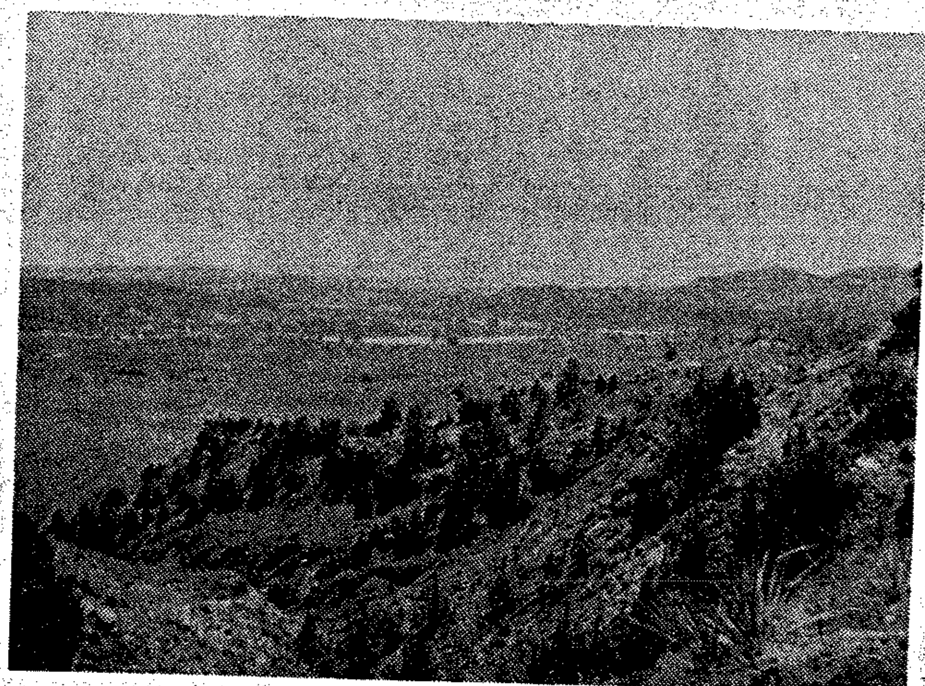
MONTANA DEPARTMENT OF FISH AND GAME

POWDER RIVER AQUATIC ECOLOGY PROJECT

FINAL REPORT

July 1, 1975 - June 30, 1978



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INTRODUCTION

The current national energy situation has placed increasing importance upon the vast western coal reserves as a solution to domestic energy needs. However since great distances lie between these reserves and the population centers, mine-mouth conversion facilities are of particular interest. Such facilities require large volumes of water which may cause ecological damage to many waterways.

The Powder River Basin is rich in coal reserves and the rush to develop this natural resource has begun. Utah International has proposed a coal gasification complex in the vicinity of Moorhead, Montana, using Powder River coal. The area of interest lies west of the River just north of the Wyoming State Line. An application for an appropriation of 106,730 af/y of Powder River water was filed by Utah International. Their water use plan centers around off-stream storage. Intake Water Company also filed on Powder River water, requesting onstream storage of 564,400 af/y. Competition for the Powder River was obvious and in September 1975, Utah International entered an agreement with the Montana Department of Fish and Game to study the aquatic resources of the Montana portion of the Powder River. The purpose of the investigation was to gather baseline data to evaluate the potential effects of development.

The major objectives of this study were: (1) to measure physical characteristics of the Powder River and major tributaries, (2) to sample aquatic invertebrate populations, and (3) to inventory fish populations.

The research was conducted from October 1975 through June 1978. The study was a drainage wide baseline survey. Game fish migrations were studied intensively during spring.

METHODS

Methods used to quantify the physical-chemical information were varied. Aerial photographs were analyzed for morphological changes associated with controlled flow in the river by the use of a digitized computer planimeter (Martin 1976). Water Surface Profile field data were collected in the prescribed manner according to Dooley (1975). Print-out data from this program were used in minimum rearing flow determinations (White 1975, Bovee 1974), and in sediment work. Discharges noted in this study were from U.S. Geological Survey Surface Water Records as well as chemical determinations. Additional discharges were taken with a type AA, Gurley Current Meter in the standard manner (U.S.G.S., 1969). Other chemical determinations were made with the aid of the YSI Co. oxygen meter (Model 57), a YSI Co. conductivity-salinity meter (Model 33), and a Owens-Corning pH meter (Model 610A). River temperatures were monitored with Taylor 30-day recording thermographs.

Macroinvertebrates were collected with a Water's round square foot sampler, a Needham kick screen and an adult net. Samples were preserved in 10 percent formalin and washed through a U.S. Series 30 mesh screen. Invertebrates were separated from debris and stored in 75 percent isopropyl alcohol.

All invertebrates collected were identified with keys by Ward and Whipple (1959), Jenson (1966), and Usinger (1956). The Shannon-Weaver diversity indices were calculated according to the formulas described by Newell (1977).

Families were used in the indices because all insects were identified to that taxanomic level. Diversity indices were not run on individual samples or on individual collecting dates because of small sample sizes.

Fish were collected with the aid of pulsed D.C. electrofishing equipment, 3-inch bar mesh gill nets and a 50-foot 1/4-inch bag seine. "Drifting" gill nets downstream was a very successful shovelnose sturgeon sampling technique. Sport fish were weighed, measured, tagged and sexed (sex products easily extrudable) prior to release.

Sauger were tagged with numbered Floy anchor tag throughout the study. During 1976, channel catfish were affixed with individually numbered plastic tags attached through the dorsal musculature with 0.032 inch diameter stainless steel wire as described by Pelgen and McCammon (1955). During 1977 and 1978 a Floy "cinch up" tag was used on channel catfish. Several different tags were used in an attempt to find one which would be retained the longest with the least damage to the shovelnose sturgeon. Tags used include Floy tags placed behind the dorsal fin, poultry tags placed around the caudal peduncle, and Floy "cinch-up" tags through the dorsal fin. The poultry tags were found to be undesirable by Elser, McFarland and Schwehr (1977) and all sturgeon are now being tagged with the Floy "cinch-up" tag affixed through the base of the dorsal fin.

Age-growth was determined for sauger and channel catfish and attempted on non-game species. Cursory work with the scale technique on cyprinid fishes proved unrewarding as no detectable annulli could be located. Sauger age and growth was based on the scale method. Channel catfish ages were based on the use of the pectoral spine sections (Sneed 1950).

A population estimate of the channel catfish migration was made using $T = \frac{m}{x/n}$ (Adams 1951). This was only accomplished during the 1977 season. Harvest and pressure statistics were also computed for that year with the aid of a voluntary creel-log census. Linear and quadradic correlations were also computed for catch rates versus discharge and temperature.

DESCRIPTION OF STUDY AREA

Location, Topography, and Climate

The Powder River drainage basin has an area of approximately 34,300 square kilometers in northeast Wyoming and southeast Montana. Over half of the drainage is contained within Wyoming. The Powder River basin is bordered on the southwest by the Bighorn Mountains. The remaining boundary of the basin is formed by low divides that separate the Powder from the Tongue, Little Missouri, Belle Fourche, Cheyenne, North Platte and Bighorn River systems. In general the Powder River flows north to its confluence with the Yellowstone River near Terry, Montana. The river, including the South Fork, is approximately 800 kilometers.

The topography of the Powder River drainage basin ranges from rugged mountains with a maximum elevation of over 3,950 meters to semiarid plains with a minimum elevation of about 700 meters. Other dominant features are high plateaus dissected by deep stream cut canyons, badlands, and river terraces. Although nearly all of the east slopes of the Bighorn Mountains are within the Powder drainage, the majority of this area would be classified as Great Plains.

The climate of the basin varies altitudinally. Precipitation ranges differ from over 0.735 meters annually in the Bighorn Mountains (mainly occurring as snow) to approximately 0.306 meters in the extreme northern prairie area. The plains section of the Powder River drainage has an average precipitation of less than 0.367 meters annually. The temperature of the area is one of extremes. Summer is characterized by highs exceeding 38°C while winter temperatures will commonly drop to -34°C. These differences in climate affect not only the type and density of vegetative cover but also the areas that will donate sediment to streams and the amount of this sediment (Hembree, Colby, Swenson, and Davis, 1952).

Geology-Water Chemistry

The geologic formations of a drainage basin greatly affect the chemical nature of the drainage water. The Powder River watershed drains, in part, Precambrian formations of granites and schists. However, the most obvious contribution to the drainage water chemistry is from a thick series of sedimentary strata that range in age from Cambrian to present. This sedimentary material is made up of limestones, sandstones, shales, siltstones, gypsum, shale and coal. Erosion of this substrate generally occurs at a moderate rate.

The chemical nature of the Powder River shown in Tables 1, 2, and 3 is the result of four contributing water types. The first is granitic water coming from Clear Creek and carrying large quantities of silica and calcium. The second type is limestone water flowing from high in the Middle Fork of the Powder River and carrying large amounts of calcium, magnesium, carbonate, chlorides and nitrates. The third water type is from the lower Middle Fork of the Powder River and is best described as a gypsum water. This water holds a great deal of sodium, potassium, and sulfate. The last type is shale water coming mainly from the Little Powder River. This water carries large amounts of sodium, potassium and sulfate (Swenson 1953). The resultant water in the main stem of the Powder River has been described as a sodium, bicarbonate, sulfate water (Clark Judy, personal communication).

River Habitat

The river habitat is typical of a prairie stream. The Powder River is silt-laden and subject to eratic flow fluctuations with much of its substrate constantly shifting as bed load. Historically, the Powder was much the same as it is now. Early settlers knew the Powder as "a mile wide and an inch deep, too thin to plow and too thick to drink". The river develops only shallow pools and lacks aquatic vegetation. The extreme turbidity of the Powder River limits light penetration which severely reduces primary productivity, which in turn results in low numbers of aquatic invertebrates.

Physical features of this waterway reflect its prairie nature. The yearly discharge (Figure 1) is commonly bi-modal with a smaller March peak followed by the large June runoff and then tapering off to minimal flows for the rest of the year.

The daily mean water temperatures of the Powder River for 1976, 1977 and March to mid-May 1978 are shown in Appendix Tables 4-20. The river gradient with area land marks is shown in Figure 2.

Table 1. Physical and chemical parameters of the Powder River at Moorhead, water year 1975 (U.S.G.S. 1975).

