FORT CALHOUN STATION

UNIT NO. 1

THERMAL IMPACT STUDY FINAL SUMMARY REPORT

1972 THROUGH 1977

by

OMAHA PUBLIC POWER DISTRICT

March, 1978

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

INTRODUCTION

The Thermal Impact Study (TIS) was conducted at the Fort Calhoun Nuclear Generating Station, Unit No. 1 (FCS) which is located about 19 miles north-northwest of Omaha, Nebraska at Missouri River Mile (RM) 646.0 (Fig. 1). The FCS is a 481 gross electrical megawatt nuclear generating station, which utilizes a pressurized water reactor that is licensed to produce 1420 megawatts thermal. Missouri River water is used in the plant's "once-through" condenser cooling system. Three circulating water pumps pump a total of 3.6×10^5 gpm to the plant's two turbine condensers. The water is returned to the Missouri through a submerged discharge ~60 ft. downstream of the intake structure which houses the circulating water pumps.

The plant rejects heat to the cooling water at a rate of $\sim 3.3 \times 10^9$ BTU/hr. At full load this results in an approximate temperature rise over ambient of 18°F (ΔT). The discharged heated water creates a thermal plume which hugs the Nebraska shoreline and extends downstream of the station. Under normal operating conditions the plume is usually below a 5°F ΔT at a distance of 2000 ft. downstream.

Drift organisms (plankton) are entrained in the condenser cooling water and subjected to both mechanical and thermal effects. Drift organisms that are not pumped through the

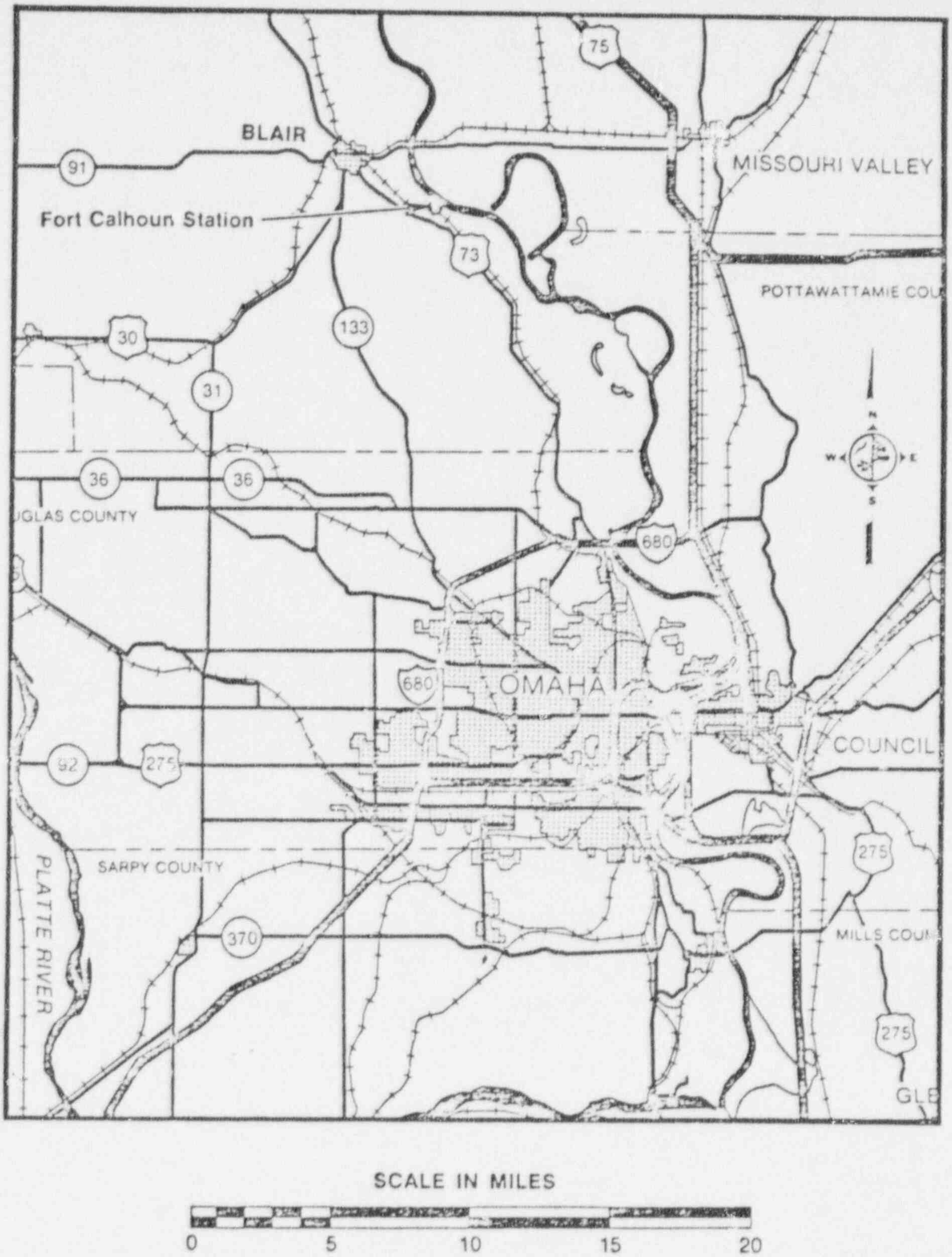


Figure 1 - Site location map

condenser may be entrained in the thermal effluent from the station. Benthic macroinvertebrates and periphyton are also exposed to the thermally enriched waters. These organisms are not discussed in this study, but are the subject of other District programs. The assessment of the effects of entrainment on the plankton and the thermal exposure of the attached organisms (aufwuchs population) of the Missouri River, was the goal of the TIS.

In the 1960's and early 1970's, the potential impact of thermal effluents from industry sources was a matter of rising concern. This situation has been documented by Merriman and Thorpe (1976). During this period thermal discharges became widely known as pollutants even though as mentioned by Merriman and Thorpe (loc. cit.), "...some are inoffensive and some may have beneficial aspects." Additional evidence of the level of concern expressed is apparent in the Federal Water Pollution Control Act, which states that, "...thermal effluents are prohibited unless it can be shown that the effluent limitation is more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made." It was during the time of prime interest in the effects of "thermal pollution" that the TIS was designed and incorporated into the operating license for FCS.

The TIS was designed as a surveillance device under a specific set of assumptions. The evidenced concerns at the

time of its implementation centered on the possibility of irreversible damage to the Missouri River ecosystem as the result of the additional heat discharged to the river. The TIS had as its priorities high frequency sampling, the shortest possible processing of sampled materials and data to permit rapid detection of perturbations, a transect grid design covering the area affected by the thermal plume, and a protocol which was acceptable to ecological scholars on an international basis. Using the International Biological Programme (IBP) rationale, the concept of energy flow through the ecosystem's various producer-consumer levels was selected as the essential feature of the TIS. The use of physiological parameters rather than taxonomic specifics permitted rapid reporting in case of significant deviations due to plant effluent effects.

Collection of TIS samples began in June of 1972 and has continued up to the time of this writing. During this time, the basic rationale of the IBP approach has remained unaltered; however, some components of the program were modified to increase the overall effectiveness of the study.

Specific objectives of the study were:

1) To describe the seasonal variation in planktonic productivity indices and the chemical and physical characteristics of Missouri River water quality.
2) To evaluate the effects of condenser passage and plume entrainment on the planktonic drift organisms at the FCS.

3) To evaluate the thermal effects on the aufwuch's population at the FCS.

4) To assess the IBP rationale as a means of evaluating thermal effects.

MATERIAL & METHODS

The sampling grid (Table 1) for this program was developed over a five-year period as the result of experience. Increased sampling frequency and relocation of sampling points were the outcome of an effort to maximize the intent of the program. The grid, which experience has shown to be most appropriate, uses one ambient transect upstream of the plant and four transects below. The sample points have been established to provide data from two in-plume and one out-of-plume locations on each transect. The degree of thermal influence at each sample point can be defined by reference to Figure 2 which relates the points to a representative thermal plume.

Parameters analyzed in this program are: photosynthesis, respiration, chlorophyll a and b content, protein content, dry weight, and caloric content. Pertinent chemical and physical data are also recorded. Procedural changes were made in two of these analyses to increase analytical capability. Thin layer chromatographic techniques for chlorophyll analysis were abandoned in favor of a more rapid spectrophotometric technique as described by Strictland and Parsons (1968).

