	3.47
						1975	268	6.70	94.28	2.38
						1976	486	12.15	178.74	4.47
2 - preoperational (means)	7.98	1.87	3.16	.64	2 - operational	1973	169	4.23	96.72	2.42
						1974	129	3.23	43.62	1.09
						1975	237	5.93	89.55	2.24
						1976	323	8.08	126.07	3.15
3 - preoperational (means)	18.10	9.73	7.01	2.37	3 - operational	1973	304	7.60	117.60	2.90
						1974	822	20.55	246.78	6.17
						1975	475	11.86	159.73	3.99
						1976	610	15.25	253.58	6.34

7.0 Hydrothermal Analysis of Helper and Open Mode Condenser Cooling

7.1 Condenser Cooling System Operational Modes

The condenser cooling system for this plant is designed to operate in three cooling modes: Open, Helper and Closed. In the Open Mode, the plant pumps 4350 cubic feet per second (cfs) of water from the river through the steam condenser where the cooling water is heated approximately 25°F before being discharged through submerged, multiport diffusers on the riverbed (Figure 7.1-1). When operating in the Helper Mode, the condenser cooling water is routed to cooling towers before being discharged through the three submerged diffusers. In the Closed Mode, the cooling tower effluent is routed into the plant intake channel for reuse as condenser cooling water.

The mixed temperature in the river downstream of the plant depends upon the performance of several subsystems of the plant cooling system. The temperature increase through the condenser depends upon the flow rate through the condenser and the megawatt generation of the plant. The cooling tower effluent temperature is primarily a function of the wet bulb temperature in the air and the temperature of the hot water from the condenser. The mixed temperature of the river downstream of the plant depends upon the flow rate and the temperature of both the thermal discharge and the river.

Because of unanticipated deficiencies in tower system performance, the system is not providing the heat removal capacity previously expected. These deficiencies have necessitated significant power reduction during the summer months of 1977. During this period, ambient river temperatures have consistently approached or exceeded the maximum thermal standard (86°F).

An analysis of plant-induced, downstream temperatures with the plant operating in Open and Helper Mode cooling during the months of June through September is presented. For this evaluation the plant was assumed to generate at the three-unit design capacity except in certain cases when the effluent temperature at design capacity would have exceeded 94°F. The 94°F temperature had been established as an operating limit to assure that the 95°F design value inlet temperature for certain plant auxiliary systems was not exceeded. A statistical analysis, based upon several years of record, is presented to evaluate the maximum temperatures expected during an average year. Severe conditions were determined by performing a simulation of plant-induced mixed temperatures using recorded meteorology, the river flows and temperatures during the summer of 1969. The predicted decay of plant-induced heating at various river miles downstream of the plant is also presented.

7.2 Mixed River Temperature Probabilities

An analysis has been performed to project the frequency distribution of the mixed river temperature for the summer months of June, July, August, and September. "Mixed river temperature" (T_m) is defined here as the temperature of the mixed effluent and river water at the end of the diffuser mixing zone (several hundred feet downstream of the diffuser as illustrated in Figure 7.2-1). For an assumed river temperature and river flow in the case of Open Mode cooling, and additionally, for a wet bulb temperature in Helper Mode cooling, the mixed river temperature can be calculated. Calculations for each month are based on approximately 3000 values of river temperature and wet bulb temperature. In all cases, the plant load was assumed constant at 3150 MW; the probabilities were calculated for Open and Helper Modes of operation. The results of the analysis are given in Figures 7.2-2 and 7.2-3 which are histograms showing the percent probability that the mixed river temperature will occur in a given temperature range. Plant-induced temperatures during July are predicted to be the most severe, whether the plant is operated in Helper or Open Mode. This analysis reveals that during Helper Mode operation, the plant will rarely, if ever, exceed a mixed temperature of 90°F. Operating in Open Mode, the mixed temperatures are more severe and will exceed 90°F unless plant generation is reduced during extreme ambient conditions.

