TENNESSEE VALLEY AUTHORITY

Office of Natural Resources and Economic Development
Division of Air and Water Resources

AN ASSESSMENT OF POTENTIAL IMPACT OF THE CLINCH RIVER BREEDER REACTOR PLANT THERMAL EFFLUENT ON THE WATTS BAR RESERVOIR STRIPED BASS POPULATION

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AN ASSESSMENT OF POTENTIAL IMPACT OF THE CLINCH RIVER BREEDER REACTOR PLANT THERMAL EFFLUENT ON THE WATTS BAR RESERVOIR STRIPED BASS POPULATION

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Introduction

This report is an assessment of potential adverse impact to striped bass (Morone saxatilis) in Watts Bar Reservoir caused by thermal effluent from operation of the the Clinch River Breeder Reactor Plant (CRBRP). The Clinch River arm of Watts Bar Reservoir is occupied by adult striped bass during the warmest months of the year. Concern was raised that operation of the CRBRP, specifically thermal discharges, could conflict with management of striped bass.[1] This concern forms the basis for the following requirements outlined in Part III, Section M of the NPDES permit (TN0028801):

> Permittee shall conduct studies to assure that thermal discharges will have minimal impact on striped bass (Morone saxatilis) during extended summer periods of zero flow as described in Section 4.1.2 of the "Update to the CRBRP Alternative Siting Analysis Within the TVA Power Service Area" (dated May 28, 1982).
>
> Permittee shall not start construction of the plant discharge structure prior to submittal of reports on these studies (see Part III.P.) and receiving approval by the Director, Water Management Division to start such construction. Such studies and reports shall include (1) coordination with TVA studies on lethal temperatures for adult and juvenile striped bass, (2) statistical analysis of streamflow during the months of July through September, (3) reevaluation of the thermal plume dispersion, and if necessary, (4) a review of alternative diffusion designs and thermal modeling. In the event that the above studies fail to demonstrate that the CRBRP thermal discharge will have no significant impact on the striped bass thermal refuge, this NPDES permit shall be modified to impose more stringent thermal limitations on plant discharges.

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[1] Letter, Dr. Charles C. Coutant of Oak Ridge National Laboratory to Dr. Michael T. Masnik of the U.S. Nuclear Regulatory Commission, December 16, 1981.

The following sections of this report address the above requirements.

Striped Bass Thermal Requirements

Literature Review

Coutant (1981) describes a "thermal niche" as the temperature selected in a thermal gradient after many hours of exposure and the temperature at which growth rate is maximum on unrestricted food ration. This "thermal niche" changes with size/age of striped bass. Whereas spawning as well as survival and growth of embryo and larva appear optimal at 64.4°F (18°C), juvenile growth is optimal at 75.2 to 78.8°F (24 to 26°C). Striped bass adults tagged with temperature sensing transmitters selected 64.4 to 68°F (18 to 20°C) water in Tennessee reservoirs in summer. Coutant concluded that while lakes with summer temperatures near 75.2 to 78.8°F provide optimal thermal conditions for juveniles, lakes without well oxygenated waters about 71.6°F (22°C) or less in temperature will be unsuitable for adult striped bass larger than about 5 kg. He attributed the "thriving population of large (greater than 14 kg) healthy striped bass" in Watts Bar Reservoir to extensive warm shallow coves for juveniles to grow and cool water (<71.6°F) in the Clinch River arm for adults to reside during summer.