TABLE 1: Thermal Impact Study sample collection grid, 1972-1977

TRANSECT DESIGNATION	1972[1]				1973[1]				1974[2]				1975[2]				1976[2]				1977[2]			
	SAMPLE POINT DESIGNATION				SAMPLE POINT DESIGNATION				SAMPLE POINT DESIGNATION				SAMPLE POINT DESIGNATION				SAMPLE POINT DESIGNATION				SAMPLE POINT DESIGNATION			
	A	B	C	D[3]	A	B	C	D[3]	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1.0	15	50	100	15	15	50	150	15	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]
1.5	NA[4]	NA[4]	NA[4]	NA[4]	15	NA[4]	NA[4]	NA[4]	15	NA[4]	NA[4]	NA[4]	15	NA[4]	NA[4]	NA[4]	15	NA[4]	NA[4]	NA[4]	15	NA[4]	NA[4]	NA[4]
2.0	15	50	100	15	15	50	150	15	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]
3.0	15	50	100	15	15	50	150	15	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]
4.0	15	50	150	15	15	50	150	15	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]
5.0	15	50	150	15	15	50	150	15	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]	15	50	250	NA[4]

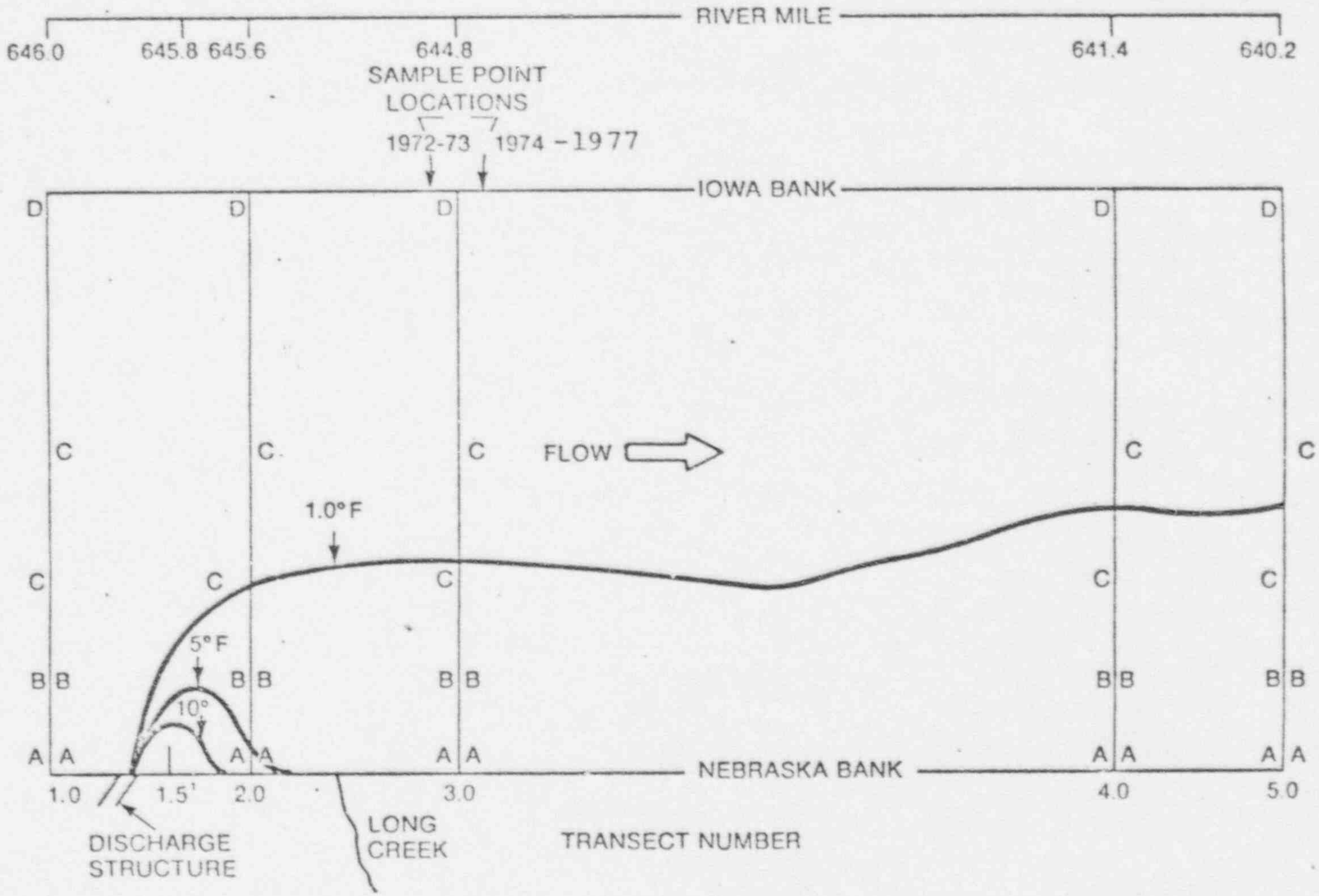
NOTE: Sample point locations (in feet from the Nebraska bank) for each transect.

[1]Collection frequency bi-weekly

[2]Collection frequency weekly

[3]Distance from Iowa Bank

[4]No sample point at this location



1 = LOCATION OF SAMPLE POINT IS 15 FEET FROM THE POINT OF DISCHARGE

NOTE: SAMPLE POINTS 1972-1973 ARE TO THE LEFT OF THE TRANSECTING LINE. SAMPLE POINTS 1974 - 1977 ARE TO THE RIGHT OF THE TRANSECT LINE.

Figure 2 - Representative thermal plume relationships to the Thermal ... act study sample location grid.

Protein analysis was modified to incorporate the utilization of a specific ion electrode technique for the determination of ammonia content instead of a distillation and colorimetry procedure. No other significant changes in parameter evaluation were made.

Drift plankton were collected through the utilization of an integrated pumped water technique. A Randolf peristaltic pump connected by 3/8" I.D. tubing to an isokenetically designed nozzle was utilized for pumping. The nozzle was fixed to a 34 Kg lead weight, which was rigged to a winch by cable. The winch and a U.S.G.S. crane assembly were used to raise and lower the collection nozzle in the vertical component of the water column at sample locations. An 18 ft. boat was used to mount the crane and winch and locate the assembly for sample collections. The rate of raising and lowering the nozzle was controlled so that the composition of the one gallon sample collected was representative of all vertical components of the water column sampled. Power was adjusted so that the boat's position remained constant. Rangefinders were used to assure that proper distances from the shore were maintained. Samples collected in amber one-gallon glass carboys were then returned to the lab for analysis.

Normal sample collection practice involved the collection of six one-gallon samples from the near vicinity of the plant. These samples were followed by six samples from downstream locations. Available laboratory equipment allowed the processing of six samples at a time. The second set of six samples

were normally delivered to the lab within four hours of the first set. This allowed sufficient time to make processing of the second set possible without an in-lab delay.

The macroinvertebrate population was sampled by means of a rock basket sampler. This device consisted of a chrome plated chicken barbeque basket that was utilized to enclose sections of cement bricks. This device is similar to that described by Weber (1973). Seven sections were placed in each basket, with a total surface area of 2100 $\pm$ 100 cm^2. These devices were positioned at opposite shore line stations on each sample transect (Figure 2). Lengths of cable were used to attach baskets to available piling or stakes that were driven into the bank. Where possible, enough cable was used to allow the baskets to be submerged six feet below the water's surface. As the river's surface elevation varied, adjustments in cable length were made to maintain a submerged condition.

Baskets were allowed a three-week incubation period prior to collection. Rock baskets were slowly raised to the surface by their attached lengths of cable for retrieval. Each basket was held over a five-gallon plastic bucket as the rocks were removed from it. Each of the seven sections of the brick was then placed in the bucket which contained filtered river water. This water was prepared by passing ambient temperature river water through a pre-filter and a .45 micron milipore filter cartridge. Prior to moving the

Environtal Lab to the Fort Calhoun site in 1975, each of the buckets were aereated by use of an air pump until they were returned to the lab. The brick surfaces were then scraped with brushes and spatulas into beakers containing 500 mℓ of filtered river water for processing.

In 1974, the collection frequency for both the pumped water and rock basket samples was modified from bi-monthly to weekly. The samples were collected from the months of April through November, which coincided with the river navigation season. No samples were collected during the winter months due to hazardous river conditions.

Both the pumped water and rock basket samples were processed by size screening and through the use of methods recommended by the International Biological Programme (IBP) for aquatic studies. In addition to the routine processing by IBP methods, fixed samples of the biota were catalogued and stored for reference. Complete step-by-step procedures for all analyses are recorded in laboratory procedure manuals.

The sorting of each sample by size was accomplished by sieving procedures. The collected material from both basket and pumped water samples are poured through a series of sieves. A 0.965 mm opening stainless steel mesh was used to collect large organims; a 0.165 mm opening stainless steel mesh was used to collect intermediate sized organisms; and a .45μ millipore membrane filter was used to collect microorganisms. Each screen and filter pad was then washed

with 30 mℓ of filtered river water. Aliquots of each sample component were then taken to perform various testing procedures.

Photosynthesis and respiration procecures were run immediately after sarple sieving. These parameters were measured by use of a Gilson Differential Respirometer using either dark or illuminated operation. Respiratory and photosynthetic rates were determined by recording gas volume changes during a 1-1/2 hour period of testing.

Dry weight was determined by drying sample aliquots in in crucibles to a constant weight at 60°C in a vacuum oven. Respiratory, photosynthetic, chlorophyll, and protein values were then normalized by dry weight (parameters 8 through 11, Table 2).

Protein content was measured by means of a kjeldahl digestion procedure. The nitrogen content was then determined by means of a distillation and spectrophotometric technique. This procedure was later replaced by a less hazardous ion electrode method. A gas-sensing ammonia electrode was utilized in basic solutir (pH 11) to determine the ammonia content. The protein concentration was then calculated based on the nitrogen content (Golterman, 1971).

