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SOME EFFECTS OF CLARK CANYON RESERVOIR ON THE LIMNOLOGY OF THE BEAVERHEAD RIVER IN MONTANA

by

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VITA

Kenneth Michael Smith was born in Santa Barbara, California, February 26, 1943 to Col. Sydney and Arkie Smith. He graduated from Pacific High School, San Bernardino, California in 1961, whereupon he entered Santa Barbara City College, Santa Barbara, California in the fall of 1961. After attending college for one semester he enlisted in the United States Air Force for four years in 1962. While enlisted in the U. S. Air Force, he married Judy Gail Walter of San Angelo, Texas in 1965. In the summer of 1967 he entered Angelo State University where he graduated in June of 1970 with a Bachelor of Science degree in Biology. He and Judy have three daughters, Gayla Joyce, 5 years, Darla Jean, 3 years, and Elaina Kay, 15 months.

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ABSTRACT

A study to determine the effects of Clark Canyon Reservoir on the Beaverhead River was conducted during the summers 1971 and 1972 and intervening winter. Sampling stations were established on each of the two tributaries to the reservoir and on the Beaverhead River from the dam site to 43 km downstream. Discharge and water temperature were the most altered physical parameters. Postimpoundment flows for 24 km downstream from the dam were less than preimpoundment flows during the autumn and winter seasons and greater during spring and summer. Diel temperature fluctuations below the dam were negligible while fluctuations in the reservoir tributaries covered a ten degree (C) range. During August 1971, 1972 and September 1971, monthly mean temperatures were (3-4°C) higher immediately below the reservoir than in the major tributary to the reservoir. Mean dissolved oxygen levels in the tailwaters were well above saturation levels (108-148%) while the reservoir tributaries had mean saturation levels below or near saturation (89-99%). The pH increased slightly below the dam when compared to levels observed in the tributaries. Ammonia and nitrite increased while nitrate decreased in the tailwaters. Periphytic phytoplankton was greatly reduced while planktonic types of algae increased immediately below the reservoir. Forty-five kilometers below the dam the planktonic types were nearly nonexistent while most of the periphytic types were restored to levels similar to those observed in the reservoir tributaries. A substantial increase in zooplankton *(Daphnia* and *Cyclops)* was noted immediately below the dam but decreased considerably within 24 km downstream.

INTRODUCTION

Clark Canyon Dam, on the Beaverhead River in southwestern Montana, was constructed in 1964. The impoundment created by this dam covers the lower portions of Red Rock River and Horse Prairie Creek which previously joined to form the Beaverhead River 0.48 km above the present dam site. Personnel of the Montana Fish and Game Department initiated studies in 1969 to determine the fish population of the reservoir and the effects of the reservoir and altered stream flow patterns on the fish populations on the Beaverhead River.

I conducted field research during the summers of 1971 and 1972 and intervening winter on the limnology of the river with emphasis on chemical analysis but discharge, water temperatures and plankton were also considered. A concurrent study was conducted by Rodney Berg on the limnology of the reservoir.

DESCRIPTION OF STUDY AREA

Red Rock River drains an area of 4,092 km^2 with half of the drainage on the slopes of the Continental Divide. The mountains are of igneous and sedimentary rocks (sandstone, limestone and quartzite) and alluvial gravels (Ryder, 1967). Upper and Lower Red Rock Lakes and Swan Lake are located in the headwater region and comprise the Red Rock Lakes National Wildlife Refuge. From the refuge to Lima Reservoir (21.9 km) the Red Rock River is a meandering, slow, aggraded stream (Fish and Wildife Service, 1956. Henceforth abbreviated F. W. S.). Below Lima Reservoir, the river is approximately 15.24 m wide with an average gradient of 5.7 m/km and meanders through mountain meadows for almost the entire distance (48.4 km) to its termination at Clark Canyon Reservoir (F. W. S., 1958). The principle land use in the Red Rock Valley is farming and many irrigation diversions are present below Lima Reservoir (F. W. S., 1956). Flows at Dell, 25.9 km above Clark Canyon Reservoir, varied from a high of 41.9 m^3/sec on June 9, 1944 to a low of zero during May, 1961 (U. S. Geol. Surv., 1967). No annual mean flow data is available due to winter ice conditions. Water temperatures at Dell for the period 1949-65 had a maximum and minimum of 17.8° C and 0.6° C, respectively (Aagaard, 1969).

Horse Prairie Creek drains approximately 1,765 km^2 and is about 103 km long with an average width of 10.6 m (F. W. S., 1956, 1958). The gradient of the lower one-half of the stream is 7.2 m/km. Maximum and minimum discharge flows for the upper one-half of Horse Prairie Creek for the period 1946-53 were 25.2 and 0.34 m^3/sec, respectively (U. S. Geol. Surv., 1953). The lower half of the stream is severely dewatered by irrigation during the summer and fall months (Wipperman, 1964). Spot observations on water temperature for the period 1963-64, near the reservoir site, showed a maximum of 23.9° C on June 24, 1964 and a minimum of near freezing on many days during the winter months (Aagaard, 1969).

The Beaverhead River is presently formed at the outlet from Clark Canyon Reservoir. The river is 99.75 km in length with a total drainage area of about 12,950 km^2 (F. W. S., 1956) and an average stream gradient of 3.6 m/km. Maximum and minimum flow data for the period 1907-60 at Barretts 24.4 km below the dam (Fig. 1) were 105 and 1.9 m^3/sec, respectively, with a 53-year average of 11.5 m^3/sec (U. S. Geol. Surv., 1960). Maximum and minimum water temperatures at Barretts were 21.6° C and 0° C, respectively, for the period 1949-67 (Aagaard, 1969). Within the study area, Grasshopper Creek is the main tributary, draining an area of approximately 906 km^2. This creek has a 22-year average discharge of 1.49 m^3/sec (U. S. Geol. Surv., 1960).

Clark Canyon Dam and Reservoir, along with Barretts Diversion Dam, the East Bench Canals, irrigation laterals and drains, constitute the Bureau of Reclamation's East Bench Unit at Dillon (Fig. 1). The

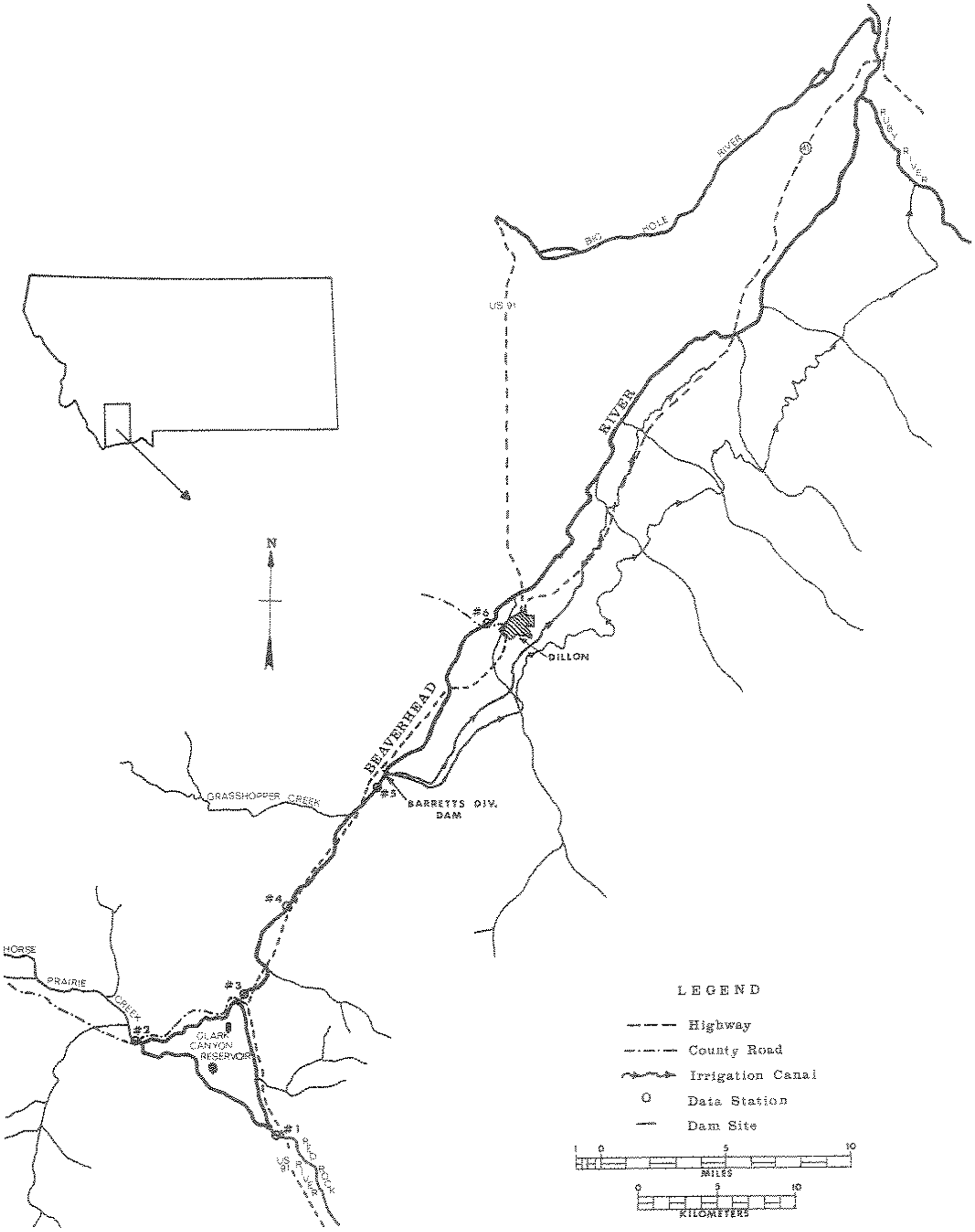

Figure 1. Map of the Beaverhead River drainage area showing the location of sampling stations.

primary functions of Clark Canyon Dam are flood control and irrigation with some recreation and fish and wildlife functions (Dinzick, personal communication).

The dam is 40.53 m high with the invert outlet located 0.15 m above the old stream bed (Table 1). When filled to the top of the irrigation storage level (1689.23 m above mean sea level) the reservoir holds 198.97 x 10^6 m^3 of water and covers an area of 20.24 km^2 (Dinzick, personal communication). The impoundment inundated the farming community of Armstead and important stream fisheries in 12.07 km of Red Rock River, 13.8 km of Horse Prairie Creek and 0.48 km of Beaverhead River (F. W. S., 1958).

Past and present flows in the Beaverhead River drainage are somewhat different from other drainages in Montana. Fall and winter runoff is proportionally greater during this period on a total annual flow basis. Consequently, the Bureau of Reclamation's reservoir operation plan calls for storage of water in the period from November through April. During this period releases may be as low as 0.71 m^3/sec or equal to or greater than the total inflow when storage approaches the 176 x 10^6 m^3 level. Releases from the dam for irrigation purposes generally occur from mid-May through September but may extend two weeks on either side of this period (Dinzick, personal communication).

Table 1. Elevations and capacities of Clark Canyon Reservoir and Dam.

	Elevation* (m above mean sea) (level)	Height (m)	Capacity* (m^3x 10^6)	Surface Area* (km^2)
Top of Dam	1,700.2	37.7	----	----
Top of Flood Control Storage	1,694.8	32.3	317.2	23.9
Top of Joint Use Storage (Normal Operation Elev.)	1,689.2	26.7	194.5	20.0
Top of Active Conservation Storage	1,687.3	24.8	157.4	18.2
Top of Inactive Storage	1,667.5	5.0	2.4	0.8
Top of Dead Storage (Bottom of Outlet Works)	1,662.6	0.1	0.08	0.1
Stream Bed	1,662.5	----	----	----

*From U. S. Dept. of the Interior, Bureau of Reclamation, Missouri River Basin Project, Three Forks Div. - East Bench Unit-Montana, Clark Canyon Dam, Reservoir Area, Denver, Colorado, May 2, 1966, #699-D-198.