7.3 Simulation of Extreme Condition

The simualtion of the plant cooling system throughout a warm summer was performed to provide an indication of the duration of long periods of extreme conditions. The summer of 1969 was previously the year during which the warmest river temperatures were recorded. River temperatures recorded during the summer of 1977 are similar to or slightly warmer than those recorded in 1969, both being several degrees above normal. River flows were slightly less than normal during those months. The year of 1969 was, therefore, chosen to represent severe summer conditions.

The data required to perform this simulation included (1) tri-hourly wet bulb temperatures recorded by the U.S. Weather Service in Huntsville, Alabama; (2) hourly river temperatures recorded at a depth of five feet in the edge of the river channel slightly downstream of the present location of the diffuser; and (3) hourly flow releases of upstream (Guntersville) and downstream (Wheeler) hydroelectric plants. These data were used to compute the plant-induced temperature rise (ΔT) and the downstream mixed temperature (T_m). The computer program utilized (1) condenser heat exchange rates recorded at the Browns Ferry Nuclear Plant; (2) cooling tower performance curves determined from tests conducted during the spring of 1977 which reflect approximately 80 percent of design performance; and (3) diffuser-induced mixing theory verified by field tests conducted in June 1977. The plant was assumed to generate at capacity except at those times when it was operated in the Helper Mode and the tower effluent exceeded 94°F. During such times the plant capacity was reduced such that the cooling tower effluent did not exceed 94°F.

Table 7.3-1 represents the number of occurrences and the duration of the mixed temperatures exceeding various levels when the plant was operated with the Helper Mode and actual river flows. This table demonstrates that, when operating under these conditions, the plant may exceed the current river maximum temperature of 86°F for two or more consecutive days, but the plant never exceeded 90°F or

a plant-induced rise of 5°F. The maximum mixed temperature predicted under these flow conditions was 89.4°F on July 7, 1969, and the maximum plant-induced temperature rise was 4.7°F predicted for September 24, 1969. Also shown in Table 7.3-1 are the times and duration of reduced operation that would have been required in order for the cooling tower effluent not to exceed 94°F. The largest megawatt reduction was 796 megawatts on July 7, 1969.

The number of occurrences and duration of mixed temperatures exceeding a specified limit with the plant operating in Open Mode and using actual river flows are presented in Table 7.3-2. Also shown are the number and duration of temperatures exceeding a plant-induced rise of 5°F. These results indicate that temperatures are considerably warmer when operating in the Open Mode than those for the Helper Mode. The maximum predicted temperature was 93.2°F and the maximum plant-induced temperature rise of 8.0°F. The principal results from the simulation of June through September of 1969 are summarized in Table 7.3-3.

7.4 Far Field Analysis of Diffuser Discharge

The changes in downstream reservoir temperatures caused by the diffuser discharge were calculated using the one-dimensional, steady-state, heat transfer equation. Figure 7.4-1 shows the downstream temperature rise predictions for river flows of 10,000, 30,000, and 50,000 cfs and initial mixed temperature rises at the diffuser of 1-5°F. Greater downstream surface heat losses are shown for lower river flows because the travel time to points downstream is longer. However, the initial mixed temperature rise at the diffuser is higher at lower river flows than at higher river flows, as indicated in the near field analysis. The river flow of 30,000 cfs is typical of daily average river flows during the summer months. This analysis, combined with the results of the simulation of extreme conditions with the plant operating in Helper Mode, indicates that the maximum temperature in the downstream portion of the Wheeler Reservoir is approximately 89°F.

TABLE 7.3-1

FREQUENCY AND DURATION OF COMPUTED ELEVATED MIXED RIVER TEMPERATURES DURING 1969

HELPER MODE COOLING AND ACTUAL RIVER FLOWS

Duration of Period - Hrs	Mixed Temperature >86°	>87°	>88°	>89°	Load Reduction Required for $T_D<94^\circ$
1	12	12	12	2	6
2	2	4	5		2
3	3	4	3		3
4	5	2	5	1	1
5	6	1			3
6	1	1			
7		1			1
8			1		
9	2	1	1		3
10	1	3			
11					1
12	1	1	1		2
13					
14					
15		1			
16		1			1
17					1
18	1				
19	1	1			
20	1	1	1		
21					
22			1		
23	1				
24		1			
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37		1			
38		1			
39					
40					
41					
42					
43					
44					
45	1				
46					
47					
48 or more	8	2			