The determination of caloric content was accomplished through the utilization of a Parr microbomb (22 mℓ) calorimeter. Samples were pelletized with benzoic acid of known caloric content. The pellets were placed in the bomb and burned in an atmosphere of O_2. The heat of combustion was

TABLE 2: Sample units by parameter number

The parameters evaluated are coded in the data sheets under the heading "Parameter" or "Index" and are numbered as follows:

Pumped Water

		Units
1.	Respiration	μℓ/hr
2.	Photosynthesis	μℓ/hr
3.	Protein	mg/ℓ
4.	Chlorophyll A	mg/ℓ
5.	Chlorophyll B	mg/ℓ
6.	Caloric Content	cal/ℓ
7.	Dry Weight	mg/ℓ
8.	Respiration	μℓ/hr/mg dry wt
9.	Photosynthesis	μℓ/mg dry wt
10.	Chlorophyll	mg/mg dry wt
11.	Protein	mg/mg dry wt
12.	Calories	cal/gm
13.	Temperature	°C
14.	Diss. O_2	ppm
15.	5 Day B.O.D.	ppm
16.	Turbidity	FTU
17.	NH_3 as (N)	ppm
18.	NO_3	ppm
19.	NO_2	ppm
20.	Organic Phosphorus	ppm
21.	Inorganic Phosphorus	ppm
22.	Calorie Content	cal/mg protein
23.	Respiration	μℓ/hr/mg protein
24.	Photosynthesis	μℓ/hr/mg protein
25.	Chlorophyll	mg/mg protein

Rock Basket

		Units
1.	Respiration	μℓ/hr/basket
2.	Photosynthesis	μℓ/hr/basket
3.	Protein	mg/basket
4.	Chlorophyll A	mg/basket
5.	Chlorophyll B	mg/basket
6.	Calorie Content	cal/basket
7.	Dry Weight	mg/basket
8.	Respiration	μℓ/hr/mg dry wt
9.	Photosynthesis	μℓ/hr/mg dry wt
10.	Chlorophyll	mg/mg dry wt
11.	Protein	mg/mg dry wt
12.	Calories	cal/gm dry wt
13.	Caloric Content	cal/mg protein
14.	Respiration	μℓ/hr/mg protein
15.	Photosynthesis	μℓ/hr/mg protein
16.	Chlorophyll	mg/mg protein

Basket surface area = 2100 cm^2 $\pm$ 100 cm^2

then measured with a calibrated thermometer. The caloric content was then determined by subtracting, from the total calories given off, the calories that were attributable to the benzoic acid and the ignition fuse. The difference was the calories per gram of sample. The caloric content of each sample component was then calculated based on its dry weight.

Chlorophyll A & B concentrations were determined by the use of a chromotographic technique prior to 1975. Separated components of chlorophyll were removed from cellulose plates, dissolved in acetone and concentrations determined spectrophotometrically. After 1975, plant cells were disrupted in acetone and the extracts directly examined spectrophotometrically. The procedure utilized was that as described by Strictland & Parsons (1968). Extinction coefficients were used to determine concentrations (mg/ℓ) of different chlorphyll components.

Biochemical oxygen demand for unsieved pumped water samples was determined by a Standard Methods procedure (1971). First and fifth day oxygen concentrations were determined by the Winkler method or a Yellow Springs MOdel 54 oxygen meter.

Turbidity was measured on all pumped water samples prior to sieving. With all suspended materials homogeneously distributed, turbidity was measured by a Hach Model 2100A Turbidometer.

Pumped water filtered through .45μ pads were analyzed for concentrations of ammonia, nitrite, nitrate, orthophosphate and total phosphate. Hach powder pillows and procedures were utilized. A Coleman Junior IIA and later a Klett-Somerson colorimeter were utilized along with established curves to determine constituent concentrations.

All data collected for each sample was accumulated on a standard analysis summary sheet (Figure 3). Parameter values for each sieved component were totaled and recorded for statistical analysis. A computer program was utilized in data analysis. Data was divided into seasonal spring, summer, and fall components based on ambient water temperature. These periods of time were indicative of the annual trends in ambient temperature, with the increase from winter lows in the spring, summer peak, and the reduction to winter lows in the fall (Figures 4 to 9).

Statistical testing was accomplished through the comparison of upstream control transect sample location data to corresponding downstream sample location data on a seasonal basis. All "A" location parameter mean values were compared to all downstream "A" location parameter mean values. The same procedure was used for comparing "B", "C", and "D" upstream control data to downstream location data. This procedure was also utilized for comparing the upstream control rock basket data to downstream rock basket data. Rock basket data comparisons were limited to one side of the river.

THERMAL IMPACT STUDY ANALYSIS SUMMARY

Fort Calhoun Station

Sample No. ____________ Sample Date ____________

Determinative Test	22 Mesh .965 mm	105 Mesh .165 mm	.45 Micron	Total
1. Respiration (ul/hr)				
2. Photosynthesis (ul/hr)				
3. Protein Content (mg)				
4. Chlorophyll A Content (mg)				
5. Chlorophyll B Content (mg)				
6. Caloric Content (Cal)				
7. Dry Weight (mg)				

8. Respiration (ul/hr/mg dry wt)				
9. Photosyn. (ul/hr/mg dry wt.)				
10. Chlorophyll (mg/mg dry wt.)				
11. Protein (mg/mg/dry wt.)				
12. Calories (Cal/gm dry wt.)				

13. Water Temperature, °C	
14. Dissolved Oxygen mg/L	
15. 5-Day B.O.D. mg/L	
16. Turbidity (F.T. units)	
17. Ammonia Nitrogen (N)	

18. Nitrate NO_3	
19. Nitrite NO_2	
20. Organic Phosphorus PO_4	
21. Inorganic Phosphorus PO_4	

22. Caloric Content (Cal/mg Protein)				
23. Respiration(ul/hr/mg protein)				
24. Photosyn. (ul/hr/mg protein)				
25. Chlorophyll (mg/mg protein)				

26. Collection Time	
27. Measurement Time	
28. Volume Filtered	2L

REMARKS:

Figure 3

Comparisons of data from opposite banks or from locations on the same transect were not utilized in the analysis of the studies results.

The two-tailed t-test was utilized for statistical analysis. Hypothesis testing was done at the 95% confidence level. The computer printout presents seasonal means for all parameters and the calculated t-values. Significant t-values are indicated by an asterisk.

RESULTS & DISCUSSION

Thermal Impact Study (TIS) sample collections began in June of 1972. Collections were generally made from April through November when access to the river was available. No winter collections were made due to icing and hazardous river conditions. Pre-operational data was collected until reactor operation began on August 21, 1973. During the pre-operational period, 450 pumped water and 134 aufwuchs sample collections were made. This period of time was utilized in refining sample collection and lab analysis procedures. For this reason, no pre-operational/post-operational statistical data comparisons were made.

Fort Calhoun Station operated at 7 to 99 percent of rated power on 236 sample collection dates (105 pumped water and 131 aufwuchs) during the study; the station was shut down for maintenance and refueling during 119 collection dates (62 pumped water and 57 aufwuchs). Aufwuchs samples were

collected on 110 occasions when the plant was operational for the full three-week artificial substrate incubation period.

Spring sample collections began in April from 1973-1977. Ambient river temperature on the first collection dates for pumped water in this period averaged 47.2°F. Maximum mid-summer ambient river temperature on pumped water collection dates averaged 78.8°F, while temperatures during the final fall collections averaged 39.2°F. Summer absolute discharge temperature on pumped water collection dates averaged 90.6°F; a maximum temperature of 97.0°F was recorded on several collection dates. Ambient river temperature and discharge temperature for pumped water collection dates are presented in Figures 4 through 9. Plant ΔT, which represents the differential between ambient and discharge temperatures, reached a maximum of 20.0°F on several occasions during summer sampling.

River flows presented graphically in Figures 10 and 11 were similar in 1973, 1974, 1976, and 1977. In 1972 and 1975, summer flows were higher than other years with 1975 flows approximately twice as great (~65,000 cfs) as the average summer flow rates. Spring (April 1) flow rates averaged 35,000 cfs, while summer (July 1) and fall (October 1) flows averaged 40,100 and 44,700 cfs, respectively. During normal operation, the plant discharge flow rate of 802 cfs amounted to an average of 2.0 percent of the spring, summer, and fall river flow rates (Carter, 1977).

Monitored parameters chosen for trend analysis were selected because of their ability to indicate variations that are attributable to thermal influence on river organisms. Special importance was placed on photoysnthesis and respiration values as the parameters most directly relating to the physiological status of the river populations. Dry weight, an indicator of biomass is also presented.

Normal seasonal variation for the Missouri River in parameter values are great. In order to provide data that is representative of organism density patterns and river temperature and flow regimes, seasonal data analysis is indicated. Breakoff dates for each seasonal period were based on ambient river temperature curves (Figures 4 to 9). The three seasons are characterized by rapid temperature increases from winter lows (spring), peak values (summer), and declining values from the summer highs (fall).

Data for the 1A pumped water location and the IN rock basket location is presented for the trend analysis.

Seasonal variations were noted in all parameters selected for presentation (Figures 12 to 16; Tables 3 to 7). Respiratory rates for pumped H_2O were usually lowest in the spring and summer and highest in the fall. Seasonal patterns in respiration were generally correlated to annual density patterns for zooplankton and macroinvertebrates (Carter, 1977). Respiratory patterns were not, however, correlated to dry weight. Mean respiratory rates for the years of the study

for each season were 33.16 ± 69.84 μℓ/hr. (spring), 32.5 ± 56.53 μℓ/hr. (summer) and 60.03 ± 75.12 μℓ/hr. (fall). Rates within seasons in different years were highly variable as demonstrated by the range of the 95% confidence intervals.