Date	Discharge (m^3/min)	ALK as. CaCo$_3$ (mg/l)	Specific Conductance (umhos/cm)	Dissolved Oxygen (ppm)	Turbidity (JTU)	pH
Oct. 16,'74	354	241	2250	10.0	390	7.9
Nov. 19,'74	371	241	1980	12.9	320	8.4
Dec. 17,'74	193	274	2150	12.8	15	8.6
Jan. 21,'75	354	299	2180	8.5	30	8.1
Feb. 19,'75	720	199	1750	11.7	50	8.1
Mar. 17,'75	1290	241	2500	11.7	240	8.2
Apr. 29,'75	959	189	1720	10.5	440	8.2

Table 2. Physical and chemical parameters of the Powder River at Locate, water year 1975 (U.S.G.S. 1975).

Date	Discharge (m^3/min)	ALK as. CaCo$_3$ (mg/l)	Specific Conductance (umhos/cm)	Dissolved Oxygen (ppm)	Turbidity (JTU)	pH
Oct. 22'74	445	221	2180	12.4	5800	8.3
Nov. 19,'74	588	236	1700	12.4	200	8.5
Dec. 17,'74	1276	282	2400	12.5	140	8.1
Jan. 29'75	383	320	2340	7.1	40	7.8
Feb. 28,'75	840	177	1380	12.4	130	8.0
Mar. 17,'75	924	219	2030	12.8	120	8.2
Apr. 29,'75	914	216	2000	10.8	720	8.3
May 18,'75	2016	-	1090	8.4	-	8.4

Table 3. Water quality measurements for Powder River at Locate and Moorhead, April 1977.

Water Flow Rate 650. CPS(M)
Gaging Station

SAMPLING SITE: Powder at Moorhead

	MG/L	MEQ/L		MG/L	MEQ/L
Calcium (CA)	122.	6.092	Bicarbonate (HCO3)	248.	4.059
Magnesium (MG)	55.	4.509	Carbonate (CO3)	0.	0.0
Sodium (NA)	250.	10.875	Chloride (CL)	105.	2.961
Potassium (K)			Sulfate (SO4)	700.	14.574
Iron (FE)			Fluoride (F)		
Manganese (MN)			Phosphate (PO4 AS P)	.0 1	0.001
Aluminum (AL)			NO3+NO2 (TOT AS N)	.39	0.028
SUM CATIONS	426.895	21.476		1053.050	21.622

Laboratory PH	7.50	Total Hardness (MG/L-CACO3)	531
Field Water Temp. (C)	12.2	Total Alkalinity (MG/L-CACO3)	203
Sum-Diss. Ions Meas. (MG/L)	1479.9	Laboratory Turbidity (JTU)	
Lab Conductivity-UMHOS-25C	1848.0	Sodium Absorption Ratio	4 7

ADDITIONAL PARAMETERS

Sediment, TOT,SUSP (MG/L)	1522.	Phosphorous, TOT (MG/L-P)	1.1

Water Flow Rate 700 CPS(M)
Gaging Station

SAMPLING SITE: Powder at Locate

	MG/L	MEQ/L		MG/L	MEQ/L
Calcium (CA)	48.9	2.440	Bicarbonate (HCO3)	26 .	4.399
Magnesium (MG)	97.	7.951	Carbonate (CO3)	0.	0.
Sodium (NA)	260.	11.310	Chloride (CL)	88.	2.482
Potasium (K)			Sulfate (SO4)	715.	14.886
Iron (FE)			Floride (F)		
Manganese (MN)			Phosphate (PO4 AS P)	.013	0.001
Aluminum (AL)			NO3+NO2 (TOT AS N)	.40	0.029
SUM CATIONS	405.546	21.701	SUM ANIONS	1071.800	21.795

Laboratory PH	8.20	Total Hardness (MG/L-CACO3)	520
Field Water Temp (C)	6.7	TOT Alkalinity (MG/L-CACO3)	220
SUM-DISS. IONS MEAS..UMG/L)	1477.3	Laboratory Tubidity (JTU)	
Lab Conductivity-UMHOS-25C	1881.0	Sodium Absorption Ratio	5.0

ADDITIONAL PARAMETERS

Sediment, TOT, SUSP (MG/L)	3000.	Phosphorous, TOT (MG/L-P)	1.6

*Samples taken by: Montana Department of Fish & Game Personnel.
Analysis by: Montana Department of Health & Environmental Sciences; Chemistry Lab. in Helena, Montana

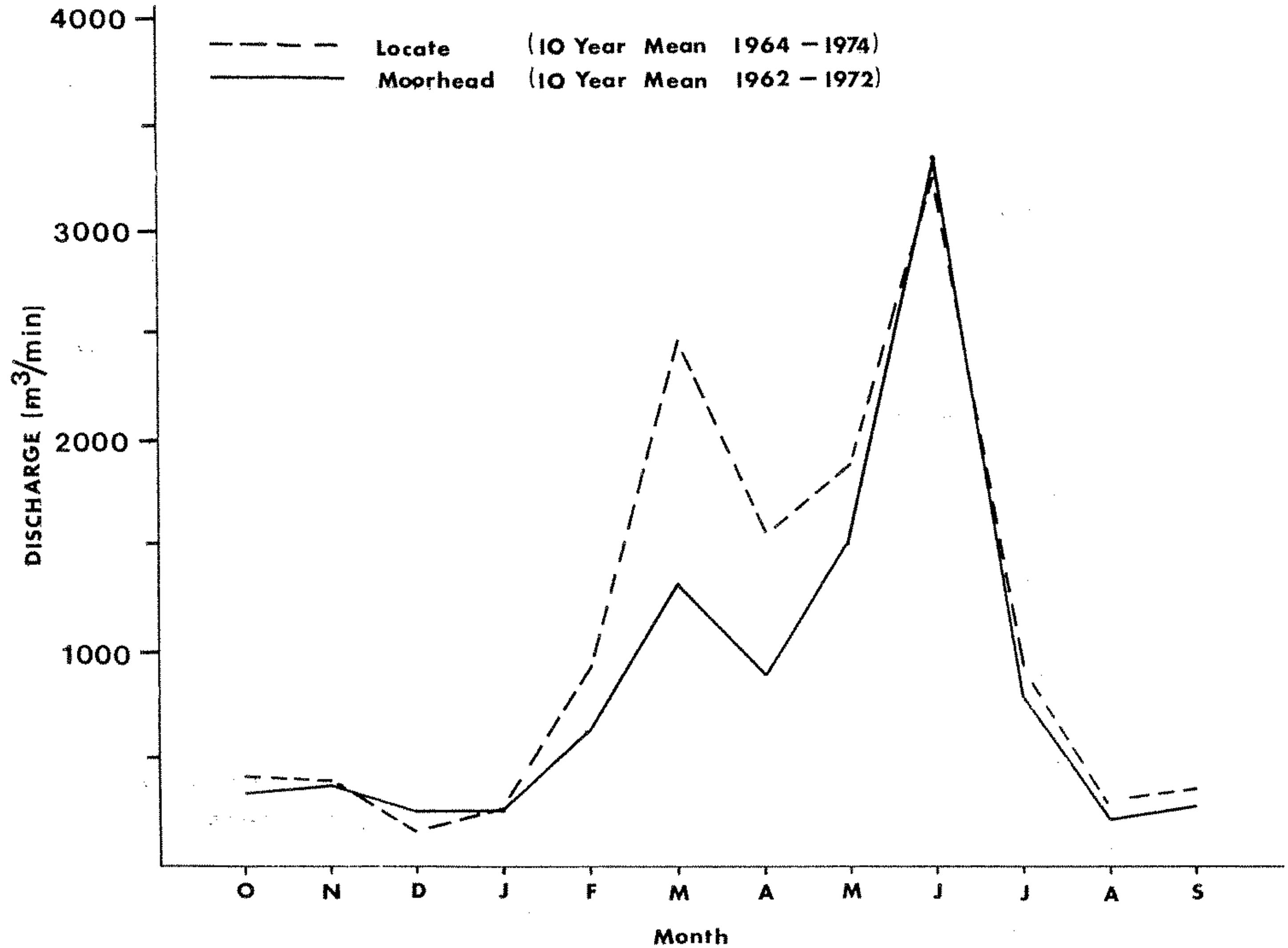

Figure 1. Summary of monthly mean discharges on the Powder River at Moorhead and Locate.

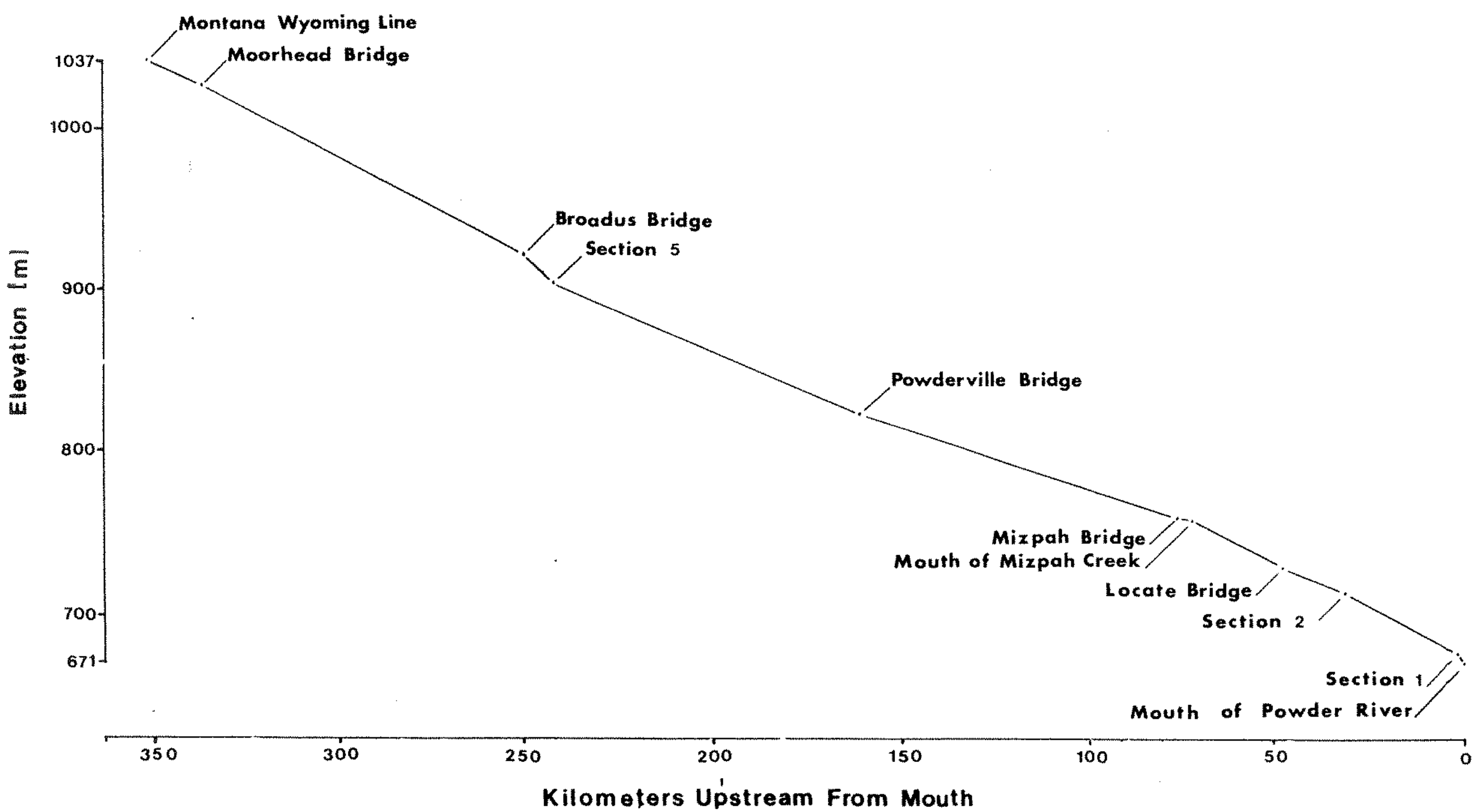

Figure 3 Longitudinal profile of Powder River.