Gift and Westman (1971) examined upper avoidance temperature of several estuarine fishes, including striped bass. Areas with temperatures above the upper avoidance level were considered unacceptable environment. Their experiments were conducted in a tank with a gradual, moving thermal gradient. They also determined the fishes' Critical

Thermal Maximum (CTM), which is the thermal point at which locomotor activity becomes disorganized and the animal loses ability to escape conditions that will soon cause death. A third temperature measured was that which caused death. This was determined experimentally by recording that temperature in the gradient which caused death of each individual and then calculating the lethal dose for death of 50 percent of the experimental population (the LD_{50}) by probit analysis. In their experiments five four-year old striped bass actively avoided a water temperature of 80°F (26.7°C), had a mean avoidance breakdown temperature (CTM) of 86.0°F (30.0°C), and an LD_{50} of 88.8°F (31.5°C). Large size relative to the experimental tank restricted completely free movement of these fish to cooler areas. Under less confinement these fish might have shown avoidance at even lower temperatures.

Few other studies are mentioned in the literature which specifically address thermal requirements for adult striped bass. Merriman (1941, in Talbot 1966), observed the maximum temperature tolerated by striped bass was around 77.0 to 80.6°F (25 to 27°C) and that fishkills occurred at these temperatures in the New England area. No mention was made of other factors which may have contributed to these kills. McLane (1958, also in Talbot 1966), observed striped bass congregated in a spring-fed tributary of the St. Johns River, Florida, having a temperature near their physiological tolerance (76.0°F, 24.4°C). Mean temperature for the St. Johns River in July is 82.6°F (28.1°C).

Axon (1979) stated one limiting factor for striped bass success in Herrington Lake, Kentucky, was natural mortality of adults larger than two to three kg (four to six pounds) in August and September. These fish occupied temperatures of 73 to 74°F (22.8 to 23.3°C) at a depth range of

28 to 32 feet. Insufficient oxygen in cooler water and intolerable temperatures in shallow oxygenated depths were believed to cause a lethal temperature/dissolved oxygen squeeze similar to that described by Coutant (1978) for Cherokee Reservoir, Tennessee.

From Cheek's (1982) description of striped bass movements throughout Watts Bar Reservoir, it is clear adults prefer the cooler, well-oxygenated (>4 ppm) water in the Clinch River arm and portions of the Tennessee River arm in late summer to the warmer 75.2 to 77.0°F (24 to 25°C) less oxygenated water (<3 ppm in August and September 1980 at depths greater than 10 m) in main portions of the reservoir. It is not clear that fish would have died if confined to the main portion of the reservoir. No heavy mortalities similar to those in Herrington Lake, Kentucky, and Cherokee Reservoir, Tennessee, have been observed in Watts Bar Reservoir during years (since 1964) striped bass have been present.

Although extensive tracking studies in several Tennessee Valley Authority (TVA) reservoirs have shown temperature is a strong factor in striped bass distribution, many factors are known to be important in influencing preferred temperature, including acclimation temperature, size, season, and photoperiod (Gift and Westman 1971). Dissolved oxygen also appears to have an important influence on distribution.

TVA Striped Bass Studies

Experiments were conducted at TVA's Aquatic Environmental Research Station at Browns Ferry Nuclear Plant in Alabama to estimate upper lethal temperature of adult striped bass and hybrid adult *Morone* (striped χ white bass), and survival and growth of juvenile striped bass and hybrid *Morone*. These experiments were conducted in outdoor heated raceways (concrete channels) under relatively natural seasonal and diel temperature fluctuations. Large heat exchangers and waste heat from the adjacent Browns Ferry Nuclear Plant were used to incrementally elevate water temperature in selected raceways.

In the lethal temperature experiment, adult Morone (striped bass and striped x white bass hybrid) were confined within the simulated "natural" thermal environment of the channels and routinely monitored for mortality during the period of warming water temperature, spring to summer. One set of channels reflected ambient Wheeler Reservoir temperatures with other channels heated approximately 6°C above ambient.

The experiment was run from October 15, 1981, through September 7, 1982, though adult striped bass were not obtained until May 6, 1982. A more complete description of this investigation is in Heuer et al. (1983 in preparation).