Photosynthetic rates for pumped water did not demonstrate patterns similar to those discussed for respiration; mean spring rates were higher than both summer and fall. Mean values (1972-1977) for spring, summer, and fall photosynthetic rates were 139.36 ± 124.35 μℓ/hr., 111.53 ± 71.76 μℓ/hr., and 113.91 ± 136.42 μℓ/hr., respectively. It was noted that there was considerable variation in rates among collection dates and study years. A high degree of variability was also reported by Kline, P. A. (1977) in phytoplankton density at Fort Calhoun Station. Variations in photosynthesis were not correlated to variations in dry weight.

Pumped water dry weights were influenced by organism densities as well as sediment and detrital loads. Dry weight was not correlated to photosynthesis or respiration, but did exhibit patterns of variation similar to those for turbidity and caloric content. Mean spring (147.32 ± 232.1 mg/ℓ) and summer (204.77 ± 439.58 mg/ℓ) dry weights were greater than fall (85.94 ± 67.39 mg/ℓ); values varied greatly between seasons and years (Figure 12; Table 3).

Rock basket parameter values did not follow patterns of activity similar to those of pumped water. Annual patterns in parameter values were similar to trends in annual temperature cycles (Figures 4 to 9). Respiration, photosynthesis,

and dry weight values were lowest in the spring and fall and highest in the summer. Parameter values maintained consistent patterns, but varied greatly in magnitude from year to year (Figures 4 to 9; Tables 3 to 7).

Respiratory rates were the lowest in the fall of 1972 (318.9 μℓ/hr/rock basket) and highest in the summer of 1975 (1799.5 μℓ/hr/rock basket). Photosynthesis rates were at their extremes at the same time when values were 262.5 μℓ/hr/rock basket (fall of 1972) and 1590.7 μℓ/hr/rock basket (summer of 1975). Dry weights were lowest in the spring of 1975 (1486 mg/rock basket) and highest in the summer of 1973 (11,556 mg/rock basket). Mean values per rock basket for the years of the study (1972 - 1977) for the respiration, photosynthesis, and dry weight were 514.6 $\pm$ 434.36 μℓ/hr., 545.28 $\pm$ 667.59 μℓ/hr., and 2525.4 $\pm$ 3754.7 mg in the spring; 1349.9 $\pm$ 1203.9 μℓ/hr., 825.82 $\pm$ 1449.52 μℓ/hr., and 7499.0 $\pm$ 8672.6 mg in the summer; and 659.94 $\pm$ 1174.51 μℓ/hr., 659.14 $\pm$ 919.79 μℓhr., and 3080.4 $\pm$ 4765.9 mg in the fall (Table 3).

Rock basket caloric content followed similar annual patterns, while departures were evident in protein values during 1972, 1975, and 1976, and chlorophyll during 1972, 1974, and 1976 (Figures 15 and 16).

For the evaluation of the data generated and assessing the plant's impact, a summary table was prepared (Table 8). This summary incorporates all statistically significant deviations

($P \leq .05$) of comparisons made by the two-tailed t-test. Included in the t-test evaluation of upstream control data to downstream sample location data were parameters 1 through 25 for pumped water and 1 through 16 for rock baskets (Table 2).

The data was further subdivided to include the direction of the significant variation (increase or decrease), and if the deviation occurred in or out of the area of the thermal plume.

During the period from 1972 to 1977, approximately 1,957 pumped water samples were collected. For each sample, 25 recorded parameters were evaluated for the level of plant effect utilizing the statistical t-test. This resulted in a total of 5,650 evaluations being conducted. Of this total, 115 proved to be statistically significant deviations from the upstream control, for an overall percentage rate of 2%.

During this same period, approximately 979 rock baskets were collected. For each of these samples, 16 recorded parameters were evaluated for the level of plant effect utilizing the t-test. This resulted in a total of 2272 evaluations being conducted. Of this total, 67 proved to be statistically significant deviations from the upstream control for an overall percentage rate of 3%.

An evaluation of the pre-operational in-and-out-of-plume significant deviations for pumped water and rock baskets demonstrates that statistically significant changes were occurring prior to plant operation (August 1973). No

significant power was produced by the plant during 1973 when samples were collected with power operations limited <50%. This indicates the extent of the variations that occurred naturally in the Missouri River in our sampling grid. Both increases and decreases were in evidence, further indicating the system's variability in parameter value.

After the start of plant operation, statistically significant increases and decreases continued to occur both in-plume and out-of-plume. The deviations from normally occurring seasonal values were neither systematic or patterned regardless of the parameter examined (Tables 9 and 10). A more restricted examination involving the zone of highest thermal stress was also undertaken.

In this zone, maximal effects due to the heating thermal effluent from the station would be expected. Transect locations further removed from the plant (Ex. 3.0, 4.0, and 5.0) not only experience lower temperature exposures, but are influenced by local environmental conditions, such as tributary inputs, agricultural runoff, variations in shoreline habitat, and river hydrology. Photosynthesis and respiration were selected as the critical parameters to be evaluated in the near-field because of their anticipated response under themal stress and their ability to indicate physiological effect. An increase in either of these parameters would indicate a stimulatory effect while a decrease would indicate inhibition.

Had there been major alterations in the river's energy flow patterns, the TIS design would have detected and quantitated them with rapidity and would have served as intended. The evidence accumulated over four full operational years is conclusive; there have been no perturbations in the parameters studied and detectable by this protocol within the grid system which extends over a five-mile reach of the Missouri River. Other than sporadic and isolated departures from ambient values both in the plume-affected and non-affected zones, there are no systematic or patterned departures from the normal fluctuating seasonal values.

The evidenced concerns of relatively massive modifications (which prompted the transect grid design, high frequency sampling efforts, rapid reporting of data) seem to have overestimated the actual effects. If there are changes due to the thermal effluent, they must be more subtle than had been feared, be detectable almost exclusively within the thermally enriched zone of the near-field plume, and perhaps are of a species specific rather than an overall energetic pattern nature. These conclusions are reached, not only from a consideration of the data generated by the TIS, but from the consideration of the entire biological monitoring program at Fort Calhoun. The fisheries studies, condenser passage studies, and periphyton studies all point to a level of change which, if existent, must be sought for, not with an extended transect grid on a semi-weekly basis, but with plume-affected near-field sample points on a seasonal basis.

SUMMARY & CONCLUSIONS

1. After four years of plant operation utilizing an analysis of what are believed to be the most critical parameters and data collected from the area of highest thermal stress, there was no evidence of a systematic plant induced effect on the drift plankton or aufwuch's populations of the Missouri River.

2. Local environmental circumstances such as tributary inputs, agricultural runnoff, shoreline habitat, and river hydrology are sufficiently diverse within the Thermal Impact Study sample grid to cause statistically significant deviations in some of the parameters evaluated.

3. Rock basket seasonal patterns for photosynthesis, respiration, dry weight, and caloric content followed trends similar to annual temperature cycles, but varied in magnitude from year to year.

4. Seasonal patterns in respiration were generally correlated to annual density patterns for zooplankton and macroinvertebrates.

Literature Cited

American Public Health Association, 1971. Standard methods for the examination of water. 13th edition. Washington, D. C.

Carter, S.R., 1977. Operational environmental monitoring in the Missouri River near Fort Calhoun Station, October 1973 - June 1977. (Project No. 5501-08778). Summary Report by NALCO Environmental Sciences for Omaha Public Power District, Omaha, Nebraska.

Golterman, H. L., 1971. Methods for chemical analysis of fresh waters. Blackwell Scientific Publications. Oxford and Edinburgh, G. B. 166 pp.

Kline, 1977. Phytoplankton entrainment study. Pages 1-30 in S. R. Carter, ed. Operational environmental monitoring in the Missouri River near Fort Calhoun Station, October 1973 - June 1977. (Project No. 5501-08778). Summary Report by NALCO Environmental Sciences for Omaha Public Power District, Omaha, Nebraska.

Merriman, D., and L. M. Thorpe, eds. 1976. The Connecticut River Ecology study: the impact of a nuclear power plant. Am. Fish. Soc. Monograph I. 252 pp.

Strickland, J. D. H., and T. R. Parsons, 1968. A practical handbook of seawater analysis. Fish. Res. Board Can. Bull. 167. 310 pp.

Weber, C. I., 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents, U. S. Environ. Prot. Agency, Cincinnati, Ohio.