METHODS

Sampling stations were located on Red Rock River, Horse Prairie Creek and the Beaverhead River (Fig. 1). Station one was on Red Rock River, 4.3 km upstream from the 1,689 m, normal operation elevation of Clark Canyon Reservoir. Station two was on Horse Prairie Creek, 0.24 km from the operation elevation. Stations three through six were on the Beaverhead River at 0.40, 10.0, 24.2 and 43.5 km downstream from the dam. Stations one through five were established in June, 1971, while station six was established in April, 1972.

Discharge data were collected from U. S. Geological Survey records, where applicable, from the following locations: Beaverhead River near Grant, at my station three; Beaverhead River at Barretts, at station five; and Beaverhead River at Dillon, at station six. Reservoir release and inflow data were supplied by the Bureau of Reclamation.

Continuous water temperature recordings were obtained through the use of Taylor and Foxboro recording thermographs at all six stations from June 16, 1971 through August 31, 1972.

Sampling for turbidity, conductivity and water chemistry was done at near biweekly intervals from June 29 through September 15, 1971 and June 16 through August 26, 1972, and at monthly intervals from September 15 to December 21, 1971 and in April and May, 1972.

Water samples for physical and chemical analyses were collected in twice-rinsed: 0.9 l plastic bottles with plastic caps; 300 ml glass dissolved oxygen bottles; and 250 ml standard glass bottles with glass stoppers. The 250 ml water sample was used for the orthophosphate determination and the 300 ml sample was used for the dissolved oxygen analysis, while all other analyses were accomplished from the 0.9 l water sample. The containers were completely immersed in the water and filled to maximum capacity, capped and immediately returned to a field laboratory in Dillon for analyses.

Analyses for turbidity, conductivity, pH, dissolved oxygen, total alkalinity, total hardness, orthophosphate, nitrate, nitrite and ammonia were carried out at near periodic intervals at all stations (Table 8). Difficulties in analytical procedures precluded the use of October 9 and November 20, 1971 data for orthophosphate; the entire summer, 1971, and September 15, 1971 data for nitrate and nitrite; and the entire summer and winter, 1971 data with the exception of May 6, 1972 for ammonia.

Hourly readings for each day were taken from the thermograph records and analyzed for daily maximum, mean and minimum and monthly maximum, mean and minimum. This analysis was carried out by the use of the Montana State University Computer Center's Sigma-7 Computer.

Turbidity was measured in a HACH Field Kit using the HACH DR Colorimeter.

Conductivity was determined by the use of a Solu-Bridge Conductivity Meter (Model RB3-338-Y147).

The pH was measured with an Orion Ionalyzer (Model 407) using a Sargent combination pH electrode.

Dissolved oxygen determinations were carried out via the Standard Winkler Method (Alsterberg modification) using phenylarsene oxide instead of sodium thiosulfate as the titrant solution (HACH, 1969). A nomogram from Mortimer (1956) was used to convert ppm DO to percent saturation.

Total alkalinity, total hardness and ammonia determinations were made as described by the American Public Health Association (1965).

The orthophosphate, nitrate and nitrite analyses were carried out as outlined by HACH (1969). A Bausch & Lomb Spectronic 20 was used for the various colorimetric measurements.

For analytical purposes the turbidity, conductivity and chemistry data were divided into three groups: group one, first summer, contained five sampling periods dating from June 29 through September 1, 1971; group two, winter, contained six sampling periods, from September 15, 1971 through May 6, 1972, exclusive of January through March, 1972; group three, second summer, contained six sampling periods dating from June 16 through August 26, 1972 (Table 8). Data for the two summers, groups one and three, were combined into a summers mean for comparing differences between stations.

Plankton samples were collected only during the spring and summer of 1972, during eight sampling dates from April 8 through August 26, 1972 (Table 8). For each collection five liters of river water were passed through a #20 plankton net and each sample was adjusted to 125 ml and preserved with Lugol's solution for later analysis. Phytoplankton were identified and enumerated by genera for each sample. Percent relative abundance was computed for each genus from a total count of 300 cells per sample. Phytoplankton genera with at least five percent relative abundance during any sampling were compared for significant differences using a modified Binomial Confidence Interval with a level of probability of 0.05. Five percent was used as a cut off point for comparisons because the lower part of the confidence interval was less than zero. The confidence interval was calculated for all necessary percentages using the equation:

$$\text{Confidence interval} = p \pm \sqrt{2\,\frac{p(1-p)}{n}} \times 1.96$$

p = proportion (percentage)
n = sample size

Zooplankton were identified to genera, counted in a rotating grooved chamber (Ward, 1955) and converted to number of organisms per liter.

RESULTS

The complete results of all determinations except flows, temperatures and plankton for all dates at all stations are given in the Appendix (Tables 8 through 18).

Physical Parameters

To determine the effect of the reservoir on flows of the Beaverhead River, comparisons were made between the pre- and postimpoundment flows at station five (Barretts) and station six (Dillon) and between reservoir inflows and releases. The preimpoundment data for station five and station six encompassed the 1950 water year to July 1964, and the 1950, '51 and 1963 water years, respectively. Postimpoundment data extended from July 1964 to September 1972 for station five and to October 1970 for station six. Above and below flow data were obtained from reservoir inflow and discharge records from September 1964 through August 1972.

Runoff from October 1963 to September 1972 in the Beaverhead River drainage was high when compared to the 53-year (1907-60) preimpoundment discharge mean at station five. These highwater years had 76% and 24% greater maximum and mean flows, respectively, than the 53-year average. Due to postimpoundment high water years the pre- and postimpoundment flow data were averaged by month for both periods, while the above and below data were averaged by month on an annual basis. Both sets of data were converted to monthly percentage of the annual flow.

Evaluation of preimpoundment (176 months) and postimpoundment (168 months) mean discharge at station five revealed a similarity in the annual flow patterns (Fig. 2). However, postimpoundment flows were less during the low water period and greater during the high water period than preimpoundment flows. The postimpoundment December flows averaged only 74% of the preimpoundment flows. The four months of May through August had 40%, 8%, 26% and 44%, respectively, higher flows relative to preimpoundment flows.

Analysis of 32 and 88 months of pre- and postimpoundment flow data at station six showed a close conformity during May, and between the November through March and the August through September months in both pattern and magnitude of flows (Fig. 2). A three percent difference was noted for these eight months. Postimpoundment flows were less than preimpoundment flows during the months of April and October by 25% and 12% each, while June and July had a 29% and 50% increase in postimpoundment flows, respectively.

Postimpoundment calculated flows for the river immediately below the Barretts Diversion Dam (Fig. 1) for May through September were obtained by subtracting the monthly mean water diverted from the monthly mean river flow for the eight year period. These means were converted to monthly percent of annual flow. The maximum and minimum amount of river water diverted during the eight irrigation seasons was 60% and

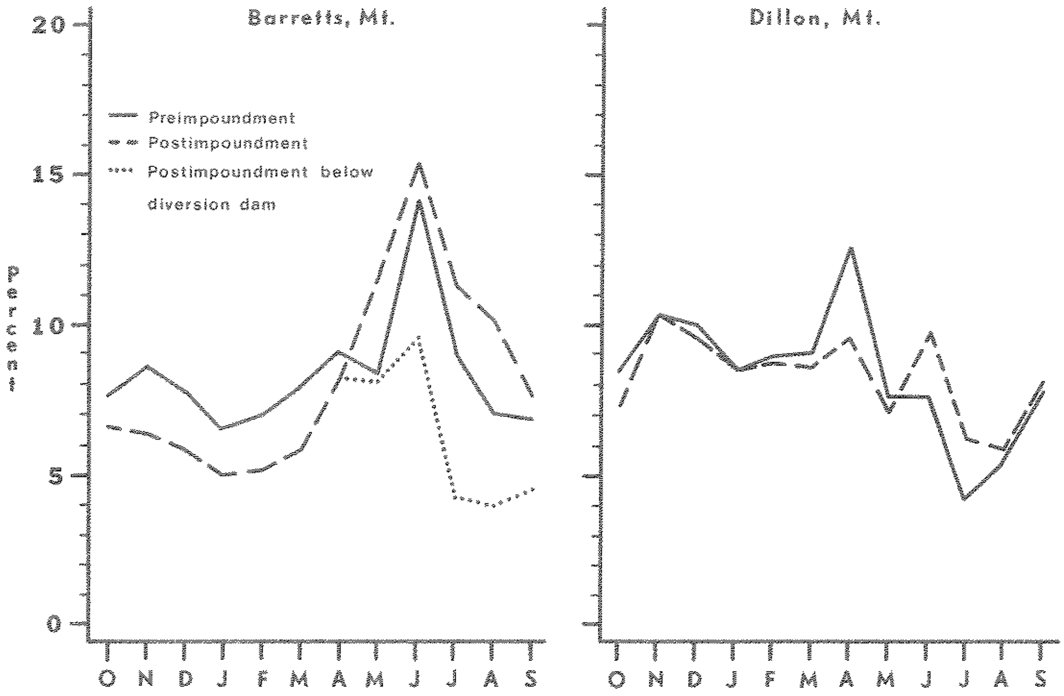

Figure 2. Percent of total annual flow by month for Barretts (station five) and Dillon (station six) by pre- and postimpoundment periods and computed postimpoundment flows for the Beaverhead River below the Barretts Diversion Dam for May and October.

30%, respectively. In comparing the calculated postimpoundment river flow below the diversion to that at station six, only the month of June was noted to be approximately the same. This lack of continuity for all other postimpoundment months could be due to irrigation losses and returns plus contributions by ground water between the two stations.

In comparing dam releases to reservoir inflow, a definite reservoir manipulated alteration in the river flows was evident (Fig. 3). Of the 63 months studied after normal operation began in June 1967, and assuming that discharge and inflow were equal if deviations were no greater than plus or minus five percent, 34 months had less, 11 months had equal and 18 months had greater discharge than inflow. October and November always had less discharge than inflow, while May was predominantly equal in flows. August and September were mainly months with greater discharge than inflow. Maximum differences in discharge and inflow were exhibited during August and July, 1967. August had a discharge rate three times greater than the inflow while July had only 24% of the inflow being discharged.