Only seven adult striped bass were obtained for the experiment, one fish died from disease and two from routine electrofishing in the channels. Of the four remaining fish, three in treatment channels lived 47, 56, and 57 days after mean daily water temperature first exceeded 78.8°F (26°C). One fish in a control channel lived 56 days after mean daily water temperature first exceeded 78.8°F. Average daily water temperature increased very gradually during the period when fish died; thus mortality of adult striped bass could not be associated with temperatures in excess of a particular upper lethal end-point. Average daily temperature ranged from about 82.4°F (28°C) to 98.6°F (37°C) during the time striped bass mortalities occurred.

An important observation was that feeding activity by adult Morone ceased after average daily temperature exceeded about 78.8°C.

Death appeared to result from marked diminishing of fitness during the warmest periods. All fish recovered during the experiment were severely emaciated and experienced considerable weight loss (up to 33 percent).

Striped bass adults stocked in early May showed no preference for cooler areas of the channels when water temperatures were less than 77°F (25°C). However, at temperatures 77°F or greater, strong association of adults with cooler regions was observed.

This study indicated adult Morone could survive brief periods of average daily temperatures as high as 89.6°F (32°C), which is the maximum expected end-of-pipe discharge temperature at the CRBRP. However, exposure to prolonged periods of temperatures in excess of 78.8°F (26°C) would likely result in significant mortality to the population.

Desirable Temperatures

In summary a suitable thermal environment for adult striped bass is still not precisely defined. Although tracking studies have shown temperatures striped bass occupy in some reservoirs, they provide little or no information on maximum temperatures tolerated. Long-term laboratory studies of adult striped bass are difficult to conduct because of large size of the fish and their requirements for large amounts of prey. Concensus of the few studies conducted to date suggest maximum desirable temperatures may be somewhat higher than the <71.6°F (22°C) stated by Coutant (1981). However, well oxygenated water with temperatures of about 71.6°F would likely provide an adequate buffer against stresses which exist at maximum tolerable temperatures. Thus, for management purposes maximum temperatures near or slightly above 71.6°F are probably optimum.

Statistical Analysis of Flows in the Vicinity of the CRBRP

A one-dimensional, unsteady flow routing model was used to determine flows at the CRBRP. This model incorporated releases from Melton Hill, Watts Bar, and Ft. Loudoun Dams to determine the net effect of these flows at the CRBRP. In previous reports, flows at the CRBRP were inferred from releases at Melton Hill Dam. Therefore, results in this report represent a more thorough analysis of flows at the site.

The flows, which were evaluated using the model, were statistically analyzed to determine frequency and duration of flows less than zero (reverse flow). Results of this analysis are presented in table 1. In addition, a frequency duration analysis was done for flows less than 1,000 cfs (28.3 m^3/s), and these results are shown in table 2.

The statistical analysis results show that under present operating conditions the maximum period of less than zero flow was 8 hours in duration. Low flows less than 1,000 cfs did not extend over 1.5 days in length. Therefore, long periods of reverse or low flow are not expected to occur at the site.

Mixing of Plant Discharge

The plant's current design for the thermal effluent (7.31 cfs [0.21 m^3/s] maximum) is to discharge through an eight-inch diameter nozzle submerged nine feet below the water surface. Therefore, the analysis of thermal impact was performed using a model that simulates mixing of a round, buoyant jet. Several ambient thermal conditions were coupled with the highest discharge temperature to determine the zone of thermal influence. In all cases the analysis was done for the zero flow situation.

Table 1. Occurrence and Duration for River Flows Less Than 0 CFS for the Total Period 1978 through 1982

Month	Total Hours	Duration (Hours)*				
		1-2	3-4	5-6	7-8	9+
January	701	167	131	4	0	0
Febuary	713	163	133	4	0	0
March	995	230	188	6	1	0
April	1,174	268	218	6	0	0
May	1,444	317	269	9	0	0
June	1,145	260	200	5	2	0
July	1,122	211	223	8	0	0
August	1,100	197	229	4	0	0
September	1,089	219	203	10	1	0
October	1,272	262	234	10	0	0
November	1,198	251	229	10	0	0
December	1,086	242	211	7	0	0

* Durations are discrete, that is a 6-hour duration was not counted as six 1-hour durations, five 2-hour durations, etc.