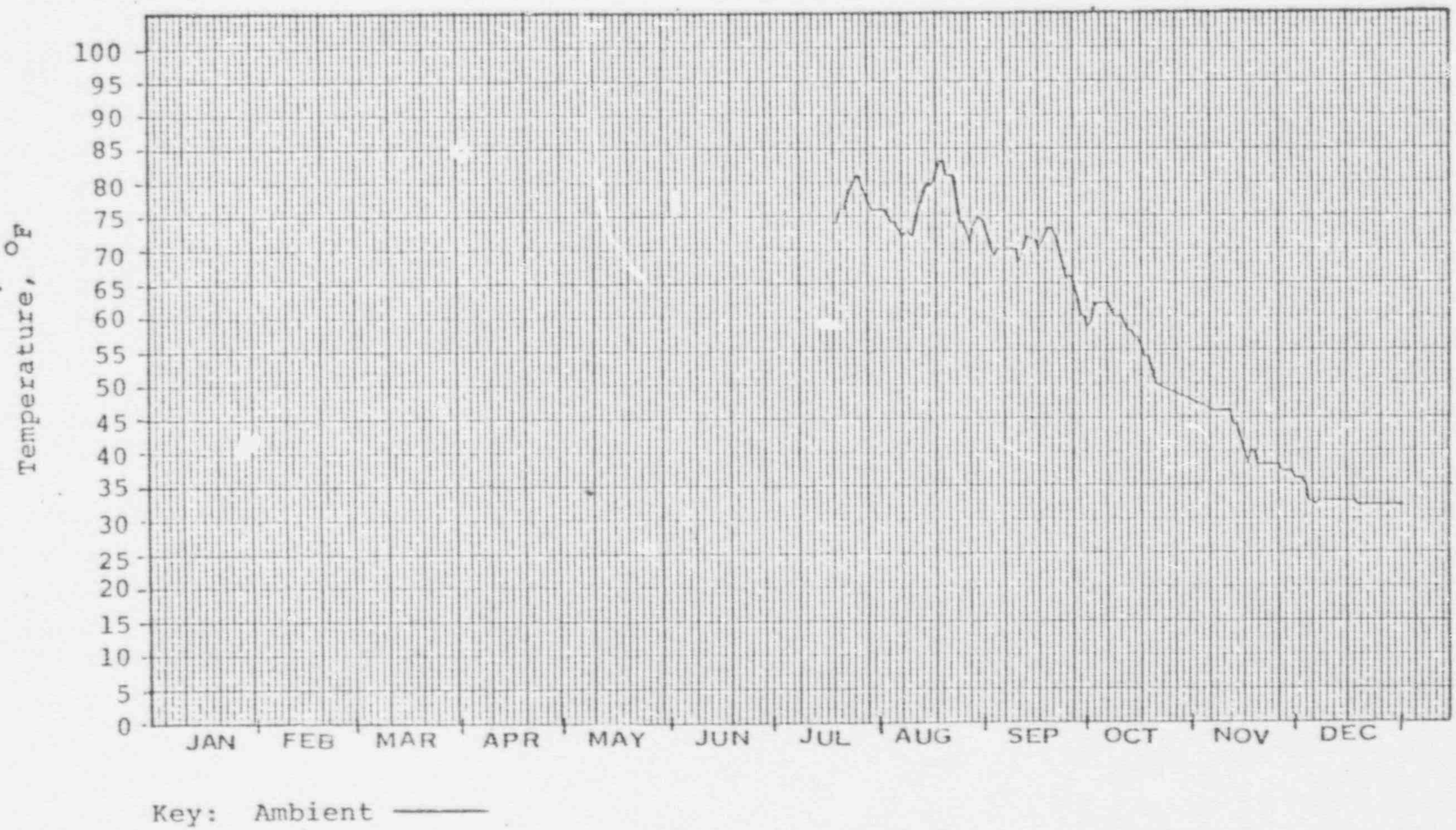
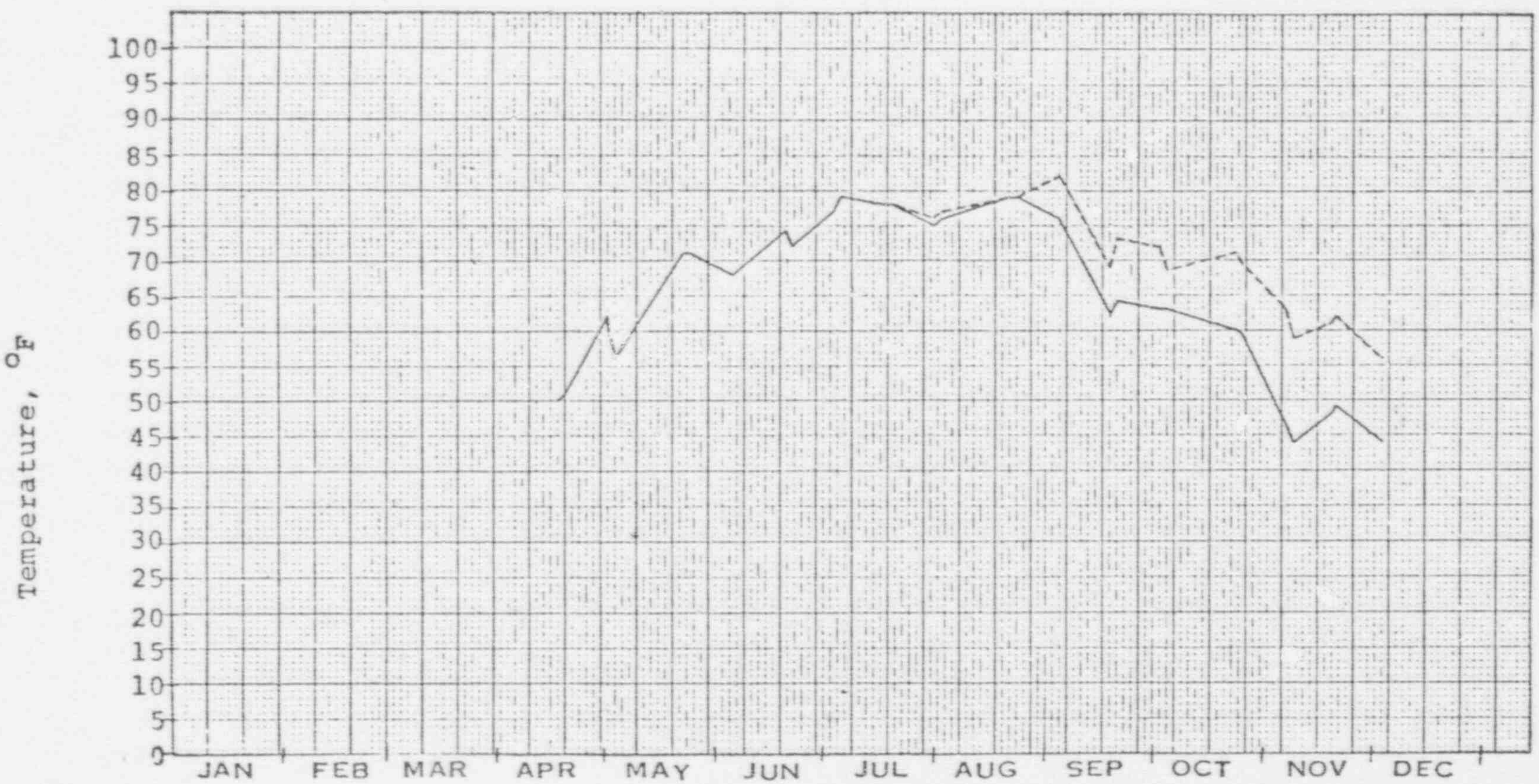


Figure 4 - Ambient river temperatures, 1972. (No discharge temperatures available prior to plant operation.)



Key: Ambient ——

Discharge ----

Figure 5 - Ambient river and plant discharge temperatures, 1973.

TABLE 3: Seasonal trends in selected Thermal Impact Study water parameters, Phytoplankton Density, Photosynthesis, Respiration, and Dry Weight.

	Spring				Summer				Fall			
	Phyto. Dens. [b]	Photo. [c]	Resp. [c]	Dry Wt. [d]	Phyto. Dens. [b]	Photo. [c]	Resp. [c]	Dry Wt. [d]	Phyto. Dens. [b]	Photo. [c]	Resp. [c]	Dry Wt [d]
1972	N.A. [a]	N.A.	N.A.	N.A.	N.A.	74.1	29.6	79.8	N.A.	153.1	93.5	65.8
1973	N.A.	192.6	28.7	142.1	N.A.	134.7	34.9	500.8	N.A.	139.4	58.5	79.8
1974	6685	113.2	7.7	277.9	4125	125.4	21.8	194.9	998	147.7	73.4	96.7
1975	N.A.	108.2	18.2	162.9	5531	130.2	17.45	302.1	3439	91.9	24.8	122.6
1976	4068	99.4	37.8	58.1	7505	77.4	16.5	66.2	N.A.	37.44	19.95	64.8
1977	7004	183.4	73.4	95.6	3372	127.4	75.0	84.8	N.A.	N.A.	N.A.	N.A
$\overline{X}$	5919.00	139.36	33.16	147.32	5133.25	111.53	32.54	204.0	2218.50	113.91	60.03	85.94
S	1610.93	44.79	25.16	83.60	1816.77	27.91	21.99	171.12	1726.05	49.14	27.06	24.24
N	3	5	5	5	4	6	6	6	2	5	5	5
95%	6931.83	124.35	69.84	232.1	5780.96	71.76	56.54	439.98	21931.19	136.42	75.12	67.39