An appreciable difference was noted between mean monthly flows for 1971 and 1972. Annual flows into the reservoir and at Barretts were 2.4% and 10%, resepectively, less during 1972 than during the 1971 water year. For the months of major interest, June, July and August, the reservoir inflows were 32% and 31% less and 72% greater, respectively, for 1972. Flows at Barretts during these three months were 45%, 40%

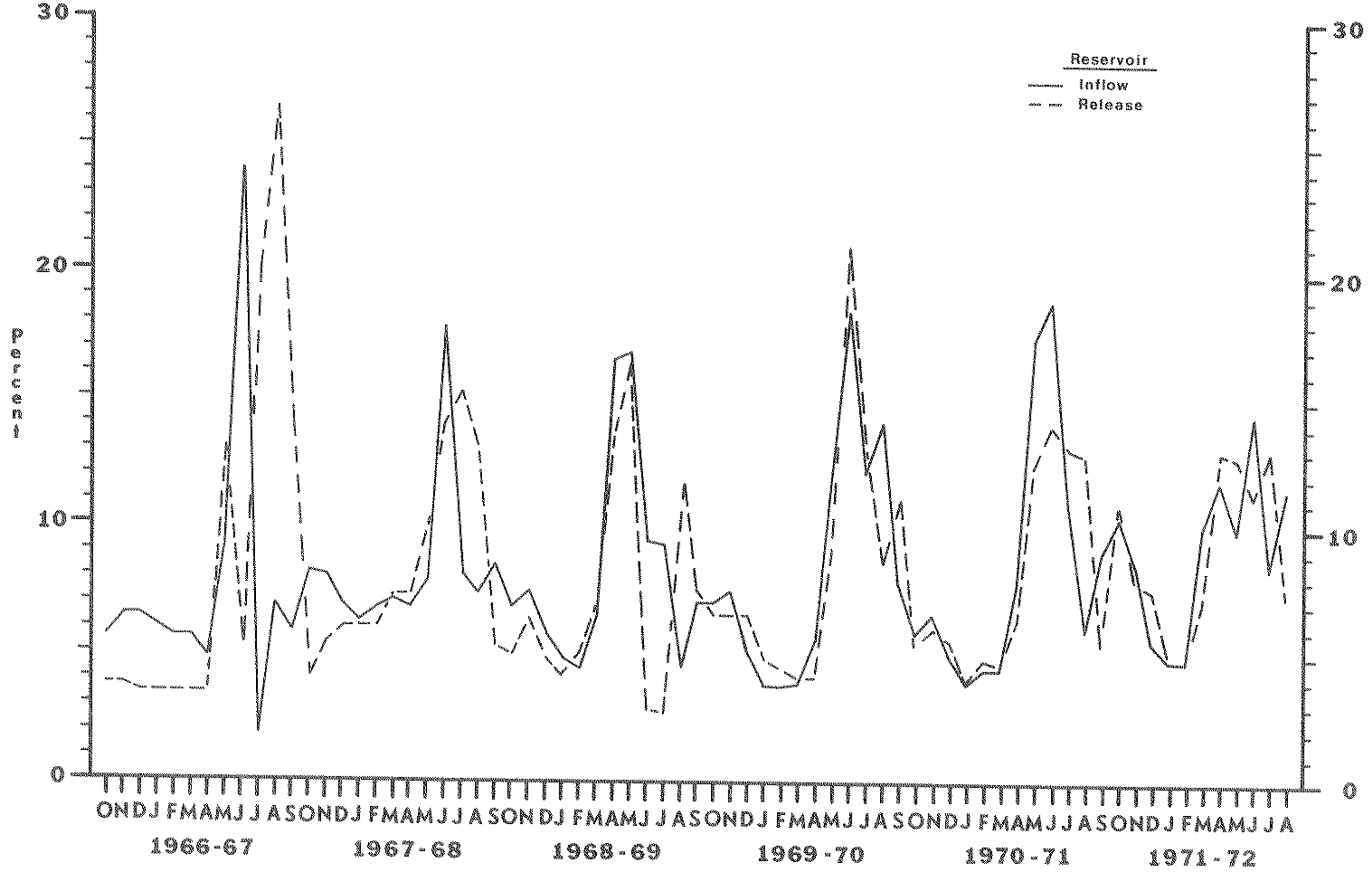

Figure 3. Percent of total annual flow by month on an annual basis for reservoir inflow and releases.

and 36% less, respectively, during 1972.

Maximum temperature recorded during the two summers was 23° C at station two, while a minimum of at or near zero degrees was recorded during the winter months at all stations (Table 2). Station two had the greatest daily fluctuations and annual range. Considering the maximum temperature occurring each month, station three had maximum monthly temperatures that were equal to or lower than at station one for all months except September 1971 and August 1972, lower than station one during the spring, summer and winter months, but higher in the fall. Except for fall, monthly maximum temperatures at station six were generally equal to or slightly greater than the maximums observed at stations one or three.

Monthly mean temperatures were mostly within a four degree (C) range each month for all stations. The greatest annual monthly mean temperature range was observed at station two (16 to 0° C). Station two exceeded station one in monthly mean temperatures during the spring, summer and early fall seasons. It was lower during the late fall and winter (Table 2). The monthly mean temperatures at station three equalled those at station one during the months of December, 1971 through April, 1972, but were lower during November 1971 and May-June, 1972. During the remaining seven months (June-October 1971, July-August 1972), station three had higher mean temperatures than station one. Monthly mean temperatures gradually increased downstream. Station six equalled

Table 2. Maximum, mean and minimum monthly temperatures (°C) for all stations during the study period.

Date		Station #						Date		Station #					
		1	2	3	4	5	6			1	2	3	4	5	6
	Max.	17	23	14	14	17	--		Max.	18	22	18	16	19	--
6/71	Mean	12	16	14	12	14	--	7/71	Mean	14	16	15	14	16	--
	Min.	8	10	12	11	12	--		Min.	10	10	13	12	13	--
	Max.	19	21	19	18	20	20		Max.	15	17	19	18	19	18
8/71	Mean	14	15	17	16	16	16	9/71	Mean	10	10	14	14	14	13
	Min.	11	9	15	14	13	11		Min.	6	3	9	10	9	8
	Max.	12	11	11	13	12	12		Max.	6	3	3	5	5	6
10/71	Mean	7	5	8	8	8	8	11/71	Mean	3	1	2	3	3	3
	Min.	1	0	2	4	4	0		Min.	1	0	1	1	2	2
	Max.	4	1	3	4	4	4		Max.	4	0	3	5	4	5
12/71	Mean	1	0	1	2	2	2	1/72	Mean	2	0	2	3	2	2
	Min.	0	0	0	1	0	1		Min.	0	0	1	1	0	0
	Max.	7	1	3	7	6	7		Max.	8	7	6	9	9	9
2/72	Mean	3	0	3	4	3	4	3/72	Mean	4	2	4	5	5	5
	Min.	0	0	1	2	0	1		Min.	1	0	3	3	2	2
	Max.	11	14	8	9	11	12		Max.	17	22	11	13	15	17
4/72	Mean	6	6	6	6	6	7	5/72	Mean	10	11	9	9	10	10
	Min.	2	1	4	4	3	3		Min.	4	2	7	7	6	6
	Max.	17	23	14	16	18	18		Max.	18	21	17	18	18	19
6/72	Mean	13	16	12	12	14	14	7/72	Mean	14	15	15	15	16	15
	Min.	9	10	10	10	12	10		Min.	9	8	13	13	13	10
	Max.	17	22	18	19	20	19								
8/72	Mean	14	15	17	17	18	15								
	Min.	11	10	16	15	16	12								

during three months and exceeded during ten months, the mean temperatures at station one.

Diel temperature curves for three consecutive days during a warm summer period (1971) and during a colder winter period were compared concurrently for stations one, three and six to ascertain reservoir effect (Fig. 4). During the warmest summer period, stations one and six had very similar daily curves, with the temperature at station six being slightly higher. Both the stations had a daily range of about five degrees. Daily temperatures at station three were more stable and fluctuated approximately one degree. The same situation existed for all three stations during the warmest summer period in 1972.

During the cold winter period, December 1971, 24 hour temperature fluctuations were one to two degrees at stations one and six, and less than one degree at station three. As in summer, station six was warmer than station one and station three was most stable.

Turbidity ranged from a maximum of 22 Jackson Turbidity Units (JTU) to a minimum of zero JTU (Table 9). Station one had the highest mean turbidity levels and was followed by station two (Table 3). Stations three and four almost always had less turbidity than station one and had generally less than station two. Station five reflected an increase in average turbidity over stations three and four which might have been due to the inflow from Grasshopper Creek. Turbidity at station six was comparable to turbidity at station one.

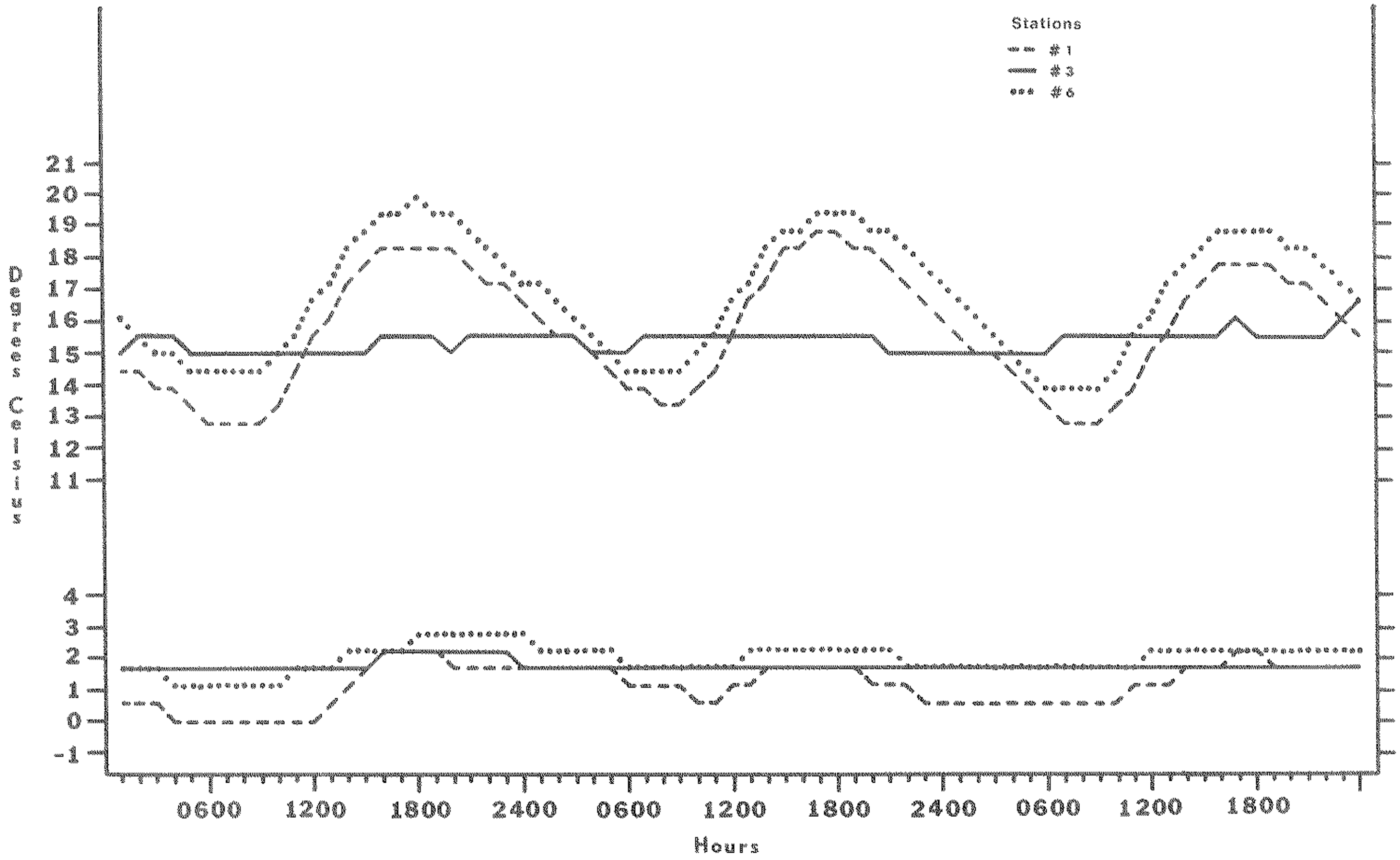

Figure 4. Diel periodicity temperature for three consecutive days at station one, three and six during a warm (upper curve) and cold period (1971).

Table 3. Turbidity means (JTU) for the summer of 1971, 1972 and winter period.

	Station					
Periods	1	2	3	4	5	6
Summer 1971	11	8	7	7	8	---
Winter	10	6	4	4	5	10
Summer 1972	8	6	4	4	7	5

Conductivity readings ranged between 420-650 μmhos at station one, 280-580 μmhos at station two and 400-695 μmhos for stations three through six (Table 10). Seasonal conductivity at station two fluctuated considerably (300 μmhos) and appeared to be related to fluctuations in flows. Conductivity at station one was more stable and less influenced by changes in flows than at station two. Conductance at station three was very similar to that at station one, even considering the time lags for retention time in the reservoir. Approximate retention times ranged from a low of 2.7 months to a high of 25.6 months during the study period.