Table 2. Occurrence and Duration of Flows Less Than 1,000 CFS for the Total Period 1978 through 1982

Month	Total Hours	Duration (Hours)*				
		1-6	7-12	13-24	25-36	37+
January	1,011	264	19	4	0	0
February	1,019	249	19	6	0	0
March	1,559	298	55	8	0	0
April	1,675	403	38	3	0	0
May	2,129	444	51	10	1	0
June	1,579	387	36	2	0	0
July	1,528	386	30	0	0	0
August	1,489	379	26	2	0	0
September	1,451	389	18	3	0	0
October	1,708	413	44	0	0	0
November	1,771	352	63	4	0	0
December	1,628	351	40	7	0	0

* Durations are discrete, that is a 6-hour duration was not counted as six 1-hour durations, five 2-hour durations, etc.

Worst case summer ambient conditions (CRBRP Environmental Report, 1981) were used to determine maximum temperatures expected in the vicinity of the discharge. Considered as worst case conditions were:

- Uniform ambient temperature of 78°F (25.6°C),
- Discharge temperature of 89.6°F (32.0°C), and
- Zero ambient flow.

Seventy-eight degrees F (25.6°C) was the maximum instantaneous temperature experienced near the site for the period 1963-1979 (the temperature recorder was at CRM 21.6, 1.5 miles downstream from Melton Hill Dam). Results of this evaluation are shown in figure 1. Because of the high discharge velocity (20.9 fps [6.4 m/s]) the plume experiences very little vertical displacement as it travels across the river. The 79°F isotherm encompasses an area approximately 29 ft (9 m) long and 4 ft (1.2 m) wide at its maximum width. This compares with a total cross sectional area of the river at this location of approximately 7,000 ft^2 (650 m^2).

A more representative summer ambient temperature would be one that reflects the thermal stratification present during these months. An analysis of temperatures resulting from mixing the discharge into a stratified (78°F at surface and 73°F [22.8°C] at bottom) environment was undertaken. These results are in figure 2. Because of ambient stratification the temperature distribution within the plume is unlike that for the previous case. However, tendency for the plume to maintain a horizonal trajectory is still evident. Zone influenced by the plume is again very small.

A third analysis was made using warmest temperatures recorded in August 1983. In figure 3 vertical displacement of the plume as it travels across the river is larger than in the previous two cases. This