a - No data collected
b - Units/mℓ
c - μℓ/hr/ℓ
d - mg/ℓ

35

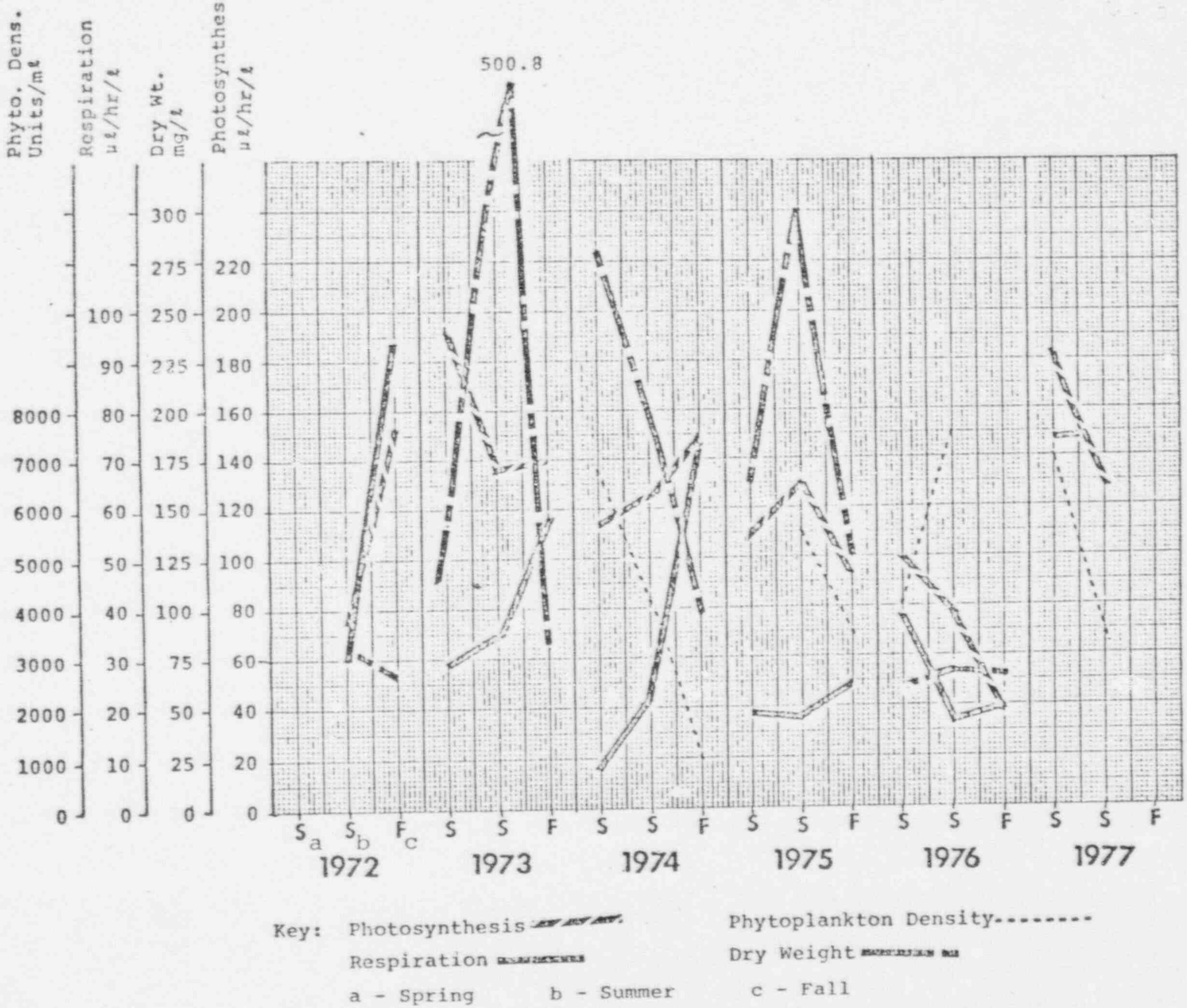
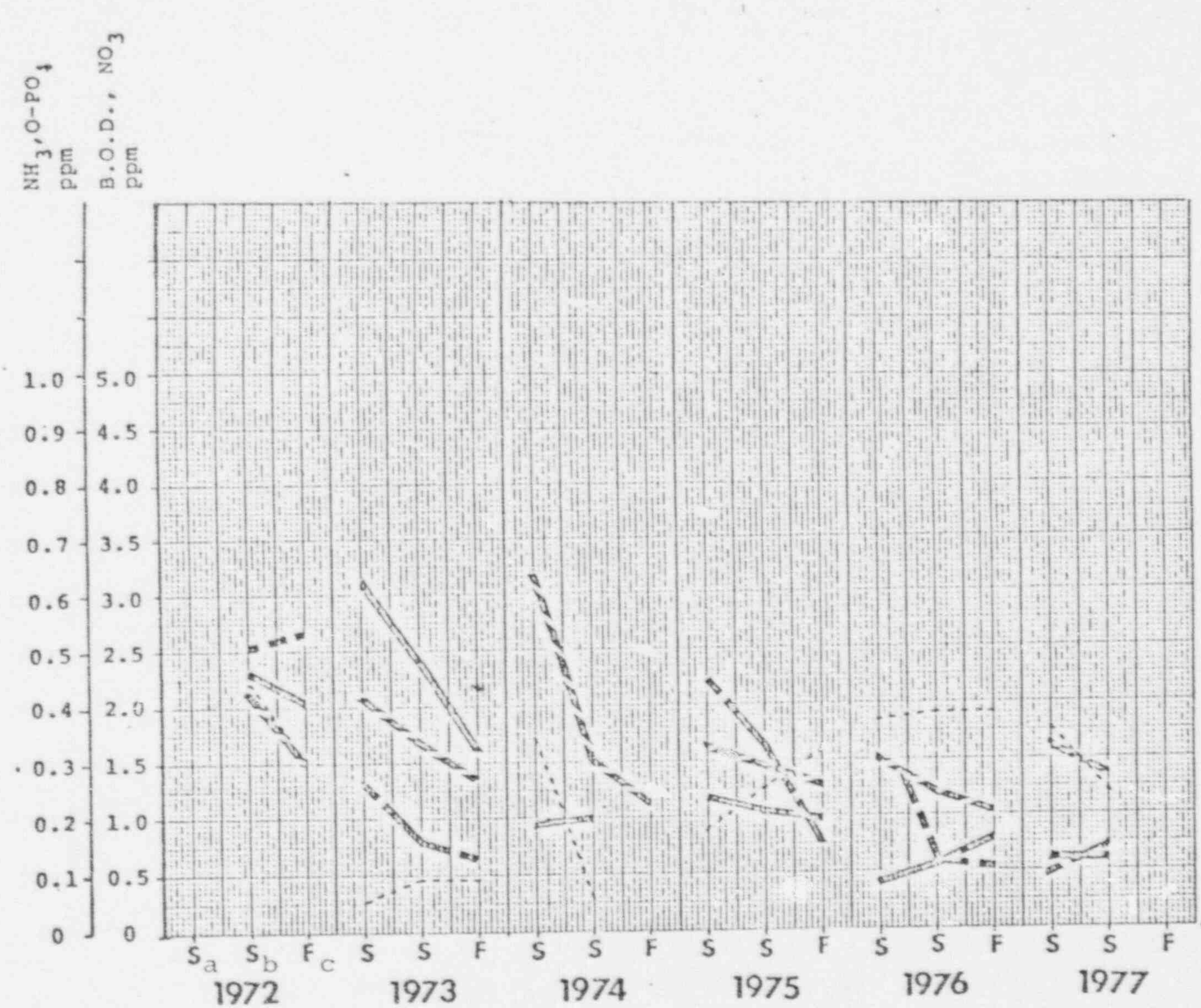


Figure 12 - Seasonal trends in selected Thermal Impact Study water parameters, Phytoplankton Density, Photosynthesis, Respiration, and Dry Weight.

TABLE 4: Seasonal trends in selected Thermal Impact Study water parameters, Biochemical Oxygen Demand, Ammonia Nitrogen, Ortho Phosphate, and Nitrate

	Spring				Summer				Fall			
	B.O.D.[b]	NH_3[b]	O-PO_4[b]	NO_3[b]	B.O.D.[b]	NH_3[b]	O-PO_4[b]	NO_3[b]	B.O.D.[b]	NH_3[b]	O-PO_4[b]	NO_3[b]
1972	N.A.[a]	N.A.	N.A.	N.A.	2.1	0.46	0.44	2.56	1.47	0.41	0.29	2.66
1973	2.09	0.62	0.05	1.33	1.69	0.47	0.09	0.77	1.36	0.32	0.09	0.64
1974	3.16	0.19	0.34	N.A	1.49	0.20	0.06	N.A	1.13	N.A.	N.A.	N.A.
1975	1.60	0.23	0.18	2.20	1.45	0.21	0.25	1.62	1.27	0.20	0.32	0.75
1976	1.52	0.08	0.37	1.32	1.20	0.11	0.38	0.63	1.04	0.16	0.38	0.53
1977	1.60	0.12	0.35	0.57	1.36	0.12	0.24	0.63	N.A.	N.A.	N.A.	N.A.
$\overline{X}$	1.99	0.25	0.26	1.36	1.55	0.26	0.24	1.24	1.25	0.27	0.27	1.15
S	0.69	0.22	0.14	0.67	0.31	0.16	0.15	0.84	0.17	0.11	0.13	1.01
N	5	5	5	4	6	6	6	5	5	4	4	4
95%	1.92	0.61	0.39	2.13	0.80	0.41	0.39	2.33	0.47	0.35	0.41	3.21

a - No data collected
b - ppm



Key: B.O.D. $O\text{-}PO_4$

NH_3 NO_3 --------

a - Spring   b - Summer   c - Fall

Figure 13 - Seasonal trends in selected Thermal Impact Study water parameters, Biochemical Oxygen Demand, Ammonia Nitrogen, Ortho Phosphate, and

TABLE 5: Seasonal trends in selected Thermal Impact Study water parameters, Chlorophyll A, Turbidity, Protein, and Calories