Mean conductivity at stations three and five for both the combined summers and winter was generally the same with a slight increase at station four and decrease at station five (Fig. 5). The slight decrease at station five could have been caused by the inflow from Grasshopper Creek. Station six had a slightly higher mean conductivity in winter compared to all upstream stations and a mean approximately 100 μmhos

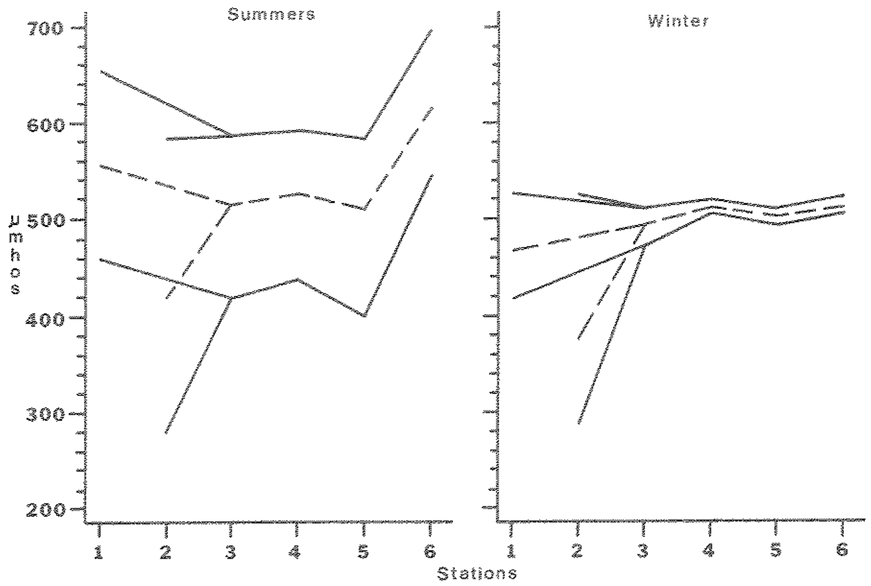

Figure 5. Conductivity maximum, mean and minimum at all stations for the combined summers and winter period.

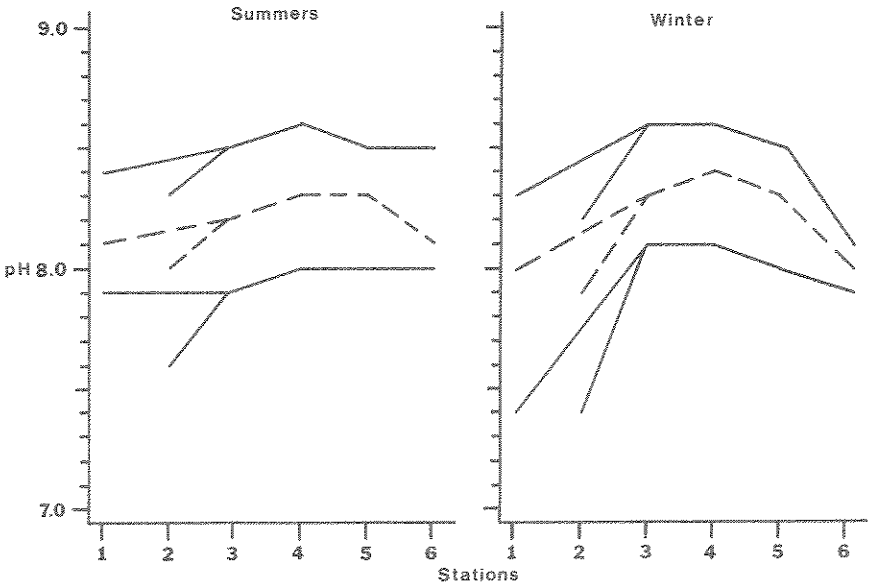

Figure 6. pH maximum, mean and minimum at all stations for the summers of 1971 and 1972 combined and intervening winter.

greater during the summer than stations three-five. The mean conductance at stations one through five ranged from 86 to 108 μmhos greater during the summer of 1972 and may have resulted from less flows in 1972.

Chemical Parameters

The pH values ranged between 7.4-8.4 for station one, 7.4-8.3 for station two and 7.9-8.6 for stations three through six (Table 11). The pattern of fluctuations for the sampling periods, June, July and August, was similar in 1971 and 1972 but the magnitude of fluctuations was greater in 1971. Greatest differences in pH between stations one and three occurred during September 1971 and April 1972, 0.6 and 0.7 pH units, respectively. The pH values for these two stations were more similar during the two summers than during the winter.

The mean pH increased at station three to a level above that at stations one and two (Fig. 6). The maximum pH was observed at stations four and five during the summer period and at station four only during the winter period. The mean pH at station six returned to the level of station one during both the summers and winter periods.

Percent saturation of dissolved oxygen (DO) ranged between 90-114% (7.06-11.08 ppm) at station one, 78-112% (6.24-11.60 ppm) at station two and 94-148% (7.40-12.80 ppm) for stations three through six (Tables 12, 13). The patterns of DO (percent saturation) fluctuations at stations one and two were not similar from June to December 1971, while an almost identical pattern was present from April through August 1972

(Fig. 7). Percent saturation for stations one and two averaged about 94% and 98%, respectively, during both summers and the winter period. Station three had higher DO readings than stations one and two during all sample periods with the exception of August 18, 1971, and at no time did the DO fall below the saturation level (Fig. 7, 8). DO fluctuations at stations four and five were similar to station three but the mean DO level was approximately 3.5% less for the summers and winter at station five. Mean percent saturation was greater at all stations, except station two, for the summer of 1972 than the summer of 1971. There was no correlation between percent saturation and discharge rate at stations three or five (R values less than 0.14).

Total alkalinity (ppm $CaCO_3$) ranged between 110-225 ppm for station one, 55-219 ppm at station two, and 98-223 ppm at stations three through six (Table 14). For stations one and three the overall annual progressions of total alkalinity were similar but with slightly higher alkalinity at station one. Station two had a lower level of total alkalinity than stations one and three, and was subject to greater fluctuation in the amount of alkalinity present (Fig. 9)

The mean alkalinity at stations three and four were essentially identical for the winter and summer periods (Fig. 9). Station five had slightly lower mean alkalinity than stations three and four, which could have been the result of inflows from Grasshopper Creek. Station six had a 15% increase in mean total alkalinity over station five for

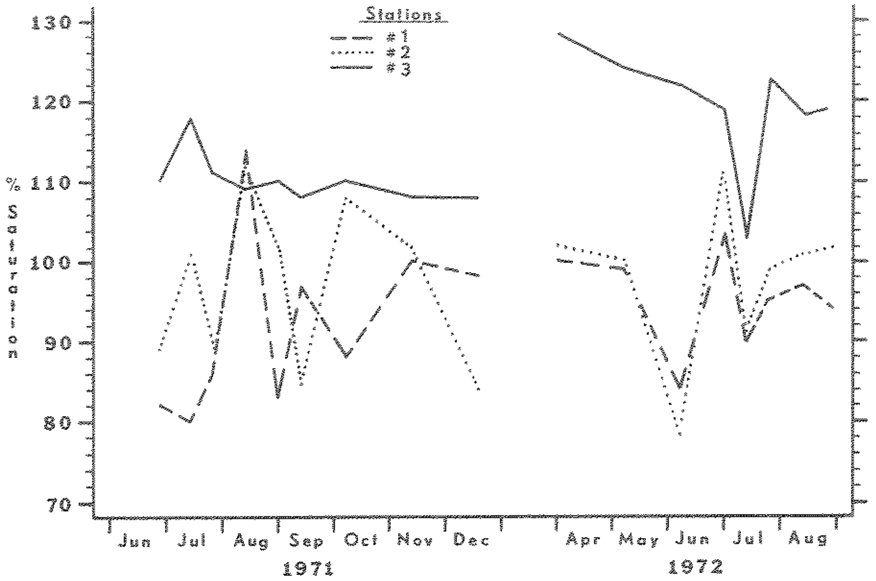

Figure 7. Dissolved oxygen percent saturation by month at stations one, two and three.

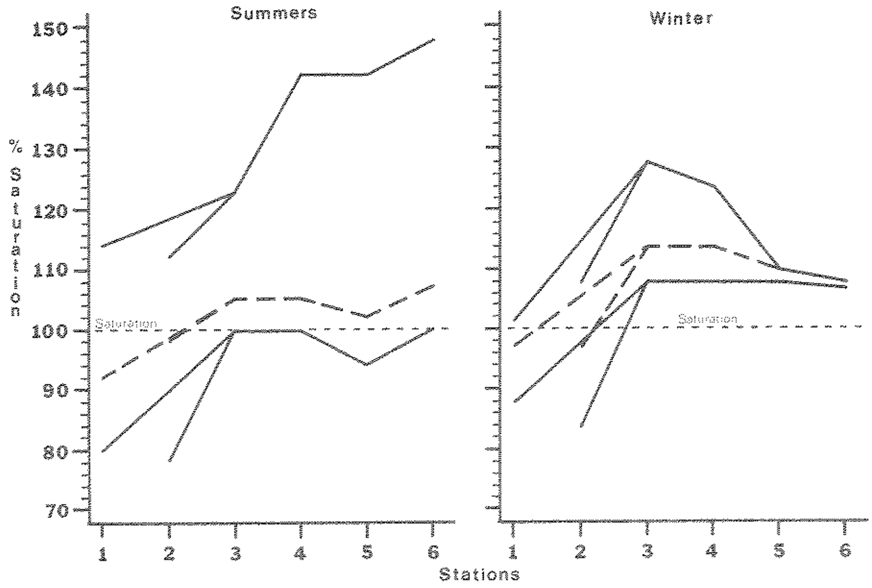

Figure 8. Dissolved oxygen percent saturation maximum, mean and minimum at all stations for the summers 1971, '72 combined and winter 1971-72.

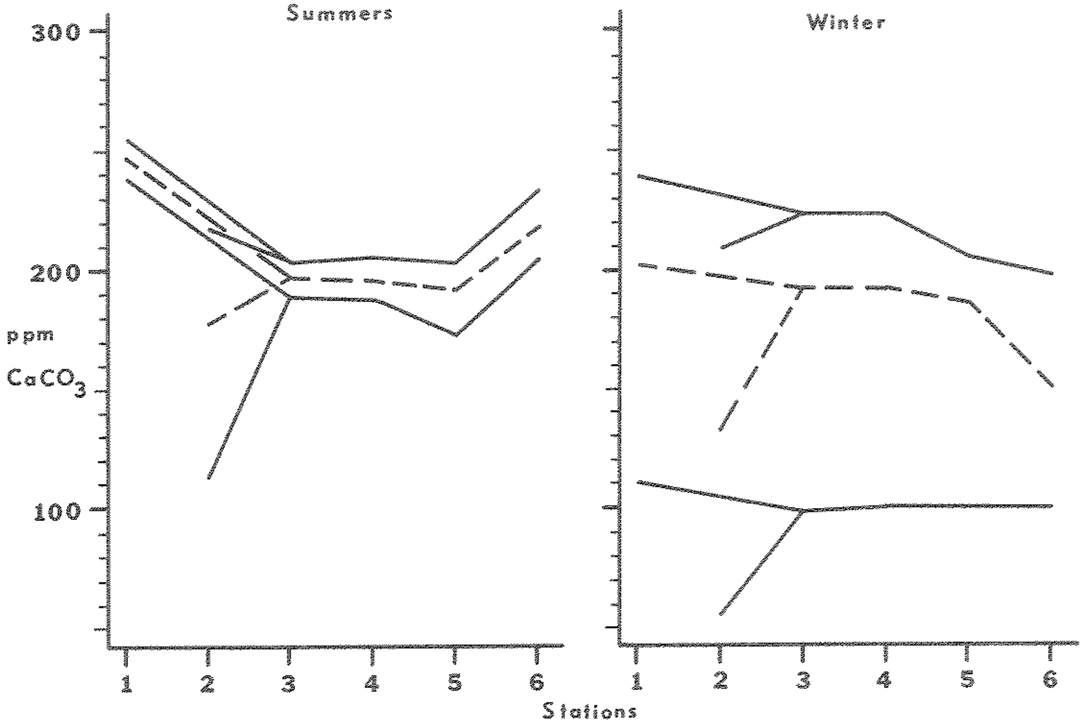

Figure 9. Total alkalinity maximum, mean and minimum at all stations for the combined summers data (1971, '72) and intervening winter.

the summer of 1972.