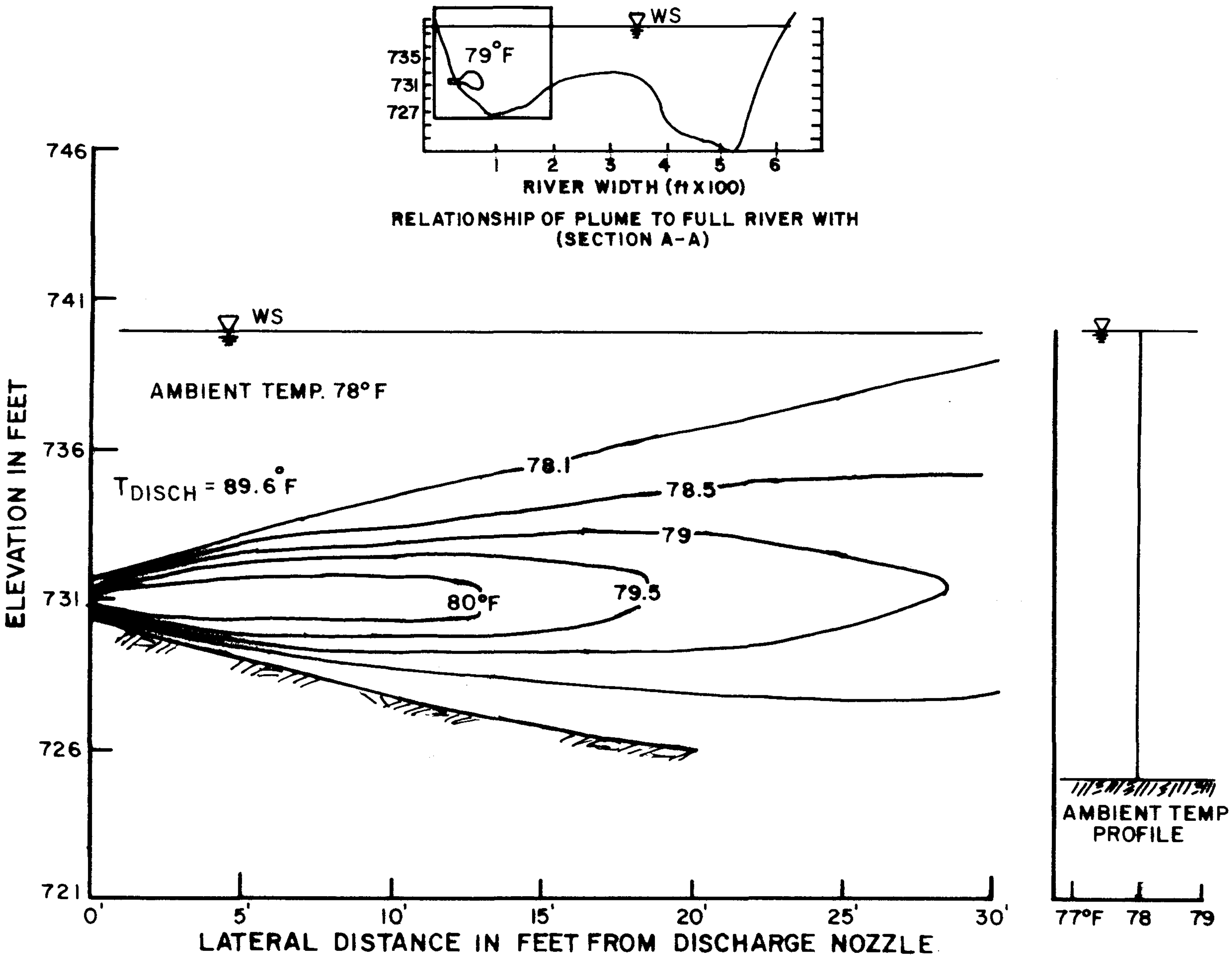

Figure 1. Temperature within Discharge Plume Under Uniform Ambient (78°F) Conditions.