TABLE 7.3-2

FREQUENCY AND DURATION OF COMPUTED ELEVATED MIXED RIVER TEMPERATURES DURING 1969

OPEN MODE COOLING AND ACTUAL RIVER FLOWS

Duration of Period - Hrs	Mixed Temperature								
	>86°	>87°	>88°	>89°	>90°	>91°	>92°	>93°	ΔT>5°F
1	11	20	16	17	7	5	3		5
2	6	4	7	3	6	3	5	1	7
3	3	8	4	2	5	7	1		3
4	6	3	4	6	7	3			9
5	5	5	1	2	3	4			15
6	5		2	4	1	1			22
7		2		2	2	1	2		12
8	1	1	2		2	1			15
9	3	1	2	5	1	1			12
10		3	4	3	4				4
11	4	4	3	1	2				3
12	4	2	3	4	1	1			2
13	3	1	3		2				
14		2							2
15		1		3	1				1
16	1	2	1	1	1				1
17									
18									
19	1	4	1	3	1				
20				1	1				
21									
22	1	1		1	1				
23		1							
24									
25			1						
26									
27									
28									
29					1				
30									
31									
32				1					
33	1								
34									
35									
36									
37									
38				1					
39	1	2							
40									
41			1						
42			1						
43		1							
44		1							
45	1		1						
46			1						
47									
48 or more	19	10	6	1					

TABLE 7.3-3

SUMMARY OF RESULTS OF SIMULATION FOR JUNE-SEPTEMBER 1969

	$T_m > 86^0$		$T_m > 88^0$		$T_m > 90^0$	
	% Time	Mean (hrs.)	% Time	Mean (hrs.)	% Time	Mean (hrs.)
Helper	21	18	4	14	0	0
Open	50	20	27	12	12	7