Location of Fish Sampling Sections and Invertebrate Sampling Stations

A map of the study area with the study sites noted is shown in Figure 3.

Permanent fish sampling sections were established as follows:

Section Number		Location
1	1.14	Above Interstate Bridge to Burlington Northern Bridge near confluence with the Yellowstone River.
2	30.89	Near Locate on the A. Young ranch
3	45.69	At Mizpah on the C. Balsam ranch
3T	9.24	Mizpah Creek on the Scott ranch
4	103.09	At Powderville on the Preston ranch
5	151.77	At Broadus on the Perry ranch
5T	8.79	Little Powder River on the Turnbough ranch
6	211.76	At Moorhead on the G. Fulton ranch
7	220.20	At the Wyoming lines on the L. Sam's ranch

Permanent invertebrate sampling stations were established as follows:

Station Number	Location
1	Above Interstate Bridge, above confluence with the Yellowstone River
2	Downstream from Locate
3	At Mizpah Bridge
3T	Mizpah Creek at the bridge
4	At Powderville Bridge
5	At Broadus Bridge
5T	Little Powder River on the Turnbough ranch
6	Moorhead Bridge

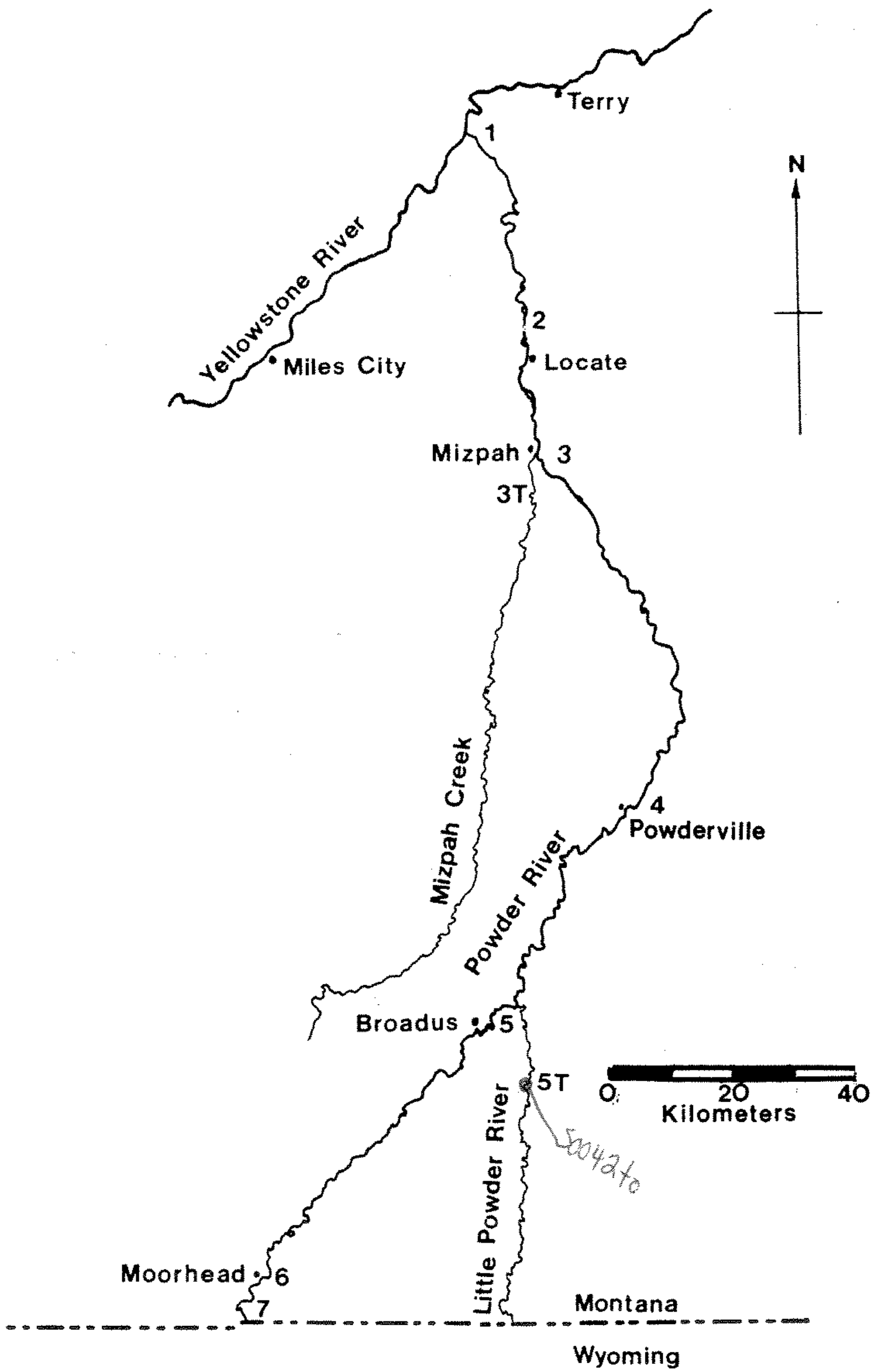

Figure 3. Map of the Powder River showing sampling sites.

RESULTS

Physical Measurements of the Powder River

Aerial Photographs

Aerial photographs of the Powder River between Powderville and the Wyoming state line were analyzed to evaluate possible changes associated with controlled flow in the river.

Changes in channel morphology of the Bighorn River between 1939 and 1974 as a result of impoundment were evaluated by comparing aerial photographs (Martin 1977). The percent change in bank riparian area, river area, vegetated island and gravel bar area, and main channel length found on the Big Horn River were directly applied to the existing Powder River values to reach the predictions.

Changes in the Bighorn River channel were the result of controlled discharge and channel degration. The number of vegetated islands, number of island gravel bars, and number of lateral gravel bars all decreased (30.6%, 51.4%, and 9.1%, respectively). There was also a trend toward area reduction of those land masses. The length of the main channel increased 1.2 percent. The total bank riparian area increased 37.5 percent (1,332 hectares). The total river area (water, islands and gravel bars) decreased 25.4 percent (1,358 hectares). The total vegetated islands and gravel bar area decreased 35.1 percent (1,200 hectares). It can be noted that the reduction in river channel area was caused by the loss of vegetated islands and gravel bars which were added to the total bank riparian area. This certainly shows the need for peak spring flows in maintaining channel morphology.

The Powder River measurements are based on a flight taken on September 22, 1976 when the Powder River discharge was measured at 2.1 m^3/s (USGS Provisional data). Vegetated "islands" totaled 54; however, they were not all isolated by water at that discharge. The other measurements are given in Table 4 with the projected changes after impoundment. These predicted changes are based entirely on those observed in the Bighorn River and do not include man-caused river-bottom changes.

Such channel changes would have definite impacts on the biology of the Powder River. Increasing the vegetative cover of the silt bars would reduce stream sedimentation, thereby possibly changing the invertebrate population and fish production. Such changes could impact the Canada goose (*Branta canadensis*) use patterns since silt bars are commonly used resting areas. The largest possible impact of the channel changes caused by a dam would be the agricultural impact. The current river bottom with its large wildlife resource exists as a result of the respect held for Powder River ice jams. A deep water dicharge from a main stream impoundment could reduce the threat of ice problems for part of the river. This would undoubtedly lead to man caused reduction of the cottonwood bottom.

Table 4. Powder River measurements and projected changes for the Powderville to Wyoming Section.

	Main Channel Length	Total Bank Riparian Area	Total River Area (water, island & bars)	Total Veg. Islands & Gravel Bars
Existing	168.70 km	6010 Hectares	1508 Hectares	1065.6 Hectare
Projected Change	2.02 km	+2254 Hectares	-383 Hectares	-374 Hectares
Resultant Areas	170.72 km	8264 Hectares	1125 Hectares	691.6 Hectare

Water Surface Profile

The Water Surface Profile (Dooley 1975) data was collected on three sites during the fall of 1976. These locations were: (1) Locate, fish sampling section 2; (2) Powderville, fish sampling section 4; and (3) Moorhead, fish sampling section 6 (the Moorhead USGS stream gaging station was within these transects). This program was selected to derive fish rearing discharge and erosion data.