Total hardness (ppm $CaCO_3$) ranged between 170-325 ppm at station one, 90-230 ppm at station two and 167-392 ppm for stations three through six (Table 15). Total hardness at stations one and two were similar in pattern of fluctuation but lower levels were present at station two (Fig. 10). Station three had hardness levels which fluctuated only slightly through June, July and August. In general, hardness appeared to increase through the summers and winter at station three but decline severely during the spring runoff. The decline in total hardness was also noted for stations one and two. Mean hardness at stations three and four were mostly intermediate to that found at stations one and two. During the summer of 1972 total hardness levels at station six increased over stations three, four and five to a level comparable with station one (Table 15, Fig. 11).

A greater range in total hardness readings was noted during the winter period than during the summer periods (Fig. 11).

Ammonia (ppm NH_3-N) for the summer period of 1972 ranged between 0.00-0.05 ppm at station one, 0.00-0.17 ppm at station two and 0.00-0.24 ppm at stations three through six (Table 16). Mean ammonia concentrations at stations one and two were below that at station three which had the greatest mean concentration (Table 4). Mean concentration of ammonia progressively decreased from station three through six with the latter station having a mean comparable with station one.

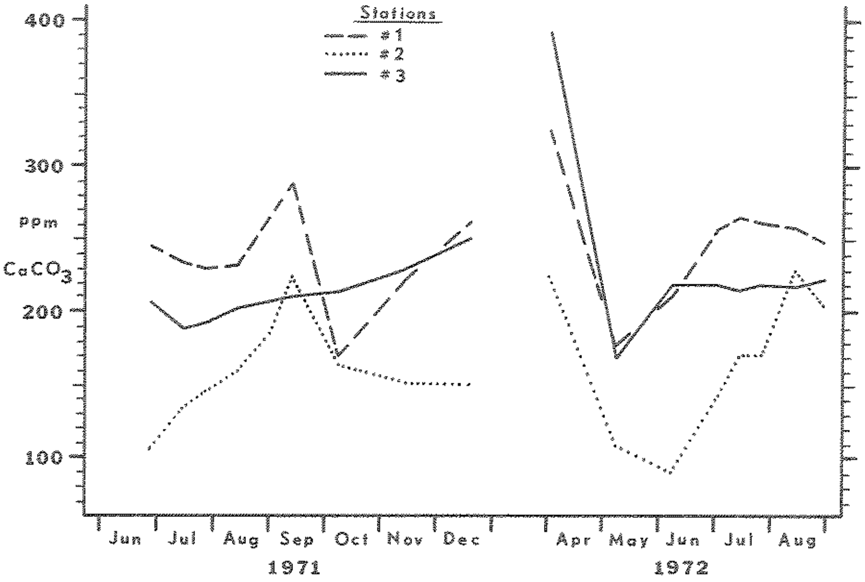

Figure 10. Total hardness (ppm $CaCO_3$) by month for stations one, two and three.

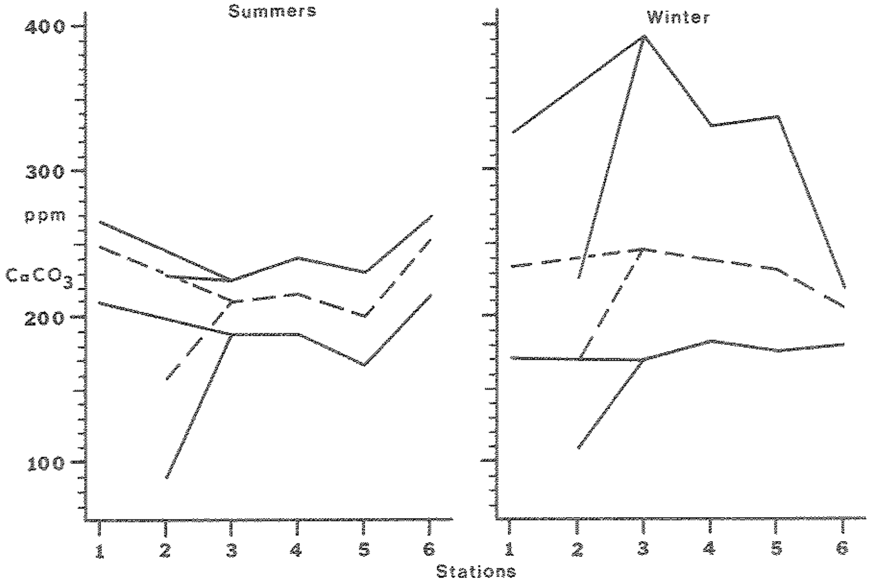

Figure 11. Total hardness maximum, mean and minimum at all stations for the combined summers data (1971, '72) and intervening winter.

Table 4. Maximum, mean and minimum ammonia (ppm NH_3-N) for the summer 1972.

Stations	Max.	Mean	Min.
#1	0.05	0.02	0.00
#2	0.17	0.05	0.00
#3	0.22	0.14	0.05
#4	0.24	0.08	0.05
#5	0.11	0.05	0.00
#6	0.05	0.02	0.00

Nitrate (ppm NO_3^--N) readings ranged between 0.057-0.375 ppm at station one, 0.003-0.199 ppm at station two and 0.000-0.305 ppm for stations three through six for the winter and summer (1972) periods (Table 17). Station two had the lowest mean levels of nitrate, while station one had the highest mean levels and appeared to be the major source of nitrates in the study area (Fig. 12). Mean nitrate at stations three, four and five were intermediate to readings at stations one and two. Mean nitrate during the winter was very similar at stations three through five while the summer mean nitrate readings at these three stations were more variable. Station six had the highest mean nitrate levels of all stations during the summer.

Nitrite (ppm NO_2^--N) levels ranged between 0.000-0.010 ppm at stations one and two and 0.000-0.041 ppm for stations three through six (Table 18). Station one had a slightly greater mean amount of nitrite than station two but both stations had the lowest nitrite means

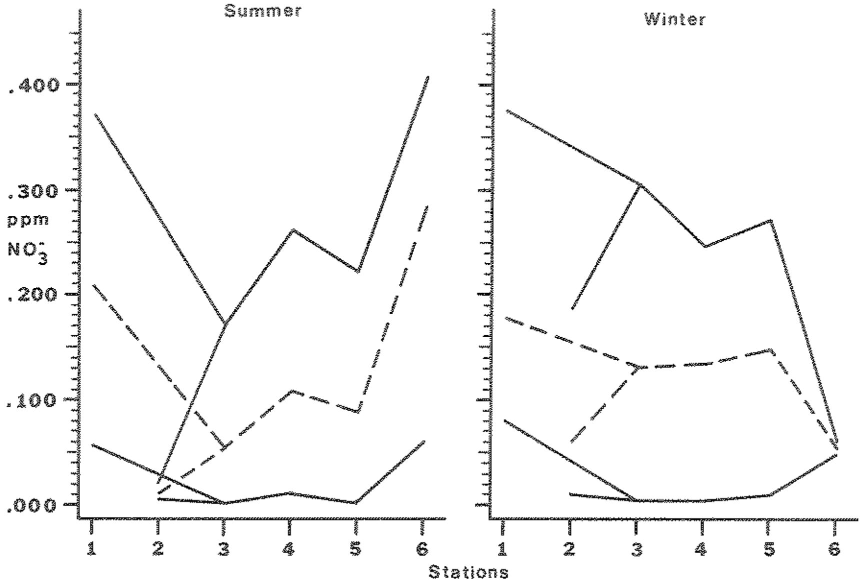

Figure 12. Nitrate (ppm NO_3^--N) maximum, mean and minimum at all stations for the winter of 1971-72 and summer of 1972.

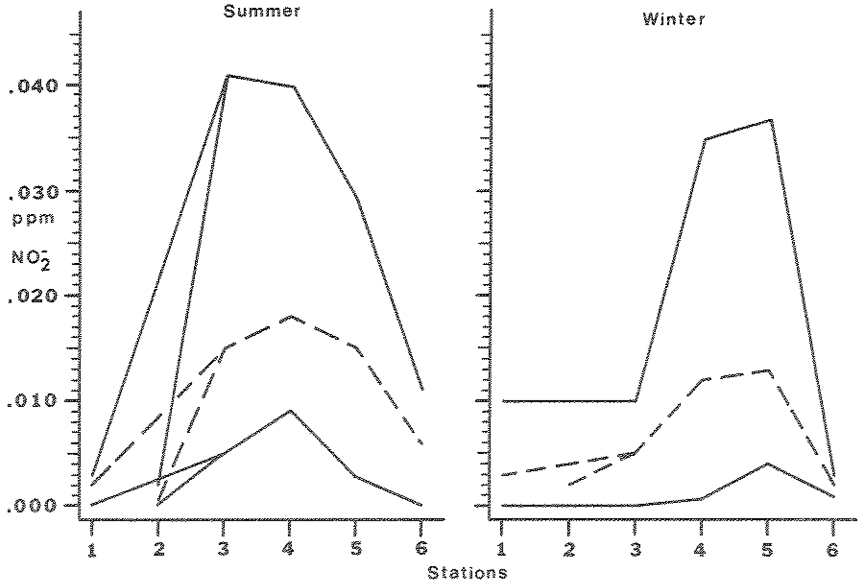

Figure 13. Nitrite (ppm NO_2^--N) maximum, mean and minimum at all stations for the winter of 1971-72 and summer of 1972.

for the study area (Fig. 13). Station three had a 67% and 650% increase over the mean nitrite at station one for the winter and summer period, respectively. Stations four and five had equal or higher mean concentrations of nitrite than station three. Mean nitrite at station six decreased considerably from that at station five, but was still higher than at station one and two for the summer period.

Orthophosphate (ppm $PO_4^{\equiv}$) readings ranged between 0.005-0.14 ppm at station one, 0.09-0.36 ppm at station two and 0.02-0.18 ppm for stations three through six (Table 19). Station two appeared to be the major source of phosphate in the study area. Station one had the lowest levels of phosphate during the combined summers only and was second in phosphate to station two during the winter period (Fig. 14). Mean phosphate at station three was intermediate to stations one and two during the combined summers but was lower than either during the winter period. In general, a decrease in mean orthophosphate was evident progressing downstream from station three through station six.

Biological Parameters

A total of 43 genera were observed during the spring and summer, 1972, and are listed in Table 20. Major plankters were species of *Fragilaria*, *Diatoma*, *Asteronella* and *Oscillatoria*, while major periphyton forms included species of *Navicula*, *Gomphonema*, *Cymbella*, *Fragilaria* and *Diatoma*. A distinct spring diatom bloom was evident (Table 5).