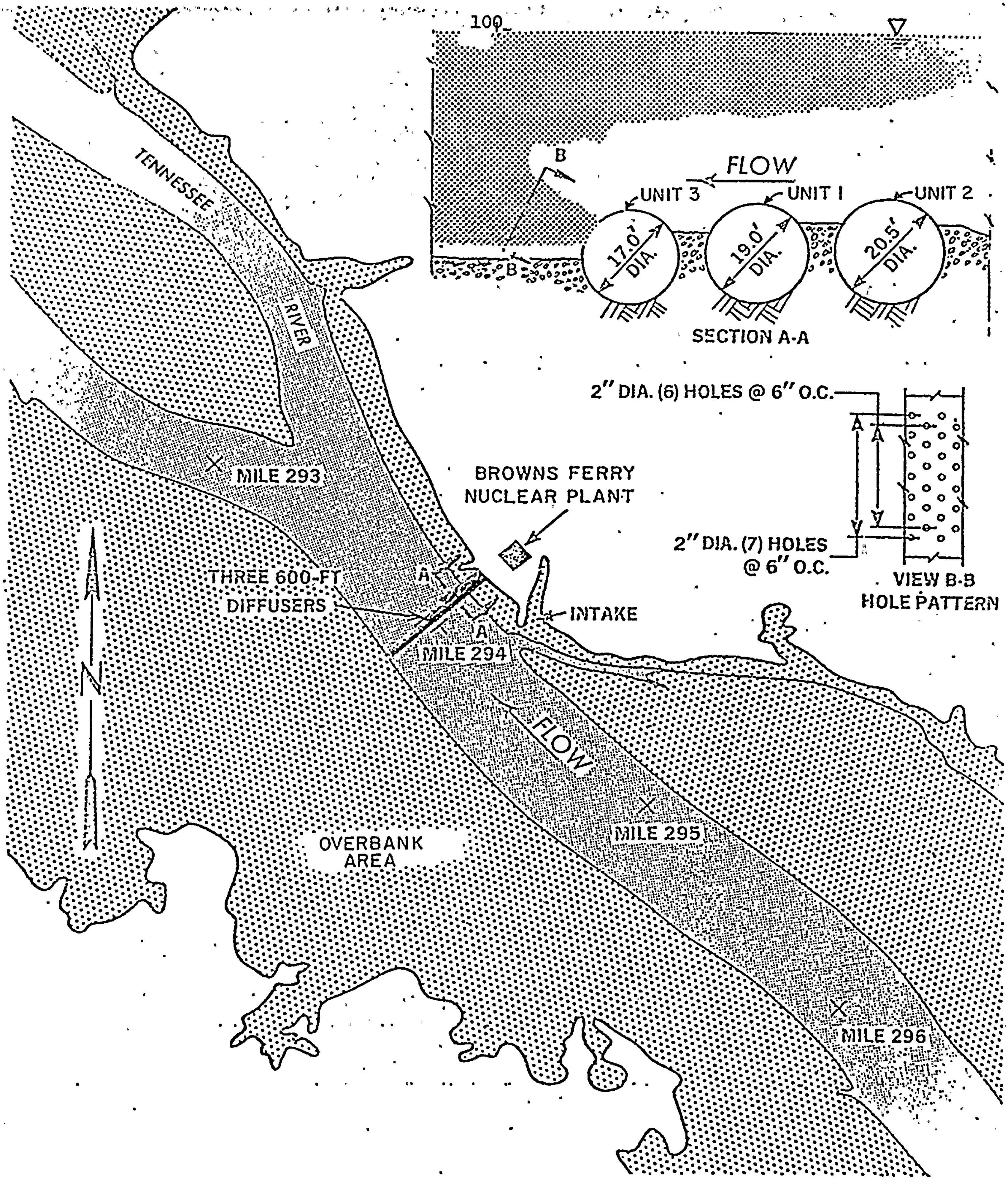


FIGURE 7.1-1 : Browns Ferry Submerged Diffuser, Description and Location

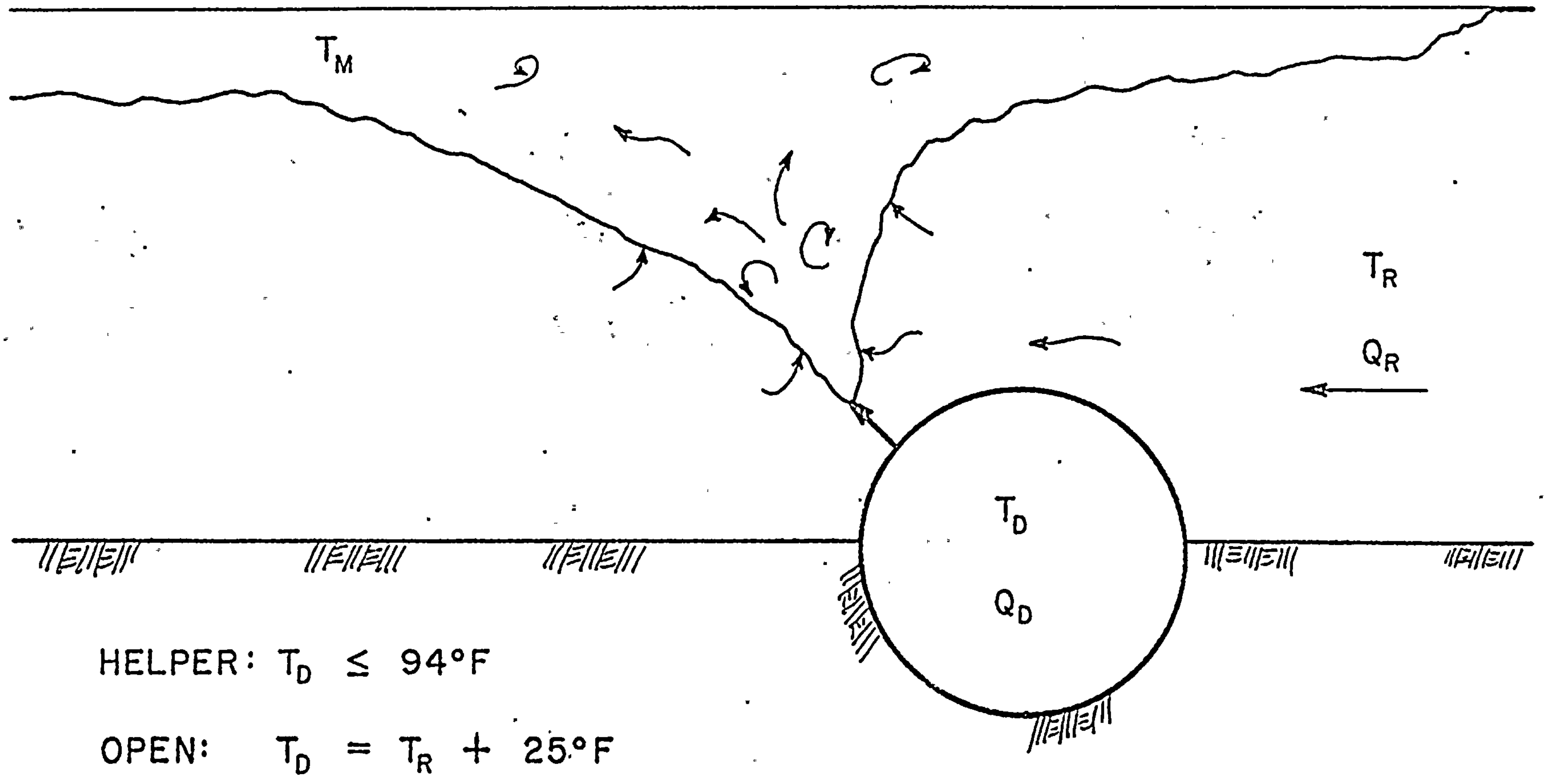


FIGURE 7.2-1 Schematic of Diffuser-Induced Mixing

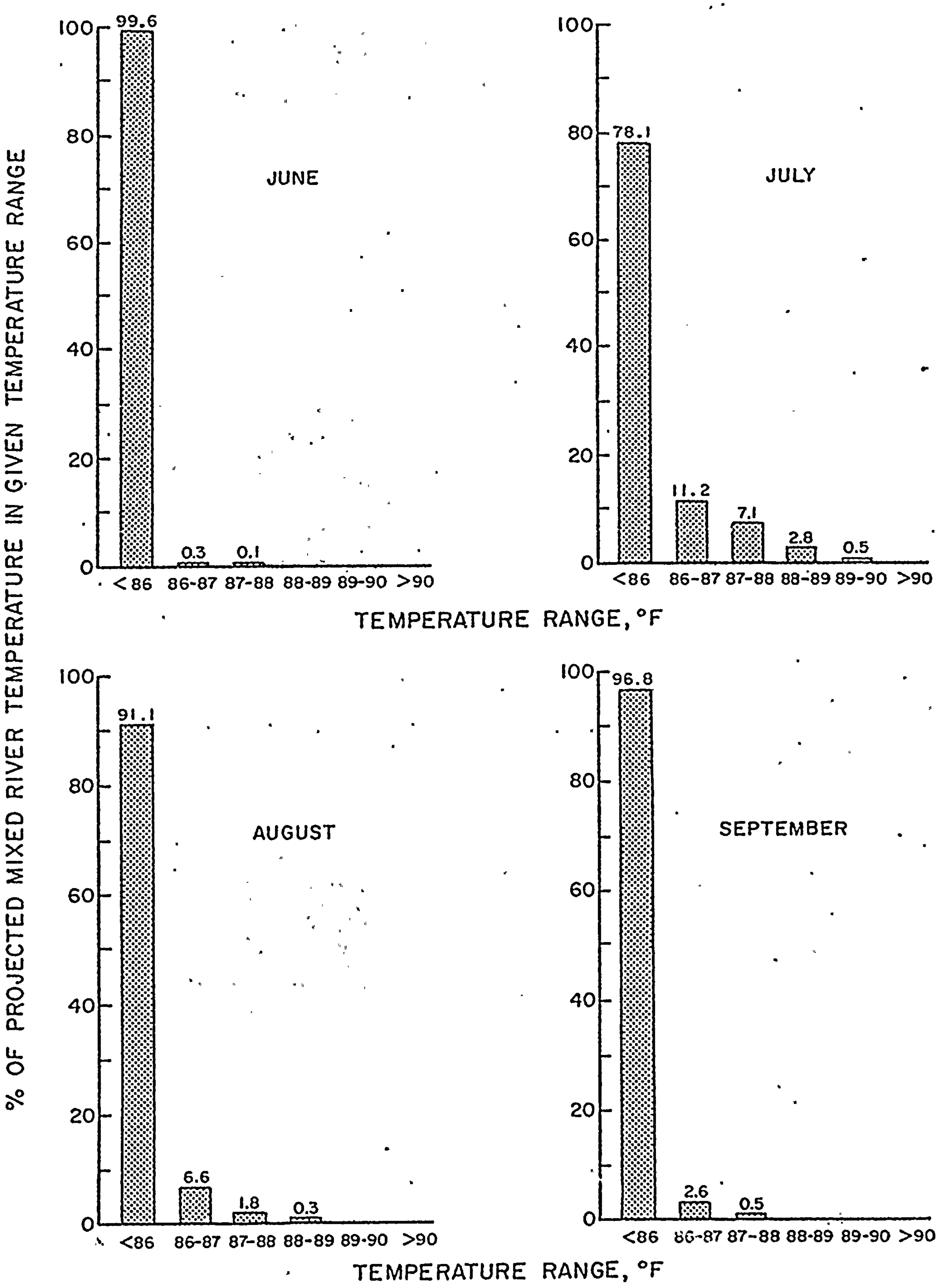


FIGURE 7.2-2 Projected Mixed River Temperature Frequency Analysis

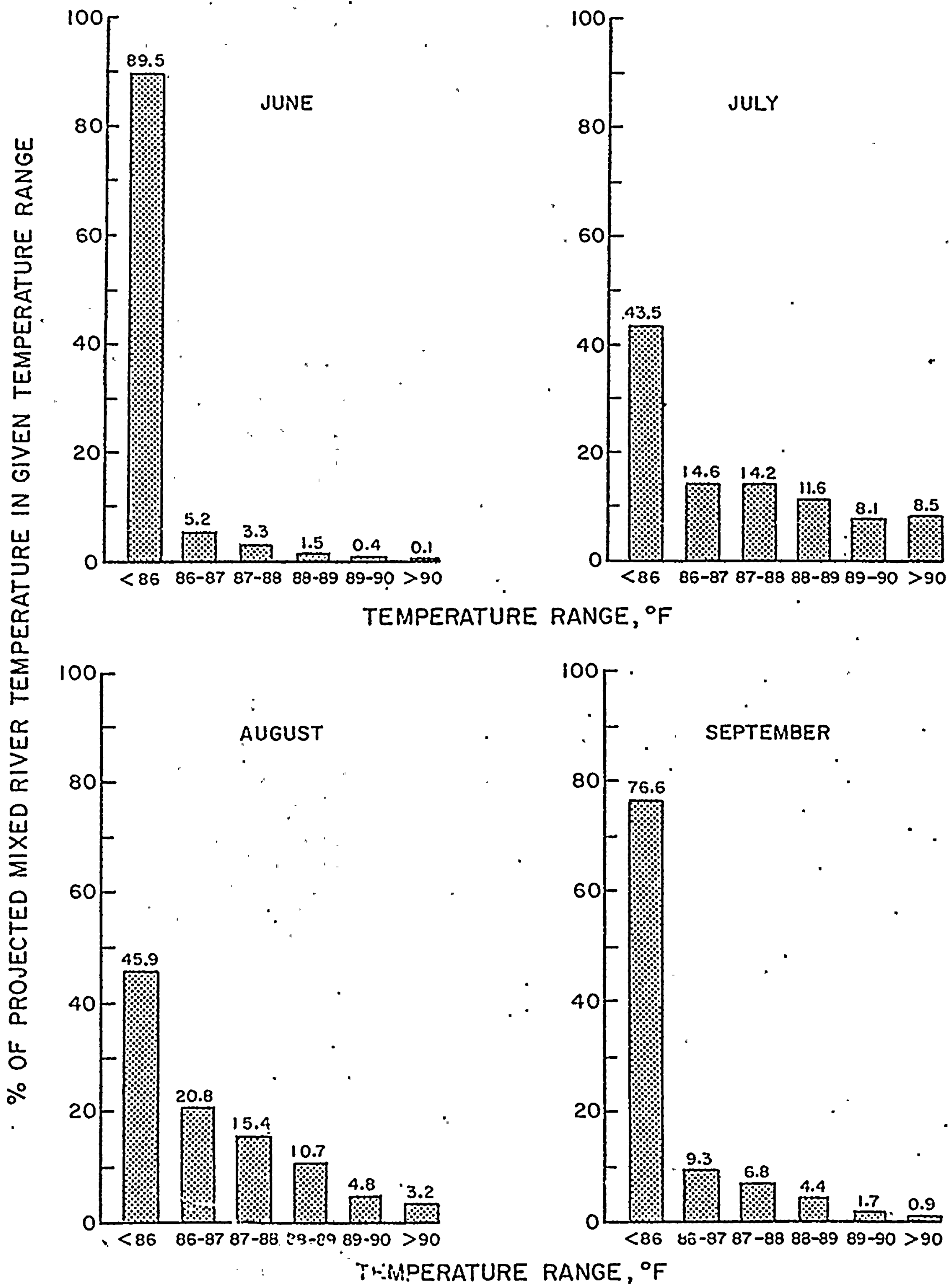


FIGURE 7.2-3 Projected Mixed River Temperature Frequency Analysis

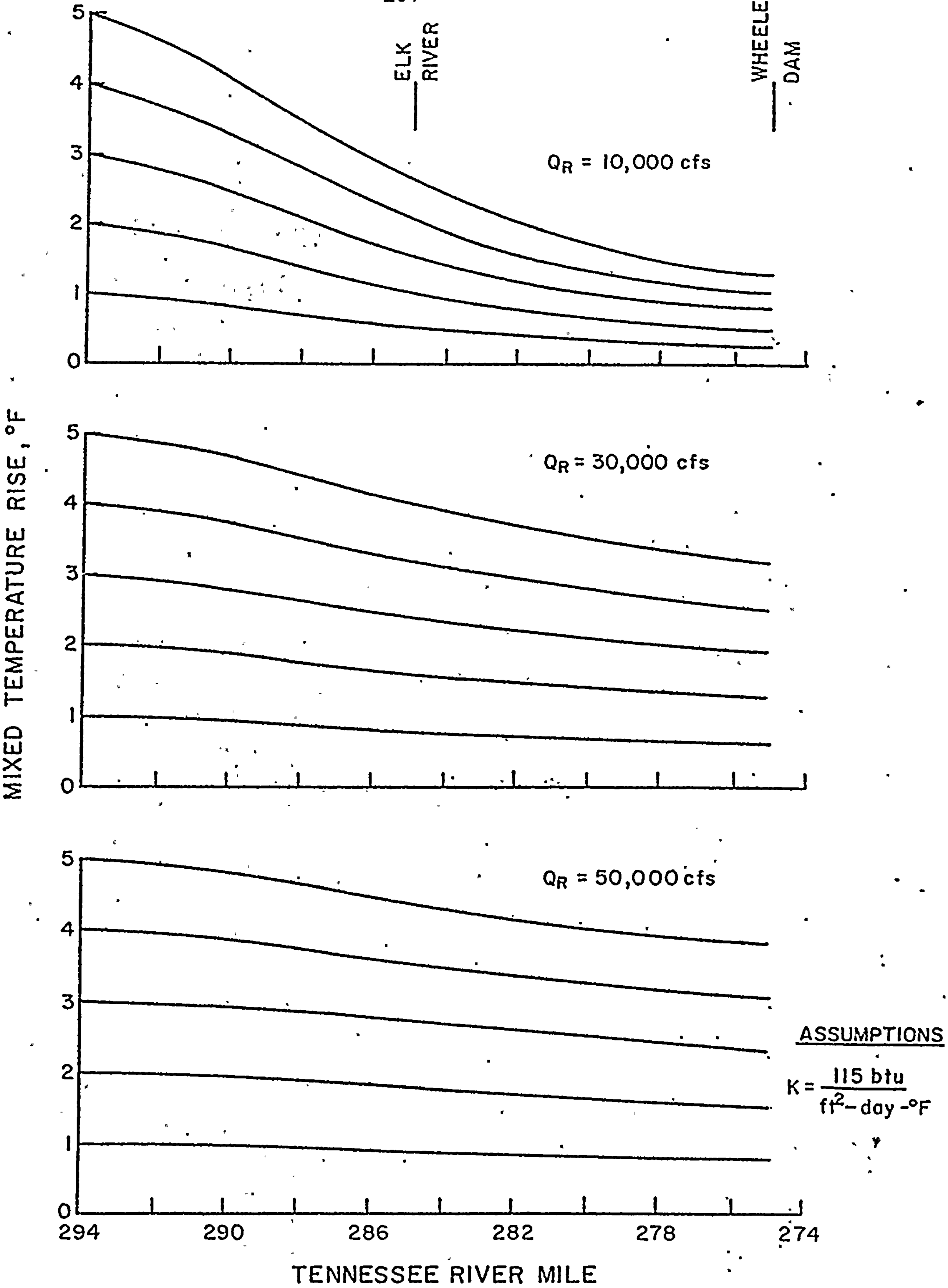


FIGURE 7.4-1 Predicted Downstream Mixed Temperature Rise

8.0 Power Supply Situation