A plot of the wetted perimeter versus discharge has been suggested by White (1975) in the Methodologies for the Determination of Stream Resource Flow Requirement (Stalnaker and Arnette, 1976) to aid in the determination of minimum flows for invertebrate production and fish rearing. One transect is selected from each section on the basis of critical habitat (a riffle). The discharge corresponding to the inflection point of this plot (Figure 4) depicts the minimum fish rearing flow. When this value is multiplied by 0.75 (Elser, et al. 1977) a minimum sustenance flow is determined. In all cases, the final computed value was approximately 75 cfs. Since nearly all late summer sampling was accomplished when discharges were considerably less than 75 cfs, this minimum rearing flow determination failed

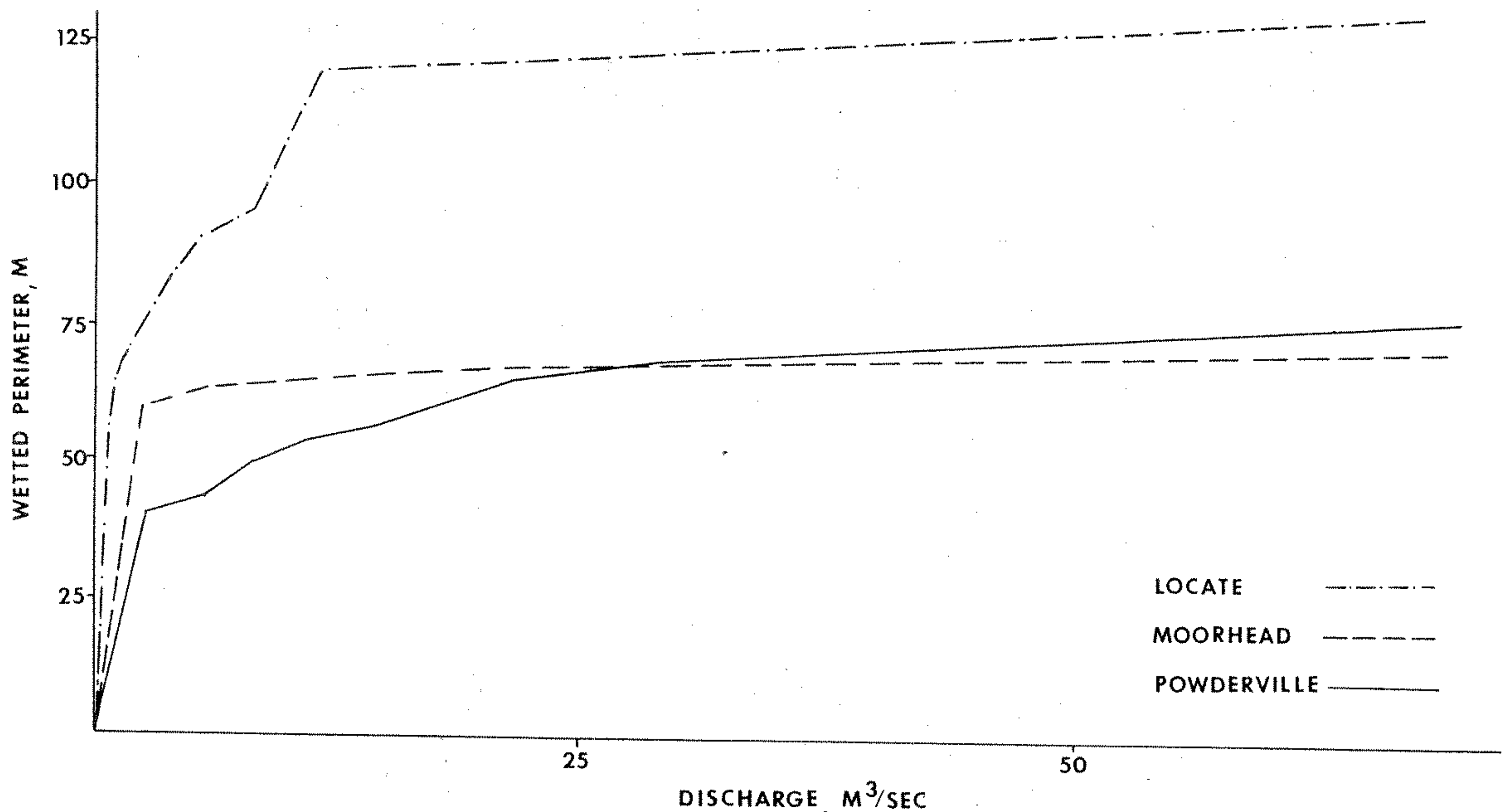

Figure 4. Discharge - wetted perimeter plot for selected site in the Powder River.

to be meaningful under such a severely depleted situation.

Tractive force information was also available from the Water Surface Profile Program. These forces were examined to allow a better understanding of the erosion that would follow main stream dam construction. The following is taken directly or para-phrased from the book Design for Small Dams pp. 789-795 (Strand 1973).

> A natural flowing stream is usually in a state of quasi-equilibrium - that is, there is no long term trend toward aggradation or degration. This state of stream equilibrium is the result of four factors: (1) bed material discharge, (2) sediment particle diameter, (3) water discharge, and (4) slope of the stream. If any one of the four variables is altered, one or more of the other variables must undergo change to return the stream to a state of equilibrium. In the case of a storage reservoir, the sediment load is eliminated or at least greatly decreased and a decreased slope downstream of the dam can be anticipated. Therefore the sediment particles remaining in the streambed will be the coarser fractions of the original material. This process of removing sediment particles from the streambed and banks is referred to a degradation and results in armoring of the streambed.
>
> Several laboratory investigations have shown that the size of a particle plucked from a streambed is proportional to the velocity of flow near the bed. The velocity at which the particle starts to move is referred to as the competent bottom velocity. The competent bottom velocity has been found to be approximately equal to 0.7 times the mean channel velocity.
>
> Tractive force is the drag or shear acting on the wetted area of the channel bed and can be expressed as:

$T.F. = y\ d\ S$ where T.F. = tractive force in lb/ft^2
y = unit weight of water ($62.4\ lb/ft^3$)
d = mean water depth in feet
S = stream gradient in ft/ft

$$\text{Tractive force} = 62.4 \times \text{hydraulic radius} \times \left(\frac{\text{discharge}}{\text{conveyance factor}}\right)^2$$

$$\text{Hydraulic radius: } \frac{\text{cross sectional area}}{\text{wetted parimeter}}$$

$$\text{Conveyance factor} = 1.486 \times \text{area} \times \left(\frac{\text{hydraulic radius}}{\text{roughness coefficient}}\right)^{2/3}$$

Strand (1973) gave plots for tractive force versus transportable sediment size. While these curves are for concrete lined canals and stabilized channels, they show the concept of tractive force. The following calculations are based on the curve for clean water (discharge from impoundment) and a mean particle diameter of 0.5 mm. It can be concluded that sediment transport will begin at a tractive force of 0.03 is equalled. According to the WSP printout, this tractive force is achieved at a discharge of slightly less than 100 cfs. Other work done on the Powder River verifies that at this discharge the sediment transport increases rapidly (Clark Judy, personal communication). Field observations made during the Powder River's only clear water period (mid to late September) show virtually no sediment transport occurring at flows of approximately 30 cfs.

It must be cautioned that the tractive forces shown on the WSP printout are not of extremely high quality. The technique used to accomplish the projected water surface elevations is one of making several computer "runs" with a known elevation and discharge and then manipulating the roughness coefficients until agreement is made. This procedure could yield slightly different "N" values which would have a significant influence on the calculated tractive force.

Example: Tractive force = 0.1836 at N = 0.035
Tractive force = 0.0939 at N = 0.025

These calculations, though of questionable accuracy, verify that the Powder River channel would degrade as a result of impoundment while armoring would take place. Substrate remaining after this erosion would be a more desirable invertebrate habitat and one of several key changes needed to increase insect population densities and productivity. The invertebrate population structure would definitely change and an altered fish population could be anticipated as well.

Sedimentation - Aggradation

The Powder River is notorious for its turbid water. However, calculations on exactly how much sediment is transported vary widely by source (Hembree, Colby, Swenson, and Davis 1952; Leopold and Miller 1975; U.S. Bureau of Reclamation 1969). The amount of sediment transported as suspended and bedload is of particular interest since off-stream storage is a proposed future development. This type of diversion will cause aggradation and its effects are well illustrated by the Rio Grande River. Channel aggradation (alluviation or subaerial sedimentation) occurs when the production of debris exceeds the amount that can be carried away by the process of transportation (Leopold, Wolman and Miller 1964).

Field determinations of the percentage of actual bedload-suspended load transport are not available. Work accomplished on other similar rivers (Niobrara and Middle Loup) have set the bedload fraction at approximately 50 percent (U.S.G.S. Professional Paper 252, 1975). The bedload determination is of special interest because it is the material that will remain in the river channel at the point of diversion and actually cause the aggradation.

There are at least two methods to calculate the volume of bedload. The first is the geological approach. The equation is:

Basin Area above Moorhead	Est. Rate of Erosion		Mass of Substrate	Total Powder River Sediment Discharge
8000 mi^2	$\frac{0.5\ ft}{1000\ yrs}$	$\frac{5280\ ft}{1\ mi^2}$	$\frac{120\ lbs/ft^3\ deposited}{100\ lbs/ft^3\ eroded}$	$\frac{1\ ac.ft}{43,560}$ = 300 Ac ft/yr

3000 Ac ft/yr x 50% (bedload fraction) = 1500 Ac. ft/yr

Total sediment transported as bedload

The second method of calculation depends on the use of actual measurements. Before assumptions can be made and calculations interpolated, the relationship of suspended sediment to other river characteristics must be examined.

"Suspended-sediment discharge fluctuates with changes in any one of several interrelated variables, which include water discharge, turbulence and temperature of the flowing water, and the availability of sediments of each size range. Resulting fluctuations in discharge of suspended sediment are large and rapid and have only a general relation to water discharge." (Hembree, Colby, Swenson, and Davis 1952). In the case of the Powder River, the source of the water within the drainage (specific tributaries) would greatly alter the suspended load at a constant water discharge.

Despite limitations, the direct calculation is possible when the diversion rate (400 cfs maximum), the maximum diversion volume (40,000 ac. ft.), the period of diversion (March, April, May, June), the minimum diversion time (50 days), the mean water discharge for that period of time (569 cfs, 464 cfs, 835 cfs, 1310 cfs) and the average suspended load for those flows (Leopold and Maddock, 1975) are all known. This computation yields values from 400 ac ft/yr to 1800 ac ft/yr of bedload deposition. Within this range of sediment deposition, substantial aggradation with its subsequent problems will occur immediately below the point of diversion.

Present and Future Irrigation Acreages

Those acres presently irrigated and the projected expansion of that type of agriculture in the Montana portion of the Powder River drainage basin are shown in Table 5. To estimate the amount of water currently used for irrigation, a general rule of 3 ac. ft/acre/year is a commonly accepted approximation. Table 6 shows three levels of depletion and the division of those levels between irrigation, energy development, and municipalities.

Table 5. Present and future development of irrigated land in the Powder River subbasin (data from DNRC, October 1976).