	Spring				Summer				Fall			
	Chloro. A[b]	Turb.[c]	Protein[b]	Cal.[d]	Chloro. A[b]	Turb.[c]	Protein[b]	Cal.[d]	Chloro. A[b]	Turb.[c]	Protein[b]	Cal.[d]
1972	N.A.[a]	N.A.	N.A.	N.A.	.0022	49.3	5.7	35.8	.007	28.1	29.7	18.0
1973	.012	30.0	2.7	17.4	.021	54.7	4.4	32.4	.0011	27.25	3.1	21.7
1974	.057	226.3	16.2	34.4	.011	61.1	23.6	21.1	.0072	30.3	2.7	5.0
1975	.010	45.8	31.6	33.0	.010	63.6	1887.1	114.0	.008	41.6	1783.7	14.0
1976	.0079	35.4	120.4	6.9	.009	36.4	6.0	5.8	.0048	32.8	1.4	10.0
1977	.011	33.4	1.8	5.9	.0126	30.75	1.4	0	N.A.	N.A.	N.A.	N.A.
$\overline{X}$	0.02	74.18	34.54	19.52	0.01	49.31	321.37	34.85	0.01	32.01	364.12	13.74
S	0.02	85.24	49.50	13.71	0.01	13.29	767.09	41.28	.03	5.78	793.66	6.56
N	5	5	5	5	6	6	6	6	5	5	5	5
95%	0.06	236.63	137.41	38.06	0.03	34.17	1972.19	106.13	0.01	16.05	2203.20	18.21

a - No data collected
b - mg/ℓ
c - Formazine turbidity units
d - Calories/ℓ

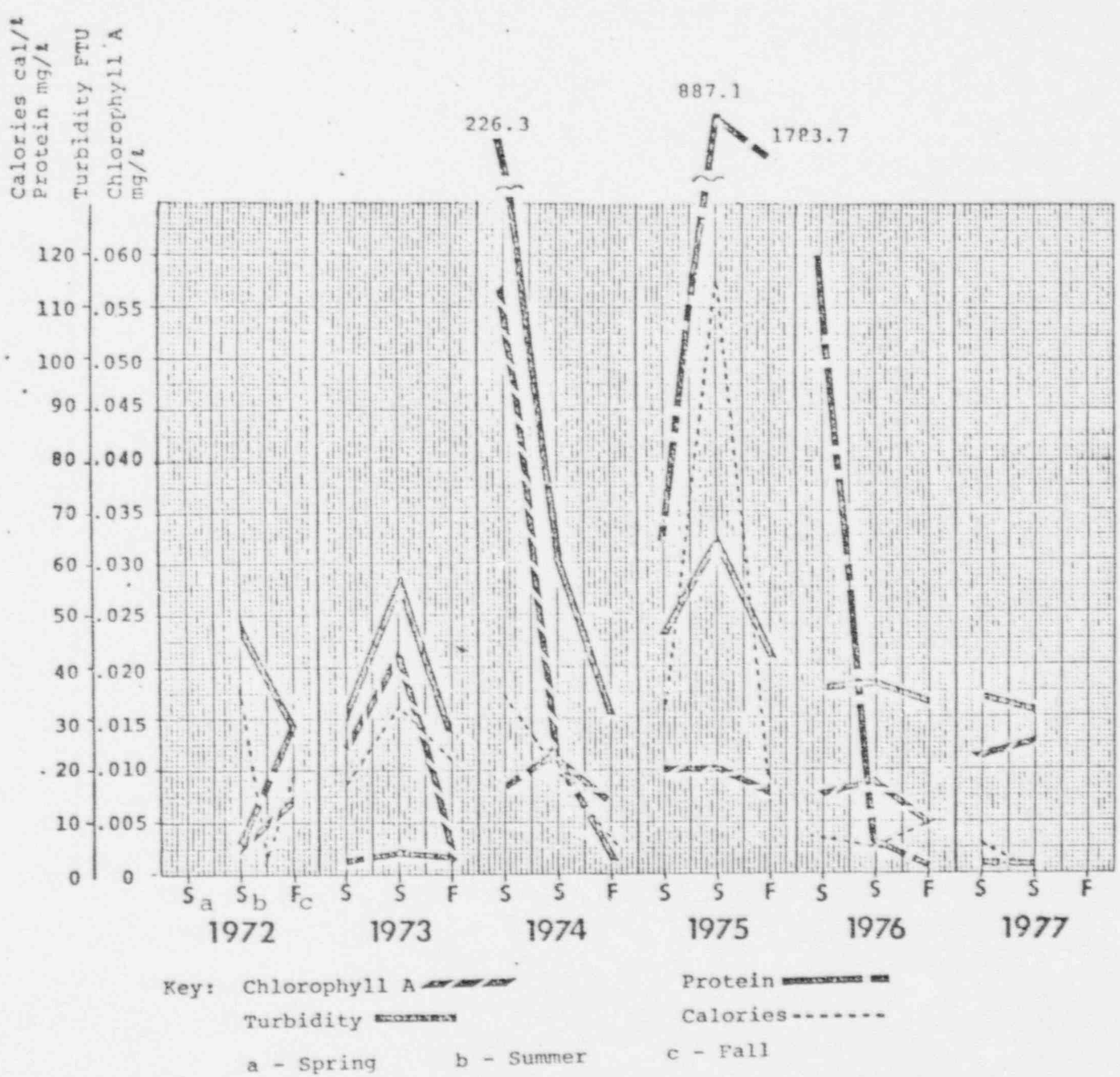


Figure 14 - Seasonal trends in selected Thermal Impact Study water parameters, Chlorophyll A, Turbidity, Protein, and Calories.

TABLE 6: Seasonal trends in selected Thermal Impact Study rock basket parameters, Photosynthesis, Respiration, and Dry Weight

	Spring			Summer			Fall		
	Photo.[b]	Resp.[b]	Dry Wt.[c]	Photo.[b]	Resp.[b]	Dry Wt.[c]	Photo.[b]	Resp.[b]	Dry Wt[c]
1972	N.A.[a]	N.A.	N.A.	385.6	597.5	5145	262.5	318.9	5973
1973	532.1	644.8	4511	1118.7	1739.4	11556	589.7	491.0	1826
1974	351.0	394.3	1581	668.7	1489.5	4543	604.7	731.5	1927
1975	330.1	711.3	1486	590.7	1799.5	10189	1182.6	1363.9	2390
1976	586.6	354.4	1687	830.8	980.5	3790	656.2	394.4	3286
1977	926.6	468.2	3362	1360.4	1492.9	9771	N.A.	N.A.	N.A.
$\overline{X}$	545.28	514.6	2525.4	825.82	1349.88	7499.0	659.14	659.94	3080.4
S	240.49	156.47	1352.56	563.8	468.26	3373.23	331.33	423.10	1716.82
N	5	5	5	6	6	6	5	5	5
95%	667.59	434.36	3754.7	1449.52	1203.9	8672.57	919.78	1174.51	4765.9

a - No data collected
b - μℓ/hr/rock basket
c - mg/rock basket

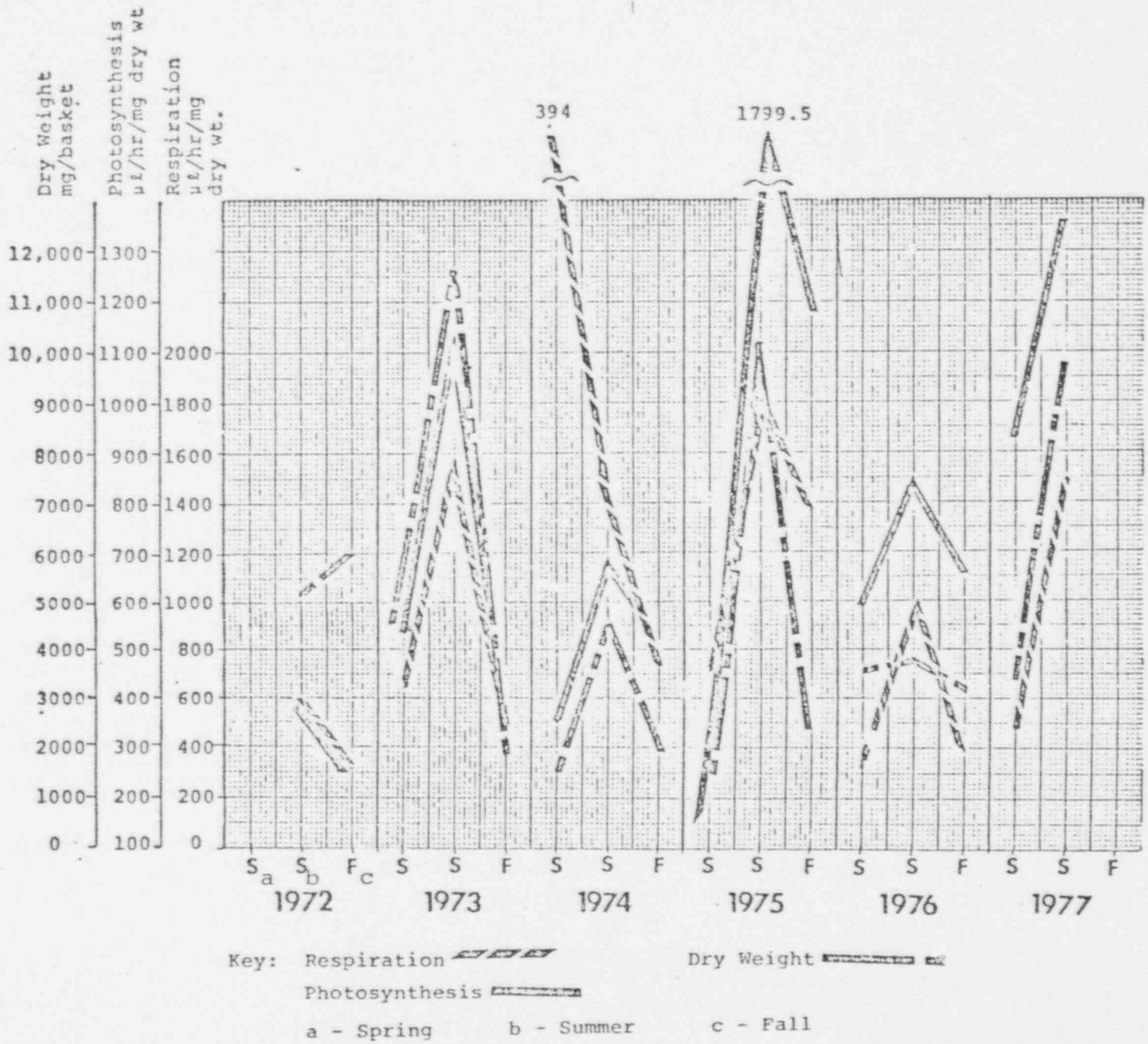


Figure 15 - Seasonal trends in selected Thermal Impact Study rock basket parameters, Photosynthesis, Respiration, and Dry Weight.