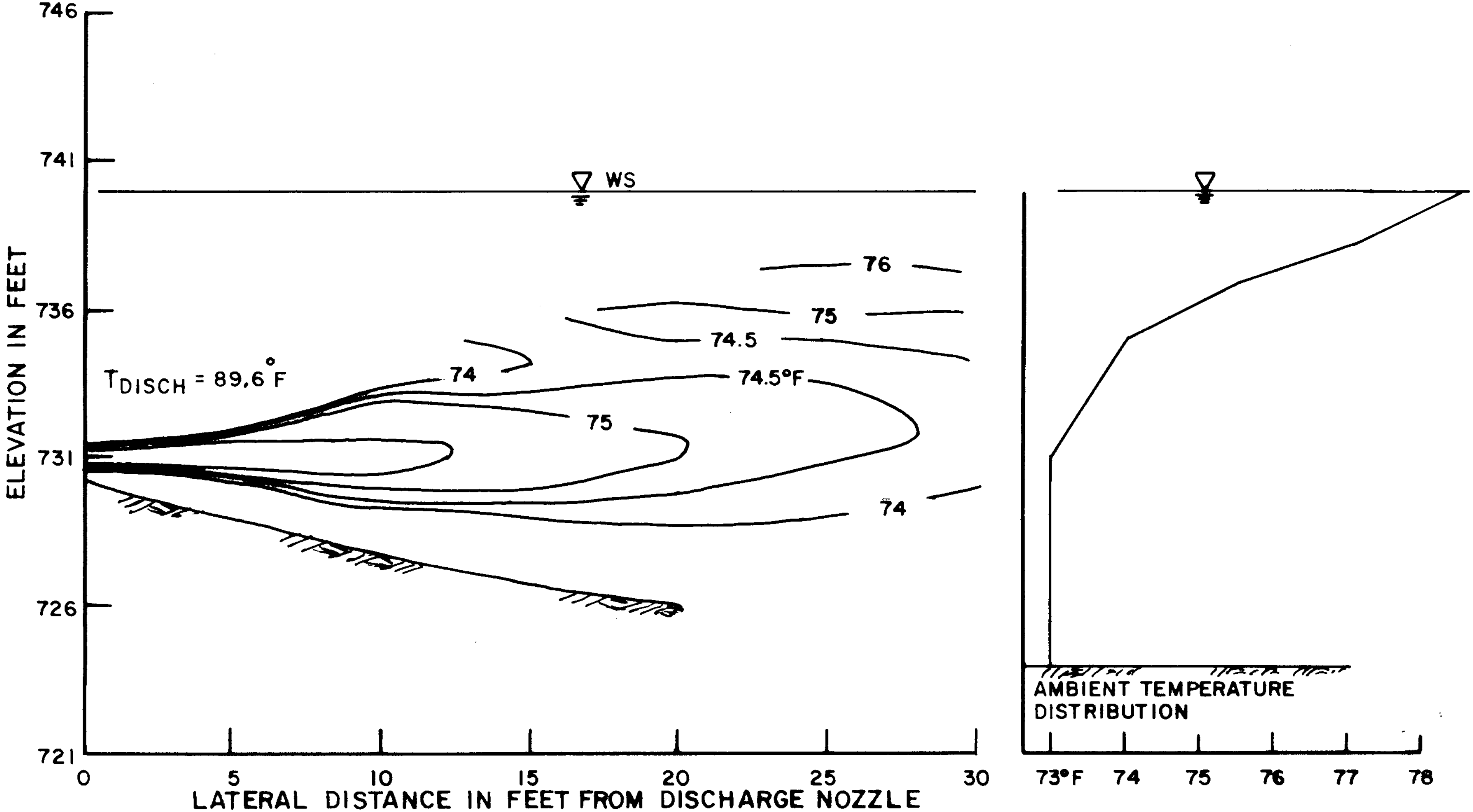

Figure 2 . Temperature within Discharge Plume Under 5°F Ambient Thermal Stratification