County	Present Number of Irrigated Acres	Feasibly Irrigable Acreage at High Level of Development
Powder River	33,339	46,853
Custer	12,995	26,438
Prairie	-0-	1,914
	46,334	75,205

Table 6. The increase in water depletion for consumptive use in 2000 for Powder River Subbasin (af/y) (data from DNRC, October 1976).

	Irrigation	Energy	Municipal	Total
Low level of development	50,140	860	360	51,360
Intermediate level of development	100,280	18,880	600	119,760
High level of development	150,400	28,150	1,140	179,690

INVERTEBRATE STUDIES

The macroinvertebrate investigation was divided into two one-year segments. During the first field season (1976), three Water's Round square foot samples were collected as well as one Needham kick screen sample at each station on the monthly basis. The 1977 sampling was reduced to one Needham kick screen sample per station each month.

The objectives of the invertebrate sampling were to determine species composition, distribution and diversity. During 1977, work was initiated to determine habitat requirements and preferences of the insects.

In 1976 a total of 4,789 organisms was collected in the invertebrate sampling. In all, 256 samples were analyzed: 63 kick samples, 185 Water's samples and 8 Ekman dredge samples. The raw data from each sample are presented in the Appendix Tables 21-29. Ephemeroptera and Trichoptera together accounted for over 60 percent of all organisms collected at each station (Table 7). These orders, plus Plecoptera and Diptera, accounted for from 81.7 to 99.6 percent of the organisms at each station. In quantitative samples, the Powder River averaged an estimated 98.2 organisms per square meter of bottom sampled. Mizpah Creek and the Little Powder River averaged 423.5 organisms per square meter of substrate sampled. This community structure is similar to those found in the Yellowstone River (Newell 1977) and in the Musselshell River of Central Montana (Gorges 1976), though the densities are lower.

In 1977, 2,211 organisms were collected in the invertebrate sampling. All 48 samples were the Needham kick type. The raw data are presented in the Appendix Tables 30-36. Ephemeroptera and Trichoptera totaled 76.7 percent of all invertebrates collected (Table 8). Plecoptera and Diptera totaled another 16.1 percent for a sum of these four orders of 92.8 percent, which is similar to the 1976 samples.

No stoneflies were found at the two tributary collecting sites (Stations 3T and 5T). This may be due to water chemistry characteristics related to the high conductivity in the two streams. The Little Powder River (Station 5T) samples were, by far, the richest samples in terms of invertebrate numbers. The most obvious external characteristic possibly accounting for this is the narrow stream channel with relatively stable flows as compared to the main river. It should be noted that some of the samples yielded no organisms. The lack of organisms at Station 2 in May 1976 was probably due to sampling substrates inundated by flood waters.

Table 7. Total numbers and percent composition (in parentheses) of macroinvertebrates by order from all collections at each station in 1976. Hyphens indicate zero counts.

Station No. of Samples	1 32	2 36	3 36	3T 20	4 36	5 32	5T 28	6 36	Line Totals
ORDER									
Ephemeroptera	14 (3.6)	22 (9.1)	53 (20.6)	179 (41.2)	108 (19.0)	120 (43.2)	676 (40.7)	266 (27.7)	1438 (30)
Trichoptera	264 (69.9)	159 (65.7)	132 (51.4)	136 (31.3)	307 (54.1)	63 (22.7)	525 (31.6)	346 (36.0)	1932 (40)
Plecoptera	49 (12.6)	45 (18.6)	60 (23.3)	-	34 (6.0)	22 (7.9)	-	61 (6.3)	271 (6)
Diptera	58 (14.9)	5 (2.1)	11 (4.3)	107 (24.7)	112 (19.8)	22 (7.9)	223 (13.4)	240 (24.9)	778 (16)
Odonata	3 (0.8)	3 (1.2)	1 (0.4)	4 (0.9)	1 (0.2)	12 (4.3)	12 (0.7)	5 (0.5)	41 (1)
Coleoptera	1 (0.3)	2 (0.8)	-	-	2 (0.4)	4 (1.4)	151 (9.1)	43 (4.5)	203 (4)
Others	-	6 (2.5)	-	8 (1.8)	3 (0.2)	35 (12.6)	73 (4.4)	1 (0.1)	126 (3)
Totals	389	242	257	434	567	278	1660	962	4789
No. of organisms per sample	12.2	6.7	7.1	21.7	15.8	8.7	59.3	26.7	

Table 8 . Total numbers and percent composition (in parentheses) of macroinvertebrates by order from all collections at each station in 1977. Hyphen indicate zero counts.

Station No. of Samples	1 7	2 7	3 7	3T 1	4 7	5 7	5T 6	6 6	Line Totals
ORDER									
Ephemeroptera	4 (23.5)	18 (28.6)	10 (16.4)	2 (7.7)	27 (46.6)	22 (36.7)	395 (23.5)	73 (29.8)	551 (24.9)
Trichoptera	5 (29.4)	14 (22.2)	15 (24.6)	-	21 (36.2)	29 (48.3)	957 (56.9)	105 (42.9)	1146 (51.8)
Plecoptera	3 (17.7)	14 (22.2)	22 (36.1)	-	6 (10.3)	5 (8.3)	-	20 (8.2)	70 (3.2)
Diptera	5 (29.4)	15 (23.8)	12 (19.6)	6 (23.1)	4 (6.9)		229 (13.6)	15 (6.1)	286 (12.9)
Odonata	-	-	-	1 (3.8)	-	3 (5.0)	1 (0.1)	1 (0.4)	6 (0.3)
Coleoptera	-	-	2 (3.3)	-	-	1 (1.7)	57 (3.4)	30 (12.2)	90 (4.1)
Others	-	2 (3.2)	-	17 (65.4)	-	-	42 (2.5)	1 (0.4)	62 (2.8)
Totals	17	63	61	26	58	60	1681	245	2211
No. of Organisms per sample	2.4	9.0	8.7	26.0	8.3	8.6	280.2	40.8	$\bar{x}$ = 46.1

The distribution of all organisms identified is presented in Figures 5 and 6. Four genera of insects excluding dipterans, had not previously been reported from the Yellowstone or Tongue Rivers (Newell 1976). The mayfly (*Anepeorus*) is an eastern and mid-western genus, apparently unknown in Montana; 47 individuals of this genus were collected during 1976. *Cinygma*, another mayfly, is a moutain river organism. The only two specimens were collected in the same sample and were in poor shape for identification. *Hetaerina americana*, a damselfly, has been collected in the Yellowstone drainage (Roemhild 1975) although not in the river. The alderfly (*Sialis*) is not uncommon but is often missed in random sampling. Among the dipterans, a very difficult order with which to work, three families and seven genera of the family Chironomidae which were found during this study were not in Newell's (1977) report. Little work has been done on the Diptera of Montana. In the future, the recognized distribution of many dipterans will probably be expanded.

Two unknown Chironomids appear to be truly unknown or at least undescribed, one of which is definitely an undescribed species of an existing genus or possibly a new genus (Dick Oswald, personal communication).

Diversity indices were calculated after the completion of one full season of quantitative and qualitative invertebrate samping in 1976 (Table 9).

The seven indexes were calculated as follows:

Shannon-Weaver function $(d) = -(N_i/N) \log_2 (N_i/N)$

Theo. Max. diversity $(d \max) = (1/N) \log_2 N - S \log_2$

Theo. Min. diversity $(d \min.) = (1/N) \log_2 N - \log_2 N-(S-1)$

Redundancy $(R) = \frac{d \max - d}{d \max - d \min.}$

Evenness $(J1) = d/\log_2 S$

Equitability $(E_m) = d/d \max -$

Species richness $(SR) = d - {}^{d}/\log_2 N$

where S = number of species

N_1 = number of individuals in the ith species

N = total number of individuals

Figure 5. Geographic distribution of aquatic macroinvertebrates collected in the Powder River Drainage during 1976.

STATION	1	2	3	3T	4	5	5T	6
<u>TAXA</u>								
Ephemeroptera								
Ephoron album						X		
Aneperorus	X	X		X	X	X		X
Rhithrogena					X			X
Stenonema			X			X	X	
Heptagenia criddlei				X	X	X	X	X
H. elegantula							X	
Cinygma						X		
Epeorus albertae		X	X		X	X		X
Isonychia							X	
Traverella albertana	X	X	X		X	X		X
Choroterpes				X	X	X	X	X
Tricorythodes minutus				X		X		X
Brachycercus	X	X	X		X	X		X
Caenis			X	X			X	X
Baetis parvus		X		X	X	X	X	X
B. propinquus		X	X	X	X	X	X	X
Ametropus		X	X		X	X	X	X
Trichoptera								
Polycentropus				X			X	
Psychomyiid Genus A	X	X	X		X	X	X	X
Hydropsyche		X		X	X		X	X
Brachycentrus								X
Plecoptera								
Brachyptera						X		X
Perlodidae	X	X	X		X	X		X
Isogenus	X	X	X		X			
Isoperla	X	X	X		X	X		X
Acroneuria	X	X	X		X	X		X
Diptera								
Ceratopogonidae			X	X				
Chironomidae	X	X	X	X	X	X	X	X
Cricotopus				X		X		
Eukiefferiella	X							
Orthocladius				X				
Hydrobaenus				X				
Cladotanytarsus				X				
Thein. gr.	X			X		X	X	X
Chironomus						X	X	
Cryptochironomus				X		X		
Dicrotendipes	X			X				X
Endochironomus				X				
Paralauterborniella							X	
Paratendipes				X				