TABLE 7: Seasonal trends in selected Thermal Impact Study rock basket parameters, Protein, Chlorophyll A, and Calories

	Spring			Summer			Fall		
	Protein[b]	Chloro. A[b]	Cal.[c]	Protein[b]	Chloro. A[b]	Cal.[c]	Protein[b]	Chloro. A[b]	Cal.[c]
1972	N.A.[a]	N.A.	N.A.	13.2	0.18	3669	42.6	.569	1748
1973	129.7	.054	2012.6	390.6	.198	84665	58.1	.054	2251.8
1974	47.7	.033	2316.8	202.3	.096	4564	80.8	.126	1013.9
1975	435.2	.100	1174	1028.0	.147	18351	1415	.089	1998
1976	71.0	.247	688	60.1	.227	54032	68.6	.242	1714
1977	105.1	.513	19.05	141.1	.527	15.7	N.A.	N.A.	N.A.
$\overline{X}$	157.74	0.19	1242.09	305.88	0.23	27549.45	333.02	0.22	1745.14
S	158.25	0.20	942.89	377.51	0.15	34365.21	605.01	0.21	462.69
N	5	5	5	5	6	6	5	5	5
95%	439.30	0.56	2617.46	1047.97	0.39	88352.95	1679.51	0.58	1284.43

a - No data collected
b - mg/rock basket
c - Calories/rock basket

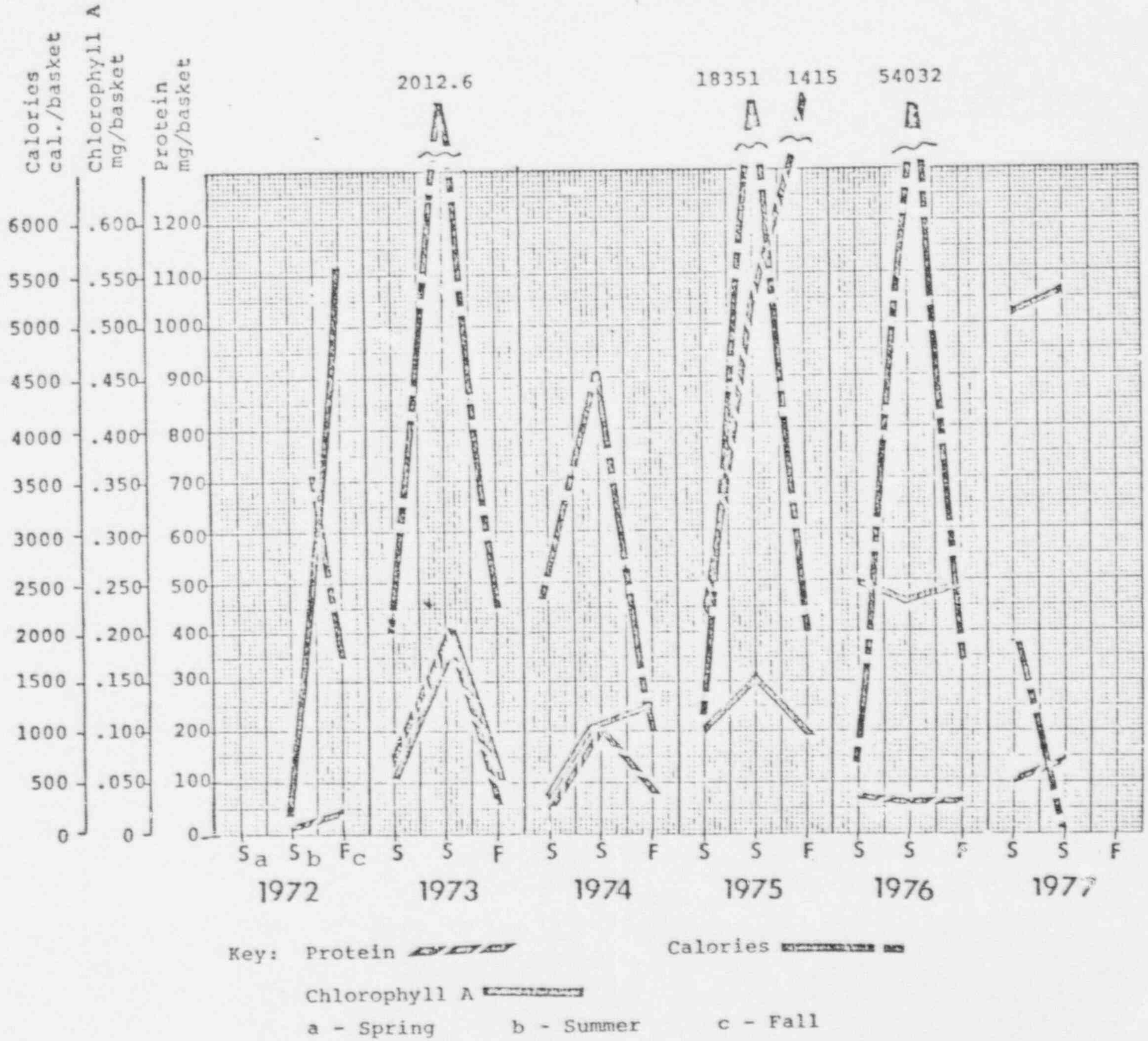


Figure 16 - Seasonal trends in selected Thermal Impact Study rock basket parameters, Protein, Chlorophyll A, and Calories.

TABLE 8

Summary of statistically significant (P<.05) deviations for pumped water and rock basket samples, 1972 through 1977

Fort Calhoun Rock

Criteria	In-Plume Points						Out-of-Plume Points					
	1972	1973	1974	1975	1976	1977	1972	1973	1974	1975	1976	1977
Increase	3	0	0	1	1	3	5	8	0	9	7	3
Decrease	0	5	3	2	1	8	0	1	5	0	0	2
Total	3	5	3	3	2	11	5	9	5	9	7	5

Fort Calhoun Water

Criteria	In-Plume Points						Out-of-Plume Points					
	1972	1973	1974	1975	1976	1977	1972	1973	1974	1975	1976	1977
Increase	7	14	14	3	13	0	2	2	7	3	8	0
Decrease	6	5	8	0	4	0	3	0	1	2	3	1
Total	13	19	22	3	17	0	5	2	8	5	11	1

TABLE 9

Pumped water parameters demonstrating statistically significant deviations ($P \leq .05$) by sample location for the years of the study (1972-1977).

Significant Increases over Control Samples

	In-Plume			Out-of-Plume	
	A	B	*C	C	D
1.5	13**,13,1, 13,16,18,13, 13,2,13,13, 19				
2.0	1,16,2,19	1,1		17,17,1, 15,1	6,1
3.0	13,1,16,18, 1,19	17,13	16	1,17,1,2	3
4.0	17,13,13,4 1,17,1,17, 13,18,2	13,2,7, 15,2	1	17,20,1, 2	
5.0	2,4,2,7	13,4,17,1 16,16,1,3, 15	2,1 16	1,17,1,2, 15	17

Significant Decreases over Control Samples

	In-Plume			Out-of-Plume	
	A	B	*C	C	D
1.5	4,3				
2.0	1,21	1,7	1,6	19	1
3.0		3	7	7	
4.0	20,2,	2,18,3 17		15,19	1
5.0	19	1,16,18, 21,19	6	6,3,19	1

* Move out-of-plume 1974-1977

**Underlined numbers indicate data from the pre-operational period

TABLE 10

Rock basket parameters demonstrating statistically significant deviations (P≤.05) by sample location for the years of the study (1972-1977)

<u>Significant Increases Over Control Samples</u>

	Nebraska	Iowa
1.5	<u>13</u>,1,13	
2.0	6,13	<u>1</u>,<u>6</u>,<u>2</u>,1,2,6,7,13,16, 1,2,4
3.0	<u>1</u>,<u>4</u>	<u>1</u>,<u>4</u>,1,2,1,3,7,3,4
4.0	13	7,4,1,2,3,4
5.0		<u>3</u>,7,1,2,4

<u>Significant Decreases Over Control Samples</u>

	Nebraska	Iowa
1.5	1,3	
2.0	1,2,3,2,1,7,4, 4,16,4	16
3.0	1,6,4,16,4	7,4,16,16
4.0	16	16
5.0	16	16,16

*Underlined numbers indicate data from the pre-operational period.