For the remainder of the 1977 summer peak period and extending into the summer peak periods of 1978 and 1979, TVA's power supply situation is expected to be tight. Even with the Browns Ferry Nuclear Plant operating at full output, TVA will be relying heavily upon neighboring utilities for emergency assistance.

The following table shows the expected deficiencies for the summer peak periods of 1977-79 with the Browns Ferry plant at full output. These margins represent approximate megawatt deficiencies of 1,500 MW in 1977, 1,300 MW in 1978, and 800 MW in 1979 below the level that TVA deems adequate for a reliable supply of bulk power.

DEFICIENCIES BELOW DESIRED RESERVES
SUMMER PEAK PERIODS

Period	Deficiencies MW
1977	
July	639
August	536
September	1,524
1978	
June	-
July	252
August	107
September	1,323
1979	
June	490
July	627
August	850
September	246

Any reductions in the output from the Browns Ferry plant will increase the above deficiencies, increase the risk that TVA will be unable to fulfill its power supply obligations to its customers, and increase TVA's reliance upon neighboring utilities for assistance. Since most of the utilities surrounding TVA are summer peaking systems, the availability of purchase power in large blocks is very uncertain; and, if it is available, the price of purchased power will likely be very high. Increased cost incurred because of purchase power to offset the reductions in the Browns Ferry Nuclear Plant output will result in an increase in rates to the consumer.

With median 96°F temperatures, the river temperature often exceeds the 86°F maximum. TVA has been forced to reduce output of the Browns Ferry plant some 1,500 MW or more because of the 86°F maximum or 5°F rise thermal standard. Increased system operating cost associated with these reductions have been as high as $40,000 to $50,000 per hour. For the three-week period ending July 16, 1977, the total estimated cost of Browns Ferry power reduction has been approximately $12.0 million.

Unsuccessful efforts to overcome deficiencies associted with reductions inthe Browns Ferry plant output could result in reductions of firm load. Such reductions could be reflected in systematic reductions in the region's industrial and commercial loads and possibly to the residential consumers, resulting in economic penalties to the region's industrial operations as well as to the employees of such industries and to the general populace. Further, since the TVA system operates as a part of an interconnedted network covering essentially the entire eastern United States, such reductions in capacity on the TVA system could affect the reliability of a large part of the Nation's power supply.