Figure 5 Continued

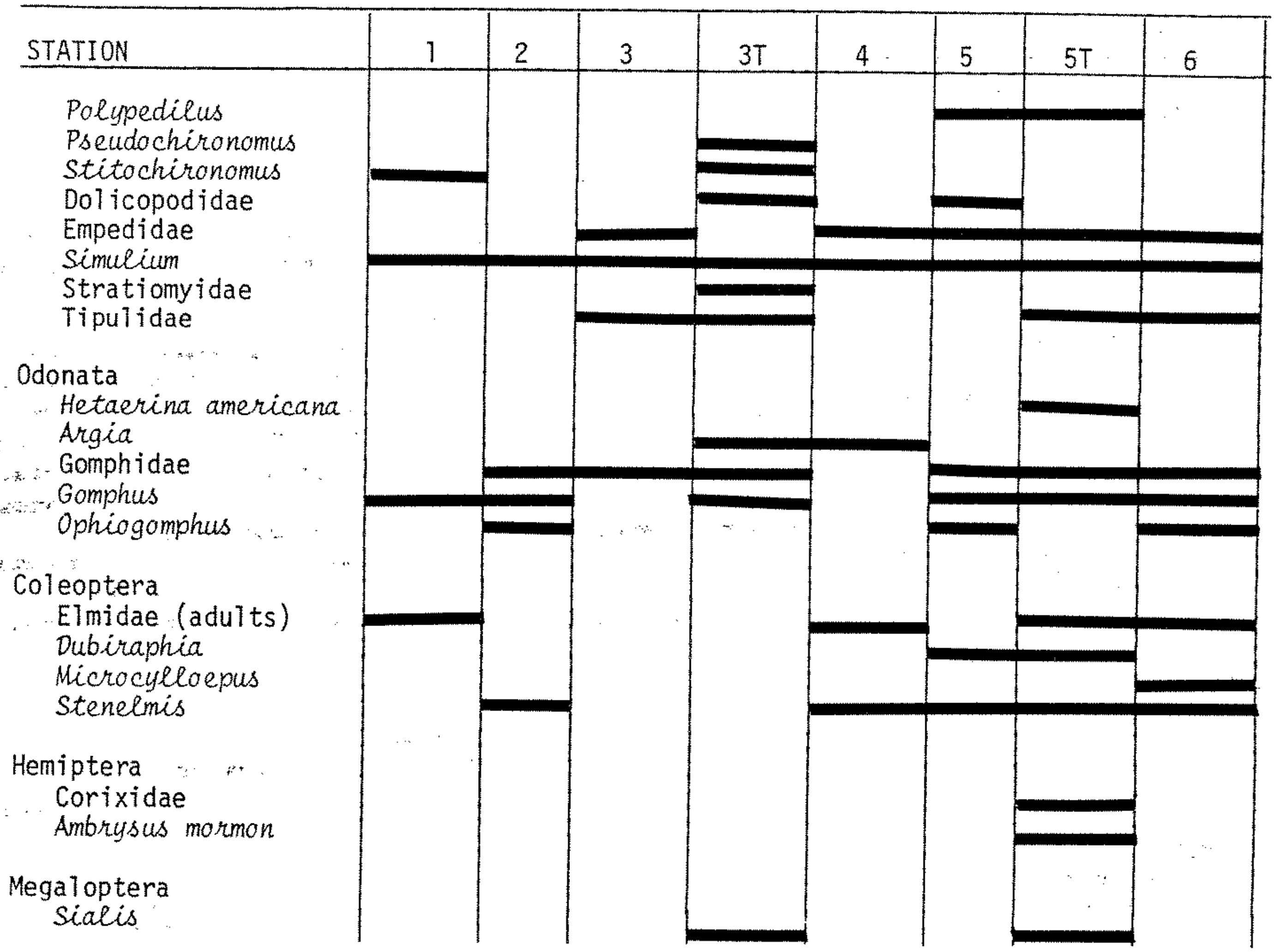

Figure 6. Geographic distribution of aquatic macroinvertebrates collected in the Powder River Drainage during 1977.

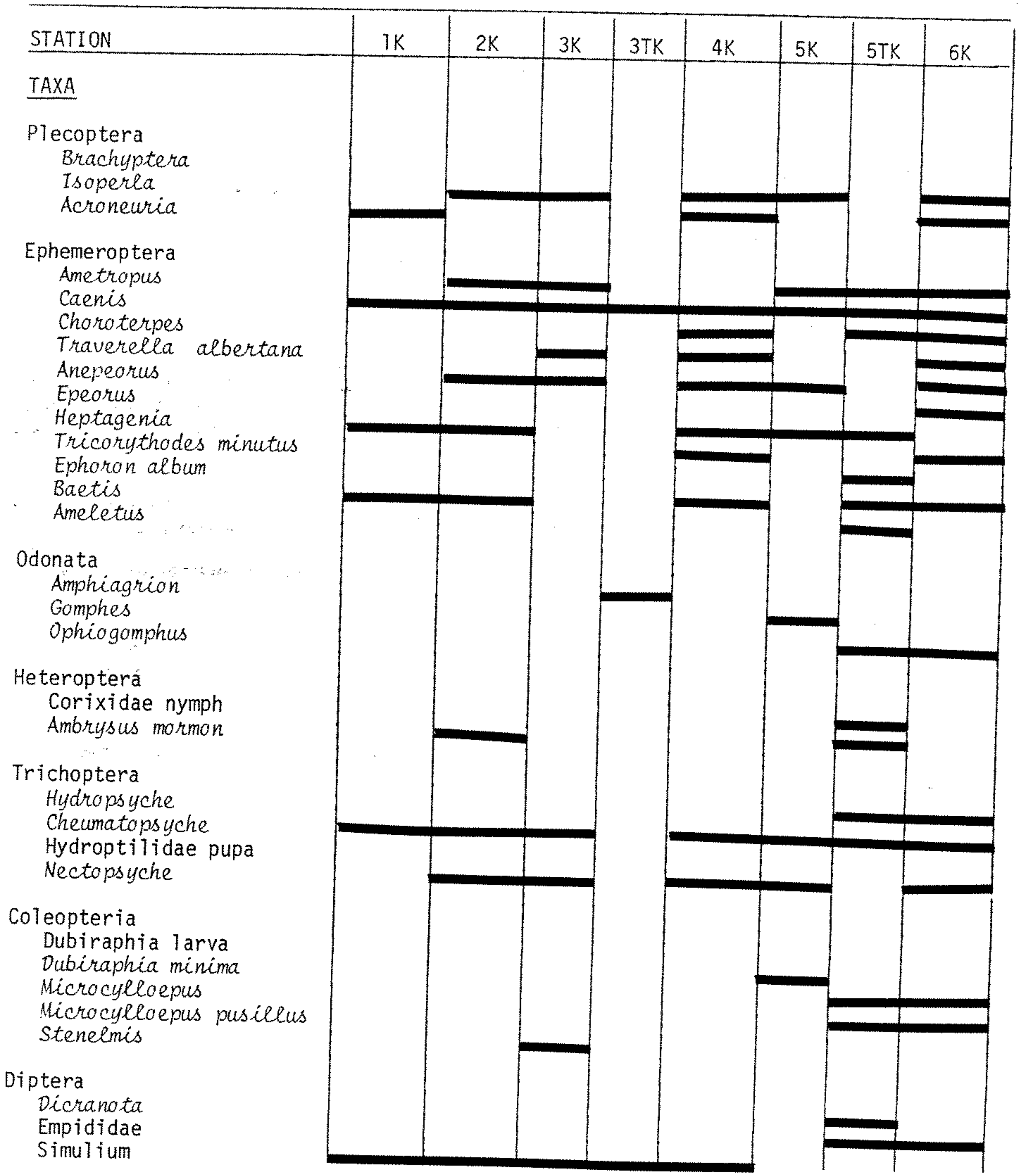

Figure 6 Continued

STATION	1K	2K	3K	3TK	4K	5K	5TK	6K
Theinemannemyia group							X	X
Diamesa								
Chironomus								X
Cryptochironomus		X						
Endochironomus				X				
Polypedilium							X	X
Pseudochironomus			X	X				
Stictochironomus							X	
Unknown Genus A					X			
Unknown Genus B							X	
Corynoneura								
Eukiefferiella							X	
Orthocladius							X	X
Tipulid larva			X					
Oligochaeta								
Limnodrilus (immature)							X	X
Limnodrilus spiralis							X	
Limnodrilus udekemianus				X			X	
Amphipoda								
Hyalella azteca				X				
Pelecypoda								
Pisidium							X	

Table 9. Diversities and related figures for the families of organisms collected in Water's Samples* at each station.

Station	1	2	3	3T	4	5	5T	6
Number of samples	24	27	27	17	27	24	21	27
Total number of organisms	257	137	173	212	410	123	950	331
Average number of organisms per sample	10.7	5.1	6.4	12.5	15.2	5.1	45.2	12.3
Estimated number of organisms per sq. meter	115	55	69	361	163	55	486	132
Number of families	8	9	8	12	11	15	11	12
Diversity	1.3045	1.6246	2.0689	1.8249	2.0728	3.0652	2.3851	1.8941
Maximum diversity	2.9999	3.1699	2.9999	3.5849	3.4594	3.9068	3.4594	3.5849
Minimum diversity	0.2568	0.4962	0.3580	0.4738	0.2464	0.9446	0.1192	0.3253
Redundancy	0.6180	0.5779	0.3524	0.5657	0.4315	0.2841	0.3216	0.5187
Evenness	0.4348	0.5125	0.6896	0.5090	0.5882	0.7845	0.6894	0.5283
Equitability	0.1629	0.2288	0.2782	0.2361	0.2388	0.4415	0.2411	0.2262
Species richness	1.1416	1.3957	1.7906	1.5887	1.8340	2.6237	2.1440	1.6678

* Eight Ekman dredge samples included in Station 3T.

The meaning of these values is best summarized by Newell (1977) as follows:

A high (3.0) Shannon-Weaver index generally means a healthy community while a low index (1.0) generally means the community is under some type of stress (Wilhm 1970 abc).

Equitability has been found to very sensitive to even slight levels of degradation. Healthy communities have values of 0.0 to 0.3 (E.P.A. 1973).

Redundancy is a measure of the repetition of information within a community and thereby expresses the dominance of one or more species and is inversely proportional to the wealth of species. Redundancy is maximal when no choice of species exists and minimal when there is a large choice of species.

Community distribution has maximum evenness if all the species abundances are equal and the greater the disparities among the different species abundances, the smaller the evenness.

Species richness is a little used index that shows maximal values with large numbers of species.

Station 5 had the most families identified in its samples; it also accounted for the least number of organisms collected. Correspondingly, Station 5 had the greatest diversity among our sampling sites. Diversities were generally higher and redundancies lower at upstream sites than at downstream stations. This could result from increased siltation and more dissolved solids in the downstream sections of the river. Station 6 does not fit into that pattern.

Twenty Water's Round samples were taken along five transects in each of three months (April, July, October 1977) at Moorhead. In addition to identification of the macroinvertebrates, the water depth, dissolved oxygen, water velocity at substrate surface, water temperature, conductivity, and substrate particle size by percent composition were recorded. A regression analysis was done to examine the importance of these factors in the aquatic invertebrate distribution. Ten different organisms were collected in these samples for April and July. The October sample was never accepted by the computer. Sample sizes sufficient for analysis were only available for three genera (*Cheumatopsyche, Coenis, Cryptochironomus*). The total "weighted" independent variables (R^2) accounted for 57 percent of the variation in *Cheumalopsyche* distribution in April and

40 percent in July. The R-square for *Cryptochironomus* equalled 66 percent in July while this value was 57 percent for *Coenis* in July. The R partial values were significant at the 0.05 level for only *Cheumatopsyche* in April when water velocity explained the most of the variation in distribution. Insufficient sample size, due to the sparse fauna present, was the main reason this technique did not show more significant and extensive correlations.