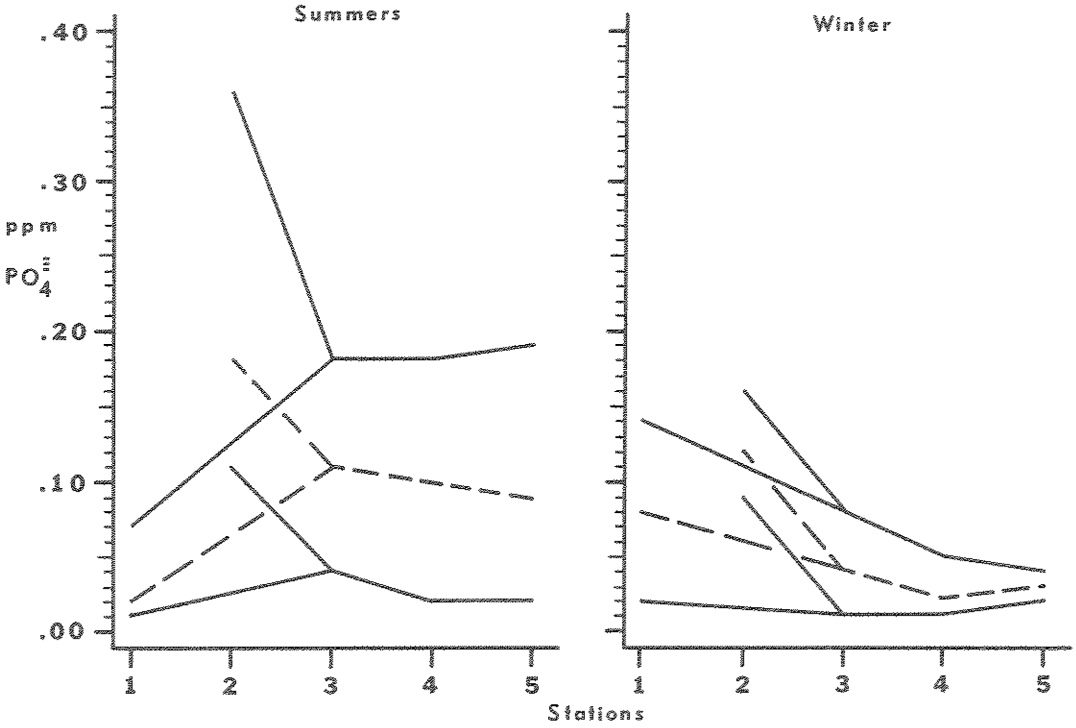

Figure 14. Orthophosphate (ppm $PO_4^{\equiv}$) maximum, mean and minimum at all stations for the combined summers data (1971, '72) and intervening winter.

Table 5. Relative abundance (percent) for those algae which had 10% or more abundance at least once during the eight sampling dates during the spring and summer 1972.

Genera	Date								Mean	
	4/8	5/7	6/17	7/11	7/14	7/26	8/13	8/26		
Station #1										
Diatoma	12	58	21	16	12	8	11	4	17.75	
Fragilaria	10	3	8	6	10	14	3	3	7.13	
Gomphonema	12	2	6	4	15	18	27	22	13.24	
Navicula	38	22	19	52	43	46	42	50	39.00	
Tabillaria	0	0	31	4	4	TR	0	0	4.94	
									81.07	Total
Station #2										
Asteronella	0	18	2	0	TR	4	TR	0	3.12	
Cymbella	7	3	4	2	6	16	30	24	11.50	
Diatoma	2	2	31	36	30	22	6	18	18.38	
Fragilaria	5	5	11	5	11	TR	2	7	5.81	
Gomphonema	44	9	8	12	13	9	11	9	14.38	
Mellosira	0	0	0	11	1	2	2	7	2.88	
Navicula	25	6	19	14	15	30	27	14	18.75	
Synedra	6	16	3	12	9	10	6	6	8.50	
Tabillaria	0	31	5	TR	2	0	0	0	4.81	
									88.06	Total
Station #3										
Asteronella	40	11	1	0	4	TR	0	TR	7.12	
Diatoma	20	46	35	60	78	69	43	11	45.25	
Fragilaria	31	33	16	2	TR	2	TR	TR	13.19	
Hannaea	TR	TR	30	8	2	2	0	TR	5.44	
Mellosira	0	0	3	1	10	4	TR	0	2.31	
Oscillatoria	0	0	1	1	0	2	46	82	16.50	
									87.25	Total
Station #6										
Asteronella	18	5	2	0	TR	0	0	0	3.19	
Diatoma	57	54	29	72	64	24	12	10	40.25	
Gomphonema	2	8	10	3	1	3	4	12	5.38	
Navicula	7	16	24	12	21	57	62	58	32.00	
Rhoicosphenia	1	5	10	3	2	4	3	5	4.12	
									85.06	Total

Of the 43 genera observed, only 12 genera were found to have had a relative abundance greater than or equal to ten percent in at least one collection date during the collection period (Table 5). Stations one, two, three and six each had five, nine, six and five genera, respectively, which had a relative abundance of ten percent or greater at least once during the spring and summer sampling period (Table 5).

Of the five genera which had a ten percent or greater abundance at station one, *Navicula* had the greatest mean relative abundance of 39%, followed by *Diatoma* and *Gomphonema* with 17.75% and 13.25%, respectively (Table 5). Station two had four genera out of nine with a mean abundance greater than ten percent. These were *Navicula*, 18.75%; *Diatoma*, 18.38%; *Gomphonema*, 14.38%; and *Cymbella*, 11.50%. Three of the six genera with at least ten percent or greater relative abundance during at least one of the sampling dates at station three had a mean relative abundance in excess of ten percent. These were *Diatoma*, with 45.25%, *Oscillatoria*, with 16.50% and *Fragilaria*, with 13.19%. At station six *Diatoma* and *Navicula* had the highest mean relative abundance with 40.25% and 32.00%, respectively.

Of the nine genera found at station two which had ten percent or greater relative abundance, at least once during the sampling period, *Diatoma*, *Fragilaria*, *Gomphonema*, *Navicula* and *Tabillaria* were also found at station one. *Cymbella* and *Synedra* were only found at station two. Four of the six genera which had at least ten percent abundance at station three were present at station(s) one and/or two for the same dates (*Asterionella*, *Diatoma*, *Fragilaria* and *Mellosira*). *Hannaea* and *Oscillatoria* were only present at station three. The five genera at station six with at least one ten percent occurrence during the sampling dates, included *Asteronella* and *Diatoma* which were present at station three also, and *Gomphonema* and *Navicula* which were not present at station three but were present at stations one and two. *Rhoiocosphenia* was only abundant at station six.

To ascertain if a significant difference ($p= 0.05$) existed between two stations for a particular genera of phytoplankton, the confidence interval for the larger relative percent abundance was compared to the smaller. Comparisons were made between stations one and two versus three, and one and two versus six, for the 15 genera which had a relative abundance of five percent or greater at least once during the collection period.

Since station two was unique in having more phytoplanktonic diversity than station one (Table 5), comparisons were limited to stations one, three and six.

Four of six periphytic diatom genera had a significant decrease between station one and stations three and six (Table 6). *Cocconeis* and *Cymbella* decreased in two while *Gomphonema* and *Navicula* decreased in six of eight samples. Stober (1962) found *Navicula* and *Cymbella* greatly decreased below the Tiber Reservoir in Montana. Compared to

Table 6. Phytoplankton which had five percent relative abundance or greater during the spring and summer of 1972 and the net number of times the relative abundance by genus at stations three and six were significantly different (p=0.05) from the relative abundance for the same genus at stations one and two. (+ for greater than; - for less than; confidence interval)

Genera	Type*	Stations			
		3 vs 1	3 vs 2	6 vs 1	6 vs 2
Asteronella	(Pl)	+1	0	+1	0
Cocconeis	(Pe)	-2	-1	0	0
Cyclotella	(Ei)	0	-1	0	-1
Cymbella	(Pe)	-2	-5	-2	-5
Diatoma	(Ei)	+6	+5	+6	+4
Dinobryon	(Pl)	+1	+1	+1	+1
Fragilaria	(Ei)	0	+4	-5	-3
Gomphonema	(Pe)	-6	-6	-4	-3
Hannaea	(Pe)	+2	+1	0	-2
Mellosira	(Ei)	+1	-1	0	-2
Navicula	(Pe)	-6	-7	+1	+3
Oscillatoria	(Ei)	+2	+2	0	0
Rhoicosphenia	(Pe)	+1	+1	0	0
Synedra	(Ei)	0	-7	0	-7
Tabillaria	(Ei)	-1	-1	-1	-1

*Pl: planktonic, Pe: periphytic, Ei: either planktonic or periphytic.

levels found at station one, *Rhoiocosphenia* and *Hannaea* had greater significant abundance at station three in one and two of eight samples, respectively. The planktonic *Asteronella* and *Dinobryon* each had an increase at station three in one of the eight sample periods. Of those genera which are either planktonic or periphytic, *Diatoma* increased significantly at station three in six out of eight samples.

Comparison of phytoplanktonic relative abundance between stations one and six revealed a general recovery of algae to levels found at station one. Phytoplankton at station six changed in type and abundance to levels which were more similar to stations one and two with *Navicula, Gomphonema* and *Cocconeis* recovering the most. *Hannaea, Mellosira* and *Oscillatoria* were only abundant at station three and decreased considerably at station six.

Diatoma, which had the greatest increase at station three, was also of great abundance at station six. This genera has species which are planktonic and others which are periphytic. While species identification was not carried out, there were indications that the species at station three were primarily planktonic and those at station six were probably periphytic (Berg, Bahls, personal communication).

Overall, of the 15 genera with a relative abundance of five percent or more, three genera were not significantly different between stations one and three while seven of the 15 genera were not significantly different between stations one and six.

Daphnia and *Cyclops* were the most abundant zooplankters in the river samples. Berg (personal communication) also noted this for his reservoir samples as did Stober (1963) for the Marias River below Tiber Reservoir.

Summer mean concentrations, organisms per liter, reflected an increase in both *Daphnia* and *Cyclops* at station three when compared to mean concentrations at stations one and two (Table 7). *Daphnia* had an approximate three and five fold increase at station three versus stations one and two, respectively. *Cyclops* had an eight fold increase at station three over stations one and two. Concentrations of both *Daphnia* and *Cyclops* were observed to decrease with progression downstream from station three, with the exception of *Cyclops* at station four which was slightly higher than the mean at station three. The mean concentration at station six was below the mean concentration at stations one and two for both species.

Table 7. Maximum, mean and minimum summer concentration (organisms/liter) for *Daphnia* and *Cyclops* at all stations.

		Stations					
		1	2	3	4	5	6
Daphnia	Max.	17.5	12.5	45.0	52.5	20.0	2.5
	Mean	7.5	4.7	21.9	9.0	2.8	0.9
	Min.	2.5	0.0	5.0	0.0	0.0	0.0
Cyclops	Max.	2.5	5.0	27.5	60.0	25.0	2.5
	Mean	1.2	0.9	8.1	8.4	3.1	0.6
	Min.	0.0	0.0	0.0	0.0	0.0	0.0

DISCUSSION

Physical Parameters

Of the physical parameters examined, flows and water temperature were altered most by the presence of the reservoir.

Even though 1971 and 1972 were high water years, with 1972 having slightly less runoff than 1971, a distinct alteration in annual flow pattern was noted below the reservoir. Both pre- and postimpoundment and reservoir inflow-release comparisons revealed that monthly mean postimpoundment flows from the dam site to Barretts Diversion Dam were altered. Mean monthly flows for this region of the Beaverhead River had less water during the low water season of autumn and winter and greater flows during the high water season of spring and summer. December postimpoundment flows only had 74% of the preimpoundment flows, while May and August each had about 40% increases in postimpoundment flows.