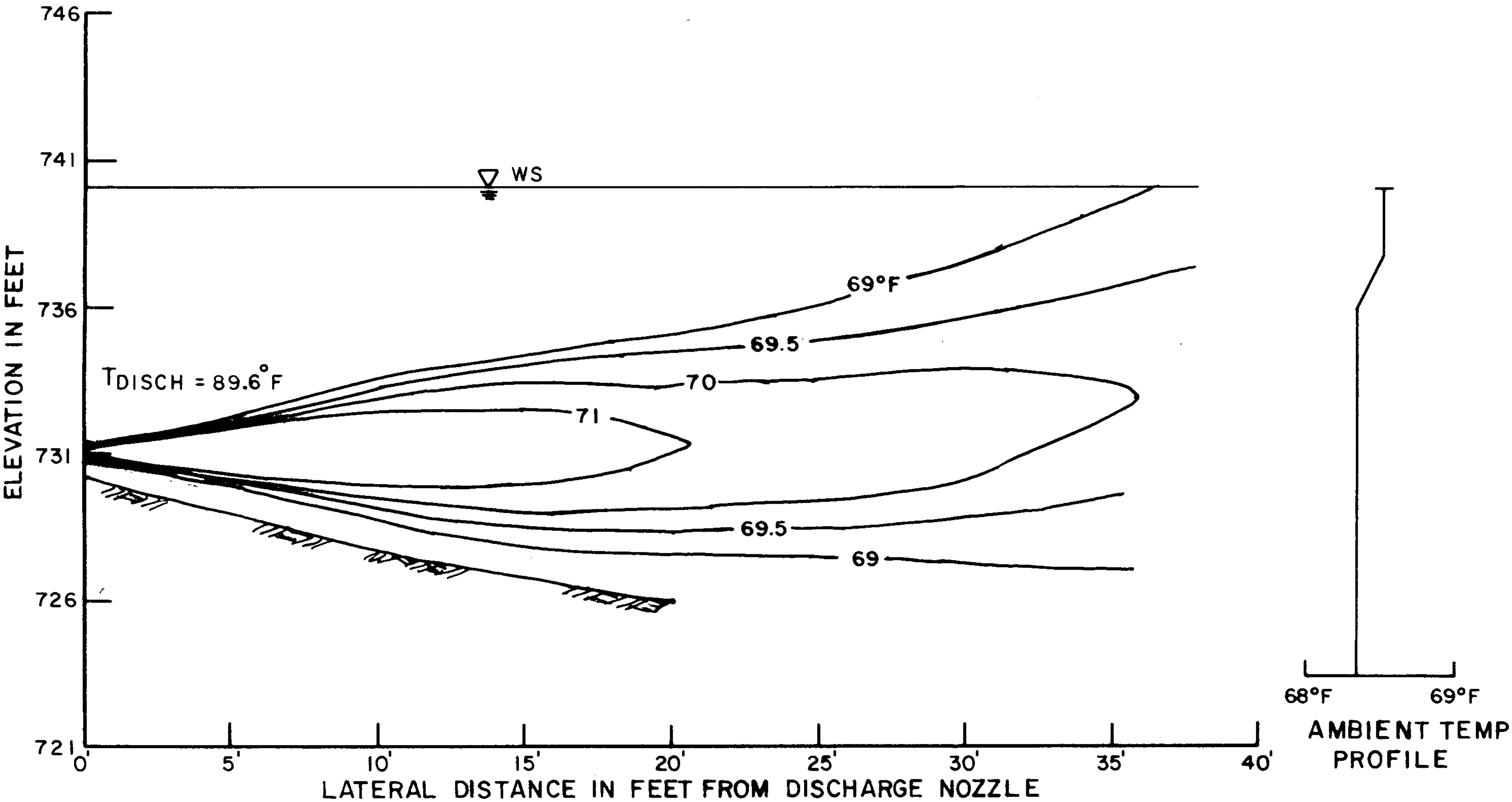

Figure 3. Temperature within Discharge Plume Under the Warmest Ambient Conditions Measured in August 1983

is the result of an increased buoyant force brought on by the larger temperature difference between the discharge and ambient (89.6°F [32°C] and 69 to 68°F [20.6 to 20.0°C], respectively). Other than this characteristic, size of the plume is comparable to the other cases investigated.

CONCLUSION

In all cases examined the thermal plume becomes nearly imperceptible within a short distance from the discharge pipe (about 30 ft [10 m]) compared to river width (about 630 ft [190 m]). Under worst case conditions any presence of the plume in the main channel (opposite side of the river from the discharge) will be confined to the surface layer of the water. An ample portion of river cross section containing ambient temperature water for passage or residence of adult striped bass will always be available in the vicinity of this thermal effluent. Although a small portion of river cross section would exceed the thermal tolerance of striped bass, the fish would naturally avoid this area and seek out adjacent cooler water. Therefore, it is concluded the CRBRP thermal effluent will not significantly affect the integrity of the striped bass thermal refuge in the Clinch River arm of Watts Bar Reservoir. At this time there is no need to consider alternative diffuser designs and thermal modeling.

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