Aquatic macroinvertebrates are not abundant in the Powder River in Montana. Sedimentation and turbidity are probably the main factors involved, however, the chemical characteristics of the river should not be overlooked. It is especially worthy of note that the Powder River is considered to be the most unique macroinvertebrate stream in Montana (Dick Oswald, personal communication). All taxa of macroinvertebrates collected in the Powder River Drainage during this study are presented in Table 10.

Table 10 . List of Taxa located in Powder River Drainage during 1976 and 1977.

TAXA

Plecoptera
- *Brachyptera*
- *Isoperla*
- *Isogenus*
- *Acroneuria*

Ephemeroptera
- *Ametrupus*
- *Caenis*
- *Chorterpes*
- *Traverella albertana*
- *Anepeorus*
- *Epeorus*
- *Epeorus albertae*
- *Heptagenia*
- *Heptagenim criddlei*
- *Heptagenia elegantula*
- *Tricorythodidae minutus*
- *Ephoron album*
- *Rithrogena*
- *Stenonema*
- *Cinygma*
- *Isonychia*
- *Brachycercus*
- *Baetis*
- *Baetis parvus*
- *Baetis propinquus*

Trichoptera
- *Polycentropus*
- *Hydropsyche*
- *Cheumatopsyche*
- *Brachycentrus*
- Hydroptilidae
- *Nectopsyche*

Odonata
- *Amphiagrion*
- *Hetaerina americana*
- *Argia*
- *Gomphus*
- *Ophiogomphus*

Heteroptera
- Corixidae
- *Ambrysus mormon*

Coleoptera
- Elmidae
- *Dubiraphia*
- *Dubiraphia minima*
- *Microcylloepus*
- *Microcylloepus pusillus*
- *Stenelmis*

Diptera
- Ceratopogonidae
- Dolicopodidae
- Empididae
- Stratiomyidae
- Tipulidae
- *Dicranota*
- Simuliidae
- *Simulium*Chironomidae
- Theinemannemyia group
- *Diamesa*
- *Chironomus*
- *Cryptochironomus*
- *Endochironomus*
- *Polypedilum*
- *Pseudochironomus*
- *Stictochironomus*
- *Corynoneura*
- *Eukiefferiella*
- *Orthocladius*
- *Cricotopus*
- *Trissocladius*
- *Calopsectra*
- *Conchapelopia*
- *Dicrotendipes*
- *Paralauterborniella*
- *Paratendipes*

Megaloptera
- *Sialis*

Pelecypoda
- *Pisidium*

Amphipoda
- *Hylella azteca*

Oligochaeta
- *Limnodrilus*
- *Limnodrilus spiralis*
- *Limnodrilus udekemianus*

FISH STUDIES

A knowledge of the Powder River's eratic discharge and how it looks at these extremes will verify the need for several different fish sampling techniques. The techniques used can be classified as (1) electrofishing, and (2) nets and traps.

Four types of electrofishing gear have been used in the Powder River with certain degrees of success.

The first and most extensively used technique was a non-motorized boat equipped (110 volt) electrofishing gear with a hand held anode. This apparatus worked satisfactorily when the discharge was between 12 m^3/s and 70 $m3/s$. Because of high turbidities, electrofishing was successful only when the fish broke the surface of the water. Until that time, fish could not be seen or captured. The limitations of this 110 volt hand held anode electrofishing unit are a small electrical field and lack of mobility during high discharges.

The second electrofishing system used was the fixed anode type placed on a jet equipped outboard powered boat (Peterman 1978). It offers a large electrical field and greater mobility. The major limitation of the boat is adequate water depth (minimum of approximately 55 m^3/s).

The third electrofishing system used was the "bank shocker" which is essentially the same as the first electrofishing apparatus minus the boat. It was used mainly in the tributaries with good success.

The last electrofisher used was a "backpack shocker." It offers greater mobility for small tributary work. This gear must be calibrated for the high conductivity of these tributaries or it is of little value.

Nets and traps in the Powder River are successful under certain conditions. All stationary nets or traps were found to be unsuccessful in this river. This included hoop nets, trap nets and dead-set gill net, all of which act as sediment traps and create silt bars. Seines (1/4-inch) were used extensively under low water conditions with success while "drifting" 3-inch bar mesh gill nets for larger sturgeon during high water was a very efficient and selective technique.

Resident Fish Species

Powder River Sampling

During the fall of 1975 and the summer and fall of 1976 all seven of the original study sections were sampled. This information was gathered to show the relative abundance of the resident fish populations. A total of 17 species of fish was collected, with the flathead chub (*Hybopsis gracilis*) the dominant species in each section (Tables 11 and 12). The sturgeon chub (*Hybopsis gelida*), one of Montana's rarest fish, is common throughout the Powder River Drainage. In general, the lower sections showed more species present than the upper ones.

The species composition of the samples show only rare occurrences of game fish. Length information is presented in tables 13 and 14. Weight information is included in the 1976 sample.

Length frequency distributions were compared for the flathead chub in two sections (1 and 7). These two areas showed close agreement with three definite modes occurring. The first mode was between 25 mm and 56 mm, the second between 56 mm and 97 mm and the third occurring between 91 mm and 122 mm. These modes closely agree with age groups zero, one and two according to Brown (1971).

With the completion of two seasons of resident fish work, the diversity indicies were calculated and are shown in Table 15. These indicies were computed in the same manner as those previously mentioned. No trends between stations nor years were noted.

Table 11. Species composition in each of the Powder River sample sections, fall, 1975.

Species	1	2	3	4	5	6	7
Flathead chub *Hybopsis gracilis*	106 89.2%	266 90.9%	108 100%	192 81.5%	250 79.6%	965 91.0%	346 87.8%
Hybognathus		3 0.9%		19 8.0%	22 7.0%	33 3.1%	11 2.8%
Sturgeon chub *Hybopsis gelida*	6 5.1%	5 1.7%		17 7.2%	27 8.6%	28 2.6%	12 3.0%
Goldeye *Hiodon alosoides*	3 2.5%	2 0.7%				10 3.5%	14 0.9%
River carpsucker *Carpoides carpio*	1 0.8%	2 0.7%		1 0.4%	2 0.6%	3 0.3%	5 1.3%
Shorthead redhorse *Moxostoma macrolepidotum*						7 0.7%	3 0.3%
Stonecat *Noturus flavus*		1 0.3%					2 0.5%
Carp *Cyprinus carpio*					1 0.3%	4 0.4%	1 0.3%
Longnose dace *Rhinichthys cataractae*		2 0.7%		2 0.8%	9 2.9%	3 0.3%	
Channel catfish *Ictalurus punctatus*	1 0.8%	7 2.5%		5 2.1%	3 1.0%	1 0.1%	
Sauger *Stizostedion canadense*						1 0.1%	
Burbot *Lota lota*	1 0.8%	1 0.3%					
Brassy minnow *Hybognathus hankinsoni*		1 0.3%					
Green sunfish *Lepomis cyanellus*		1 0.3%					
Sandshiner *Notropis stramineus*						5 0.5%	
Creek chub *Semotilus atromaculatus*		2 0.7%					
Total	119	292	108	236	314	1060	394

Table 12. Species composition expressed as numbers caught and percent of total sample, in each of Powder River sample sections, summer 1976.

Species	SECTION 1	2	3	4	5	6	7
Flathead chub	88 87.1%	126 79.2%	39 63.9%	47 77.0%	57 90.4%	233 67.1%	21 35.6%
Sturgeon chub	6 5.9%	2 1.3%	1 1.6%			2 0.6%	
Channel catfish	2 2.0%	3 1.9%	2 3.3%			1 0.3%	
River carpsucker	1 1.0%						1 1.7%
Hybognathus	1 1.0%	11 6.9%	13 21.4%	14 23.0%	5 7.9%	110 31.7%	34 57.6%
Goldeye	3 3.0%	15 9.4%				1 0.3%	3 5.1%
Stonecat		2 1.3%					
Longnose dace			5 8.2%				
Green sunfish			1 1.6%				
Carp					1 1.7%		

Table 13. Fish length (mean and range in mm) by species and study sections, Powder River, 1975.

	7	6	5	4	3	2	1
Flathead chub	73.66 (20-160)	80 (41-178)				73 (23-259)	
Lake Chub	67 (41-99)	72 (38-132)	74 (46-112)	69 (48-89)		104	
Sturgeon chub	74 (41-79)	71 (66-76)	74 (38-89)	70 (43-79)		58 (28-79)	
Goldeye	301 (284-325)	301 (287-343)				303 (295-312)	86 (71-102)
River carpsucker	110 (38-325)	68 (36-124)	42 (38-46)	28		30 (28-33)	97
Shorthead redhorse	218 (135-264)	285 (201-345)					224
Stonecat	94 (89-99)					180	
Carp	462	97 (81-122)	81				
Longnose dace		74 (66-81)	69 (56-79)	67 (64-71_		58 (53-64)	
Channel cat		58	49 (46-53)	54 (43-64)		58 (51-64)	66
Sauger		523					
Burbot						490	305
Bassy minnow						124	
Green sunfish						38	

Table 14. Mean length (mm) and weight (g) of fish species by study sections, Powder River 1976.

Section	1		2		3		4		5		6		7	
Species	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
Flathead chub	77.44	4.95	88.90	7.58	67.92	3.15	73.32	4.28	75.89	5.76	88.64	7.70	75.67	4.38
Sturgeon chub	78.16	3.16	77.50	3.00	60.00	1.50								
Channel catfish	47.50	1.00	89.00	7.67	86.00	6.00								
River carpsucker	47.00	1.00											112.00	16.00
Hybognathus	59.00	1.00	65.00	3.00			66.64	3.29						
Goldeye	314	-	320.40	-									310.30	-
Stonecat			205.50	77.00										
Longnose dace					60.40	2.20								
Green sunfish					55.00	3.00								
Carp									440.00	-				

Table 15. Shannon-Weaver diversity indices for resident fish population in Powder River by section.