Vincent (1969, 1971) reported flows in the Madison River during the late winter and early spring were much reduced during 1967 by renewed storage in Hebgen Reservoir. The resulting late winter and/or early spring dewatering of the Madison River resulted in lowered survival and weight gain of brown trout. Good early spring flows were maintained during the years of 1968-71 with a resulting increase in survival and weight gain in brown trout. While severe low flows were not experienced from the dam site to Barretts Diversion Dam or below during winter and early spring, future low water years could result in survival problems for trout in this area.

Monthly mean flows at station six were found to be essentially unchanged except for the months of April, June and July. April had less postimpoundment flows than preimpoundment flows while the reverse was true for June and July.

Stabilization of diel fluctuations at station three was the greatest effect of the reservoir on water temperatures. Summer diel fluctuations at stations one and six were essentially the same with a fluctuation range of about five degrees (C). Station three had a diel temperature range of only one degree during the summer. During the winter stations one and six had diel temperature ranges of one or two degrees while station three had a diel range of less than one degree. The lack of a diel fluctuation at station three was the result of the bottom draw found at Clark Canyon Reservoir. The water which was released from the reservoir was from the deeper part and consequently of uniform temperature.

Station three had lower monthly maximums than station one by at least three degrees during June and November, 1971, and February, April and May, 1972. Only during the month of September 1971 did the monthly maximum temperature at station three exceed the monthly maximum temperature at station one. During September 1971 the reservoir had 40% of the active storage remaining and was fairly uniform in temperature (top: 14.8; bottom: 14.5° C) throughout its entire depth (Berg, personal communication). This condition in the reservoir resulted in a warmer monthly maximum at station three than at station one. The greatest difference in monthly mean temperatures between stations one and three occurred during September 1971, four degrees, and August 1971 and 1972, three degrees, when the temperature at station three exceeded those at station one. As previously noted, August and September were months where discharge from the reservoir greatly exceeded inflow. This may have drawn water from the warmer epilimnion which resulted in the higher mean temperatures at station three. Stober (1963) reported finding cooler water below Tiber Reservoir during the summer and early fall. These differences in results between my study and Stober's can be explained by the depth of the outlet works, and the size of the reservoirs. Tiber Reservoir is twice the size of Clark Canyon and about twice as deep at the level of the outlet works.

Monthly mean temperatures at station three corresponded very closely to the monthly mean temperature found within the reservoir (Berg, personal communication).

Turbidity in the Beaverhead River was decreased somewhat by the presence of the reservoir. This slight effect was not unexpected since the Red Rock River and Horse Prairie Creek are clear water streams except during the spring runoff. The Marias River, immediately below Tiber Reservoir, had a marked decrease in turbidity due to the reservoir's presence (Stober, 1963).

Chemical Parameters

Of the chemical parameters studied, the reservoir had its greatest effect upon the dissolved oxygen levels in the tailwaters. The pH, ammonia and nitrite were also altered enough to be considered changed by the reservoirs presence.

The pH immediately below the reservoir was higher than the pH observed at stations one and two. The pH reached its highest level at approximately ten kilometers and preceeded to decrease to a level at station six which was comparable to the levels found at station one.

Comparisons of the pH on the bottom of the reservoir (Berg, personal communication) with the pH observed at at station three for the same dates revealed that the pH at station three was 0.2 pH units higher during the summer of 1971, generally the same during the winter and approximately 0.2 pH units less during the summer of 1972.

Mean dissolved oxygen levels in the Beaverhead River were found to be well above the saturation level while stations one and two were very near saturation but not above. While oxygen levels at the bottom of the reservoir were at their lowest levels during June, July and August (0.2-3.0 ppm DO) (Berg, personal communication), the dissolved oxygen at station three was always above the saturation level. These DO levels at station three were contrary to results reported by Fish (1959) at the Kerr and Roanoke Rapids Reservoirs in North Carolina. Sylevester and Seabloom (1965) found that the DO level in water released from the Howard A. Hanson Reservoir at Tacoma, Washington was at saturation during the summer.

High DO at station three may have been caused by a hydrolic ram situation in the outlet works. The presence of a 50.8 cm air intake pipe immediately behind the dam gates may have been the source of oxygen which was physically forced into solution as the water passed under the dam. The presence of high DO at all stations below the reservoir may have been an artifact caused by suspended microbubbles of gaseous air being present in the water samples. In any case, critically low DO due to the release of water from the bottom of the reservoir (Fish, 1959) is not likely to become a problem.

Nitrogen, in the form of ammonia (NH_3-N) and nitrite (NO_2^--N), was found to increase at station three above amounts found at stations one and two. The increase in ammonia and nitrite probably resulted from reduction of nitrates and/or the decomposition of organic matter in the deeper parts of the reservoir. Nitrogen fixation is not, however, to be ruled out as a source of inorganic nitrogen. During May-August 1972, ammonia concentrations on the bottom of the reservoir were higher than observed at station three, while nitrate and nitrite concentrations were approximately the same as at station three (Berg, personal communication).

With progression downstream, from station three to station six, ammonia decreased to a level comparable to concentrations found at station one. Nitrite, during the winter and summer, decreased with progression downstream while nitrate increased. This general decrease in ammonia and nitrite with corresponding increase in nitrate is probably attributable to oxidation.

Biological Parameters

Periphytic forms were greatly reduced immediately below the dam from kinds and numbers found in the two reservoir tributaries. These conclusions agree with Stober's (1963) findings on the Marias River. At Dillon most of the periphytic forms which were affected immediately below the reservoir were back to or near levels observed in the two reservoir tributaries. Generally, planktonic forms which were much increased in numbers and kinds below the dam were reduced or nearly nonexistent by 43 km downstream from the reservoir.

Concentrations of *Daphnia* were higher at station three than observed in the reservoir during April, lower during May-June and essentially the same during July-August. *Cyclops* concentrations were approximately the same in the reservoir and at station three (Berg, personal communication).

The presence of *Daphnia* and *Cyclops* at stations one and two could be explained by the presence of Lima Reservoir above station one and the sidewaters and irrigation returns on both tributary streams. Stober (1963) also found small numbers of *Daphnia* and *Cyclops* in a tributary to the Tiber Reservoir.

A substantial increase in zooplankton below the reservoir was noted in this study, as observed earlier by Stober (1963). As the Beaverhead River progressed downstream, the *Daphnia* and *Cyclops* were reduced in numbers to levels found at station six, which were less than those observed in the tributaries to the reservoir. The zooplankton may provide additional food for small fish through at least the first ten kilometers of river below the reservoir.

APPENDIX

Table 8. Sampling schedule of turbidity, conductivity, water chemistry and plankton samples.

	1971									1972							
Month	6	7		8	9		10	11	12	4	5	6	7			8	
Day	29	14,28		18	1,15		9	20	21	8	6	16	1,14,26			13,26	
Turbidity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Conductivity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Oxygen	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total Alkalinity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total Hardness	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ortho-phosphate				X	X	X			X	X	X	X	X	X	X	X	X
Nitrate							X	X	X	X	X	X	X	X	X	X	X
Nitrite							X	X	X	X	X	X	X	X	X	X	X
Ammonia											X	X	X	X	X	X	X
Plankton										X	X	X	X	X	X	X	X

Table 9. Turbidity (Jackson Turbidity Units) by sampling date for the summers 1971, '72 and intervening winter.

	Stations					
Date	#1	#2	#3	#4	#5	#6
6/29/71	22	19	19	20	21	--
7/14	10	7	1	2	2	--
7/28	8	6	2	2	4	--
8/18	6	3	5	5	4	--
9/1/71	10	7	7	8	9	--
Mean	11	8	7	7	8	--
9/15/71	10	2	3	2	2	--
10/9	9	3	0	2	2	--
11/20	8	3	3	5	3	--
12/21/71	1	0	4	3	6	--
4/8/72	18	10	8	9	13	13
5/6/72	12	20	6	6	6	8
Mean	10	6	4	4	5	10
6/16/72	10	16	8	7	18	13
7/1	8	6	4	3	3	2
7/14	8	8	4	6	8	5
7/26	4	4	3	4	6	5
8/13	9	3	4	3	5	2
8/26/72	10	2	4	3	3	1
Mean	8	6	4	4	7	5

Table 10. Conductivity (μmhos @ 25°C) by sampling date and stations for the summers 1971, '72 and intervening winter.

	Stations					
Date	#1	#2	#3	#4	#5	#6
6/29/71	495	280	460	462	418	---
7/14	510	315	485	510	485	---
7/28	465	337	420	435	400	---
8/18	520	485	462	470	475	---
9/1/71	545	485	460	485	495	---
Mean	507	380	457	472	455	---
9/15/71	520	525	498	510	510	---
10/9	500	390	495	510	495	---
11/20	495	360	500	515	495	---
12/21/71	525	365	510	520	505	---
4/8/72	420	295	495	515	495	505
5/6/72	455	300	475	510	495	525
Mean	486	372	496	513	499	515
6/16/72	650	340	570	575	510	560
7/1	600	410	540	545	520	545
7/14	620	520	570	570	570	625
7/26	580	465	575	585	580	635
8/13	590	480	585	590	585	640
8/26/72	545	580	550	565	565	695
Mean	598	466	565	572	555	617

Table 11. pH values by sampling date and stations for the summers 1971, '72 and intervening winter.

	Stations					
Date	#1	#2	#3	#4	#5	#6
6/29/71	8.0	7.9	8.2	8.3	8.3	---
7/14	8.2	8.3	8.2	8.3	8.4	---
7/28	8.3	8.1	8.2	8.2	8.3	---
8/18	8.4	8.2	8.1	8.3	8.3	---
9/1/71	8.1	8.2	8.5	8.6	8.5	---
Mean	8.2	8.2	8.2	8.3	8.4	---
9/15/71	8.0	8.1	8.6	8.6	8.5	---
10/9	7.7	8.1	8.1	8.5	8.4	---
11/20	8.3	8.2	8.4	8.5	8.4	---
12/21/71	8.3	7.7	8.3	8.4	8.5	---
4/8/72	7.4	7.4	8.1	8.1	8.0	7.9
5/6	8.3	7.9	8.3	8.2	8.2	8.1
Mean	8.0	7.9	8.3	8.4	8.3	8.0
6/16/72	7.9	7.6	8.1	8.2	8.2	8.0
7/1	8.0	8.0	8.0	8.4	8.5	8.5
7/14	8.0	8.0	7.9	8.0	8.0	8.0
7/26	8.0	8.0	8.1	8.1	8.1	8.0
8/13	8.1	8.1	8.1	8.1	8.2	8.0
8/26/72	8.0	8.0	8.3	8.4	8.4	8.2
Mean	8.0	7.9	8.1	8.2	8.2	8.1

Table 12. Dissolved oxygen (ppm) by sampling date and stations for the summers 1971, '72 and intervening winter.

Date	Stations					
	#1	#2	#3	#4	#5	#6
6/29/71	7.48	7.68	9.14	8.90	8.42	----
7/14	6.72	8.24	9.16	9.00	9.22	----
7/28	7.24	7.26	8.70	8.04	7.88	----
8/18	9.38	9.12	8.20	8.66	7.98	----
9/1/71	7.06	8.78	8.38	8.82	8.80	----
Mean	7.58	8.22	8.72	8.68	8.46	----
9/15/71	7.80	8.42	8.62	8.58	8.96	----
10/9	8.40	10.24	9.96	10.30	9.80	----
11/20	10.60	11.60	11.90	12.20	12.10	----
12/21	11.08	9.44	11.96	11.80	11.96	----
4/8/72	10.40	11.10	12.50	11.40	11.00	10.60
5/6/72	9.40	9.60	12.00	11.90	10.70	10.40
Mean	9.61	10.07	11.16	11.03	10.75	10.50
6/16/72	7.44	6.24	10.62	10.84	10.22	9.66
7/1	8.80	9.00	9.90	11.40	11.20	12.80
7/14	7.40	7.40	9.00	8.20	7.40	8.80
7/26	8.06	8.20	9.66	8.46	8.32	8.40
8/13	8.20	8.40	9.00	8.40	8.00	9.40
8/26/72	8.20	9.00	9.24	11.00	10.70	10.70
Mean	7.85	8.04	9.57	9.72	9.31	9.96

Table 13. Dissolved oxygen (percent saturation) by sampling date and stations for the summers 1971, '72 and intervening winter.

Date	Stations					
	#1	#2	#3	#4	#5	#6
6/29/71	82	89	110	108	101	---
7/14	80	104	119	112	117	---
7/28	86	89	111	100	96	---
8/18	114	112	107	106	105	---
9/1/71	83	102	110	116	115	---
Mean	89	99	111	108	107	---
9/15/71	97	85	108	108	110	---
10/9	88	108	110	115	110	---
11/20	100	102	108	112	110	---
12/21	98	84	108	110	108	---
4/8/72	101	102	128	118	110	107
5/6/72	99	100	124	124	110	108
Mean	97	97	114	114	110	108
6/16/72	84	78	122	126	121	112
7/1	104	111	119	142	142	148
7/14	89	91	113	101	94	102
7/26	95	99	123	106	104	100
8/13	97	101	118	109	102	112
8/26/72	94	102	119	142	137	130
Mean	94	97	119	121	117	117

Table 14. Total alkalinity (ppm $CaCO_3$) by sampling date and stations for the summers 1971, '72 and intervening winter.

Date	Stations #1	#2	#3	#4	#5	#6
6/29/71	255	123	192	188	172	---
7/14	240	140	191	192	188	---
7/28	238	148	196	188	190	---
8/18	246	202	195	194	195	---
9/1/71	252	194	201	202	202	---
Mean	246	161	195	193	189	---
9/15/71	238	209	206	206	204	---
10/9	217	152	206	209	204	---
11/20	217	141	211	205	198	---
12/21	230	139	223	223	206	---
4/8/72	110	55	98	100	100	100
5/6/72	209	102	199	203	195	199
Mean	204	133	190	190	184	150
6/16/72	248	111	202	202	182	204
7/1	250	152	198	198	180	218
7/14	246	172	189	190	182	217
7/26	247	169	199	200	197	222
8/13	250	219	200	200	199	234
8/26/72	242	206	202	204	202	218
Mean	247	188	198	199	190	218

Table 15. Total hardness (ppm $CaCO_3$) by sampling date and stations for the summers 1971, '72 and intervening winter.

	Stations					
Date	#1	#2	#3	#4	#5	#6
6/29/71	243	105	203	208	175	---
7/14	234	132	186	187	168	---
7/28	230	145	192	192	167	---
8/18	233	161	201	204	188	---
9/1/71	266	186	206	213	213	---
Mean	241	146	198	200	182	---
9/15/71	239	209	224	228	224	---
10/9	170	166	211	192	189	---
11/20	222	152	228	234	218	---
12/21/71	264	152	252	257	244	---
4/8/72	325	226	392	330	334	219
5/6/72	178	109	169	192	183	189
Mean	233	169	246	239	232	204
6/16/72	210	90	220	224	199	215
7/1	256	140	220	226	207	251
7/14	267	172	214	241	211	257
7/26	264	170	222	229	224	262
8/13	258	230	219	226	224	268
8/26/72	248	205	224	233	229	260
Mean	250	168	220	230	216	252

Table 16. Ammonia (ppm NH_3-N) concentrations for the summer 1972 by sampling date.

Date	Stations #1	#2	#3	#4	#5	#6
6/16/72	0.00	0.17	0.12	0.05*	0.05*	0.00
7/1	0.05	0.05	0.22	0.24	0.05	0.00
7/14	0.00	0.00	0.16	0.05	0.00	0.00
7/26	0.00	0.00	0.16	0.05	0.05	0.00
8/13	0.00	0.05	0.11	0.05	0.05	0.05
8/26/72	0.05	0.05	0.05	0.05	0.11	0.05
Mean	0.02	0.05	0.14	0.08	0.05	0.02

*Trace readings were arbitrarily assigned a 0.05 ppm value for computation of means.

Table 17. Nitrate (ppm NO_3^--N) by sampling date for the winter 1971-72 and summer 1972.

Date	Stations					
	#1	#2	#3	#4	#5	#6
10/9/71	0.159	0.019	0.090	0.195	0.273	-----
11/20	0.190	0.060	0.160	0.192	0.185	-----
12/21/71	0.375	0.199	0.305	0.245	0.259	-----
4/8/72	0.080	0.010	0.005*	0.005*	0.009	0.059
5/6/72	0.059	0.010	0.090	0.016	0.017	0.047
Mean	0.173	0.060	0.130	0.131	0.149	0.053
6/16/72	0.074	0.005*	0.005*	0.039	0.022	0.324
7/1	0.197	0.005*	0.080	0.125	0.007	0.060
7/14	0.057	0.009	0.070	0.145	0.110	0.264
7/26	0.199	0.015	0.000	0.083	0.174	0.404
8/13	0.370	0.020	0.169	0.260	0.221	0.399
8/26/72	0.359	0.005*	0.020	0.011	0.000	0.257
Mean	0.209	0.010	0.057	0.110	0.089	0.285

*Trace readings were arbitrarily assigned the value of 0.005 ppm for computation of means.

Table 18. Nitrite (ppm NO_2^--N) by sampling date for the winter 1971-72 and summer 1972.

	Stations					
Date	#1	#2	#3	#4	#5	#6
10/9/71	0.006	0.001	0.010	0.035	0.037	-----
11/20	0.010	0.010	0.010	0.018	0.015	-----
12/21/71	0.000	0.001	0.005	0.005	0.011	-----
4/8/72	0.000	0.000	0.000	0.0005*	0.001	0.001
5/6/72	0.001	0.0005*	0.001	0.004	0.003	0.003
Mean	0.003	0.002	0.005	0.012	0.013	0.002
6/16/72	0.006	0.002	0.006	0.011	0.008	0.006
7/1	0.003	0.000	0.010	0.015	0.003	0.000
7/14	0.003	0.001	0.020	0.025	0.020	0.006
7/26	0.001	0.000	0.005	0.007	0.026	0.011
8/13	0.000	0.000	0.041	0.040	0.029	0.011
8/26/72	0.001	0.0005*	0.010	0.009	0.005	0.003
Mean	0.002	0.0005*	0.015	0.018	0.015	0.006

*Trace readings were arbitrarily assigned the value of 0.0005 ppm for computation of means.

Table 19. Orthophosphate (ppm $PO_4^{\equiv}$) by sampling date and stations for the summers 1971, '72 and intervening winter.

Date	Stations #1	#2	#3	#4	#5	#6
8/18/71	0.04	0.17	0.16	0.18	0.19	----
9/1/71	0.05	0.11	0.06	0.04	0.04	----
Mean	0.04	0.14	0.11	0.11	0.12	----
9/15/71	0.08	0.09	0.03	0.01	0.02	----
12/21/71	0.02	0.09	0.02	0.02	0.03	----
4/8/72	0.14	0.13	0.08	0.05	0.04	----
5/6/72	0.09	0.16	0.01	0.02	0.04	0.03
Mean	0.08	0.12	0.04	0.02	0.03	0.03
6/16/72	0.005*	0.36	0.08	0.06	0.09	0.05
7/1	0.07	0.26	0.16	0.18	0.09	0.05
7/14	0.01	0.16	0.18	0.12	0.10	0.03
7/26	0.005*	0.12	0.10	0.09	0.10	0.08
8/13	0.02	0.11	0.09	0.10	0.11	0.07
8/26	0.005*	0.14	0.04	0.02	0.02	0.02
Mean	0.02	0.19	0.11	0.10	0.08	0.05

*Trace readings were assigned a 0.005 ppm value for computation of means.

Table 20. Classification of algae and stations where observed during the spring and summer of 1972.

- DIVISION: Chlorophyta
  - CLASS: Chlorophyceae
    - ORDER: Tetrasporales
      - FAMILY: Tetrasporaceae
        - GENUS: *Tetraspora* (3)
    - ORDER: Ulotrichales
      - SUBORDER: Ulotrichineae
        - FAMILY: Ulotrichaceae
          - GENUS: *Ulothrix* (1,3,4,5,6)
        - FAMILY: Chaetophoraceae
          - GENERA: *Draparnaldia*
            Stiggoclonium (4,5,6)
    - ORDER: Cladophorales
      - FAMILY: Cladophoraceae
        - GENUS: *Cladophora* (1,2,4,5,6)
    - ORDER: Chlorococcales
      - FAMILY: Oocystaceae
        - GENUS: *Ankistrodesmus* (1,3,4,5,6)
    - ORDER: Zygnamatales
      - FAMILY: Zygnemataceae
        - GENERA: *Mougeotia* (2,3)
          Spirogyra (1,3,4)
          Zygnema (5)
      - FAMILY: Desmidiaceae
        - GENERA: *Closterium* (3,4,5)
          Staurastrum (4)
- DIVISION: Chrysophyta
  - CLASS: Xanthophyceae
    - ORDER: Heterotrichales
      - FAMILY: Tribonemataceae
        - GENUS: *Tribonema* (1)
  - CLASS: Chrysophyceae
    - ORDER: Chrysomonadales
      - FAMILY: Ochromonadaceae
        - GENERA: *Dinobryon* (3,4,5,6)
          Uroglenopsis (3,4)

Table 20. (Continued).

CLASS: Bacillariophyceae
ORDER: Centrales
SUBORDER: Cosinodiscineae
FAMILY: Coscinodiscaceae
GENERA: *Cyclotella* (2,3,4,5,6)
Melosira (all)
Stephanodiscus (2,3,4,5,6)

ORDER: Pennales
SUBORDER: Fragilarineae
FAMILY: Tabellariaceae
GENERA: *Tabellaria* (1,2)
Tetracyclus (1,2,5,6)

FAMILY: Diatomaceae
GENUS: *Diatoma* (all)

FAMILY: Eunotiaceae
GENUS: *Hannaea* (all)

FAMILY: Fragilariaceae
GENERA: *Asterionella* (all)
Fragilaria (all)
Synedra (all)

SUBORDER: Achnanthineae
FAMILY: Achnanthaceae
GENERA: *Cocconeis* (all)
Rhoiocosphenia (all)

SUBORDER: Naviculinaea
FAMILY: Naviculaceae
GENERA: *Gyrosigma* (6)
Navicula (all)
Pinnularia (1,2,6)

FAMILY: Gomphonemataceae
GENUS: *Gomphonema* (all)

FAMILY: Cymbellaceae
GENERA: *Amphora* (3,4,5,6)
Cymbella (all)
Epithema (1,2)

SUBORDER: Surirellineae
FAMILY: Nitzschiaceae
GENERA: *Denticula* (2)
Nitzschia (all)

Table 20. (Continued).

FAMILY: Surirellaceae
GENERA: *Cymatopleura* (1,2,5,6)
Surirella (2,4,5,6)

DIVISION: Cyanophyta
CLASS: Mysophyceae
ORDER: Chroococcales
FAMILY: Chroococcaceae
GENUS: *Anacystis* (3)

ORDER: Oscillatoriales
SUBORDER: Oscillatorineae
FAMILY: Oscillatoriaceae
GENERA: *Oscillatoria* (2,3,4,5,6)
Spirulina (1,2,5)

SUBORDER: Nostochineae
FAMILY: Nostocaceae
GENUS: *Anabaena* (2,3,4,5,6)

FAMILY: Rivulariaceae
GENERA: *Gloeotrichia* (1)
Rivularia (4,5)

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