Year		1	2	3	4	5	6	7
1975	Diversity $\bar{d}$	0.7315	0.7477	0.0	1.0177	1.1187	0.6626	0.8273
	$\bar{d}$ Max.	2.8073	3.8073	0.0	2.5849	2.8073	3.4594	2.9999
	$\bar{d}$ Min.	0.4185	0.4261	0.0	0.1972	0.1857	0.1083	0.1785
	Redundancy	0.8689	0.9048	-	0.6563	0.6441	0.8345	0.7700
	Evenness	0.2605	0.1964	-	0.3937	0.3985	0.1915	0.2757
	Equitability	0.1061	0.0912	-	0.1291	0.1348	0.0659	0.0959
	Species Richness	0.6254	0.6565	-	0.8886	0.9838	0.5967	0.7313
1976	Diversity $\bar{d}$	0.8097	1.1511	1.7059	0.9491	0.5156	1.2792	1.4368
	$\bar{d}$ Max.	2.5849	2.8073	2.8073	1.5849	1.5849	2.5849	2.3219
	$\bar{d}$ Min.	0.3992	0.3293	0.7180	0.2409	0.2348	0.2038	0.5069
	Redundacy	0.8121	0.6683	0.5271	0.4730	0.7920	0.5483	0.4876
	Evenness	0.3132	0.4100	0.6076	0.5988	0.3253	0.4948	0.6188
	Equitability	0.1216	0.1574	0.2876	0.1600	0.0862	0.1634	0.2463
	Species Richness	0.6881	0.9937	1.4182	0.7891	0.4293	1.1150	1.1905

Tributary Sampling

Chemical and physical data collected are presented in Table 16.

Table 16. Chemical and physical data for two tributaries of the Powder River, 1976.

Tributary	Date	Salinity	Temp.	Specific Conductance	Dissolved Oxygen	pH
Mizpah Cr.	6/11	1.0/1000	22.8°C	1340 umhos/cm	9.4 ppm	8.90
Little Powder River	6/11	0.8/1000	21.2°C	1180 umhos/cm	6.5 ppm	8.22

Mizpah Creek

During the summer of 1976, tributary fish sampling work was initiated to define those areas of probable game fish use. One of the two large Montana tributaries to the Powder is Mizpah Creek. Sampling was accomplished on two occasions: the first in July 1976 (Table 17), and the second in August of 1976 (Table 18). The study section encompased 1.50 km of stream 2 km above Mizpah Creek's confluence with the Powder River. These two collections indicate a total of fifteen species in the lower portion of the creek. This represents the greatest diversity of any sites sampled.

Table 17. Electrofishing sample from Mizpah Creek, July 1976.

Species	Number	Mean Length (mm)	Mean Weight (g)
River carpsucker (*Carpoides carpio*)	14	269	286
Goldeye (*Hiodon alosoides*)	6	296	178
Green Sunfish	1	90	20
Channel Catfish (*Ictalurus punctatus*)	1	355	320
Carp (*Cyprinus carpio*)	1	468	120

Table 18. Fish sampled in Mizpah Creek (seining) August 1976.

Species	Number	Percent
Flathead chub	34	27.0
Sand shiner	19	14.3
Channel catfish	16	12.7
River carpsucker	14	11.1
Fathead minnow	13	10.3
Silver minnow	8	6.3
Carp	8	6.3
Plains minnow	5	4.0
Black bullhead	4	3.2
Longnose dace	3	2.4
Shorthead redhorse	1	0.8
White sucker	1	0.8
Creek chub	1	0.8
Total	126	100.0

Little Powder River

The Little Powder River is a permanent tributary that enters the Powder River 249 km upstream from the confluence with the Yellowstone. Two sampling runs were made on a 762 meter section approximately 8 km upstream from the mouth. A mark and recapture population estimate was attempted in May 1976 to determine if it was feasible and applicable to the Powder River.

Flathead chubs (*Hybopsis gracilis*) were not handled due to time limitations. However, they appeared to be the most abundant fish in the stream. The river carpsucker (*Carpoides carpio*) followed by the shorthead redhorse (*Moxostoma macrolepidotum*) were the next most abundant fish species (Table 19). The redhorse appeared to be associated with gravel bottoms in areas of riffles while the carpsuckers were found mainly in areas of silted bottoms and still water.

Of the species present, an estimate using Chapmans modification of the Petersen estimator (Ricker 1958) was made for the shorthead redhorse and river caprsucker (Table 20).

The Little Powder River was sampled in August 1976 (Table 21), using a 1/4-inch bar mesh seine. On the basis of this work, the spring 1977 work to sample channel catfish was initiated. The channel catfish fell into 3 general lengths (45, 75 and 195 mm), which appear to be very early age classes.

Table 19. Species and numbers of fish captured in the Little Powder River. May 1976.

Species	Sample 1	Sample 2
Flathead chub (*Hybopsis gracilis*)	*	*
River carpsucker (*Carpoides carpio*)	85	66
Shorthead redhorse (*Moxostoma macrolepidotum*)	57	49
Carp (*Cyprinus carpio*)	54	18
Goldeye (*Hiodon alosoides*)	25	13
White sucker (*Catostomus commersoni*)	9	18
Green sunfish (*Lepomis cyanellus*)	7	3
Stonecat (*Noturus flavus*)	5	5
Channel catfish (*Ictalurus punctatus*)	3	5

Table 20. Estimated numbers of shorthead redhorse and river carpsucker in the study section of the Little Powder River

Species	Population Estimate (95% confidence intervals)
Shorthead redhorse *Moxostoma macrolepidotum*	138 (± 45)
River carpsucker *Carpoides carpio*	360 (± 152)

Table 21. Fish sample from the Little Powder River, August 1976.

Species	Number	Percent
Plains minnow	141	69.5
Silvery minnow	24	11.8
Channel catfish	24	11.9
Goldeye	8	3.9
River carpsucker	3	1.5
Flathead chub	1	0.5
Carp	1	0.5
Stonecat	1	0.5

During the 1976 spring sampling, 8 adult channel catfish were captured in the Little Powder River. This was followed by August 1976 seining which showed very good numbers of young-of-the-year channel catfish. This information led to a hypothesis that the Little Powder River was an important tributary for reproduction. A large portion of the sampling effort during the 1977 spring was directed at this location in an attempt to verify this theory. A total of 56 adult channel catfish was sampled. These fish averaged 631 mm in length and 2630 gr in weight. The Little Powder became productive on May 18 and remained so until June 16. On the basis of tag returns, angler information, and the presence of sexually "ripe" catfish; it is concluded that the Little Powder River is an important site of channel catfish reproduction.

Clear Creek, Wyoming

In an attempt to recover tagged migrating game fish, one sampling run was made on this tributary of the Powder River which enters near Arvada, Wyoming. Sampling problems limited the section to approximately 0.45 km. The results of the June sampling are given in Table 22. Another sampling run was made in July 1976. The results of this work are shown in Table 23. The presence of both sauger and channel catfish in this sample combined with their non-existence in an earlier one, suggest that these could be migrating fish.

Table 22. Species, numbers, mean lengths and mean weights of fish captured in Clear Creek, June 1976.

Species	Number	Mean Length (mm)	Mean Weight (g)
White sucker (*Catostomus commersoni*)	27	215	116
Flathead chub (*Hybopsis gracilis*)	14	124	---
Shorthead redhorse (*Moxostoma macrolepidotum*)	12	287	221
Longnose sucker (*Catostomus catosumus*)	3	288	270
Goldeye (*Hiodon alosoides*)	3	306	180
Rockbass (*Amblplites rupestris*)	2	125	35
River carpsucker (*Carpoides carpio*)	1	286	250
Carp (*Cyprinus carpio*)	1	455	1000
Brown trout (*Salmo trutta*)	1	290	200

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Table 23. Fish sample and percent composition taken in Clear Creek, July 1976.

Species	Number	Percent
Shorthead redhorse	56	38.3
Goldeye	31	21.2
Flathead chub	24	16.4
White sucker	15	10.3
Longnose sucker	9	6.2
Carp	5	3.4
River carpsucker	3	2.1
Sauger	1	0.7
Rockbass	1	0.7
Channel catfish	1	0.7
Total	146	100.0

Discussion

The tributary work has shown additional species in the drainage and a definite difference between the two major types of tributaries. Summer and fall sampling in the two major Montana tributaries (Mizpah Creek and the Little Powder River) yielded small channel catfish. Of numerous other smaller tributaries sampled, only one small catfish was collected. Both Mizpah Creek and the Little Powder River have higher spring discharges that are of greater duration (because of their respective drainage areas) than do the other tributaries. Minimum passage and rearing flows are required from late April to early July. Therein appears to be the explanation of young catfish presence.

Migrant Fish Species

Field work to determine the species composition and magnitude of game fish migration into the Powder River from the Yellowstone River was begun early each spring for three years (April 5, 1976; March 14, 1977; March 28, 1978). In an effort to tag as many migrating game fish as possible, Section 1 (near the confluence with the Yellowstone River) was intensively sampled. During the spring of 1976, Sections 2-8 were also sampled to monitor upstream movement of tagged and untagged fish. In 1977, only Sections 1 and 5T were monitored, while the 1978 work forcused on Sections 1 and 2.

Prior to this study the importance of Yellowstone River game fish movements into the Powder River had not been assessed in terms of the potential or realized fishery of the Powder River or to the reproduction of the Yellowstone River game fish.

Sauger

Sauger (*Stizostedion canadense*) are native to Montana and are one of the most important game fish of the lower Yellowstone River. During the 1976 season (April 6 to May 18) 178 sauger averaging 381 mm in length and 464 grams in weight were captured, marked with individually numbered Floy tags and released. The 1977 season began March 18 and ran until April 28. During that season, 292 sauger averaging 381 mm in length and 482 grams in weight were captured, tagged and released. The 1978 sampling started on April 3 and ran through May 2. During the last season, the 49 sauger sampled had a mean length of 409 mm and a mean weight of 647 grams.

In general, the first two year's sauger "runs" occurred during a discharge pattern of decreasing flows early and increasing flows late (Figure 7 and 8). During 1978, the discharge was very high early, decreasing rapidly through April, then increasing to extremely high levels (Figure 9). The mean daily temperature was low initially, gradually increased, then decreased with the mid-run discharge mode, then again increased through the remainder of the period (Figures 10, 11 and 12). The 1976 sauger collection period had a mean discharge of 867 cfs (partially estimated due to 7 days of missing provisional records from U.S.G.S.) with a range of 697 to 1380 cfs. The mean temperature was 11.2 C (range 6.1- 16.4) in 1976. The 1977 "run" occurred during a period with a mean discharge of 720 cfs (range 490 - 1100) and a mean temperature of 8.7 C (range 1.4 - 16.4). The sauger

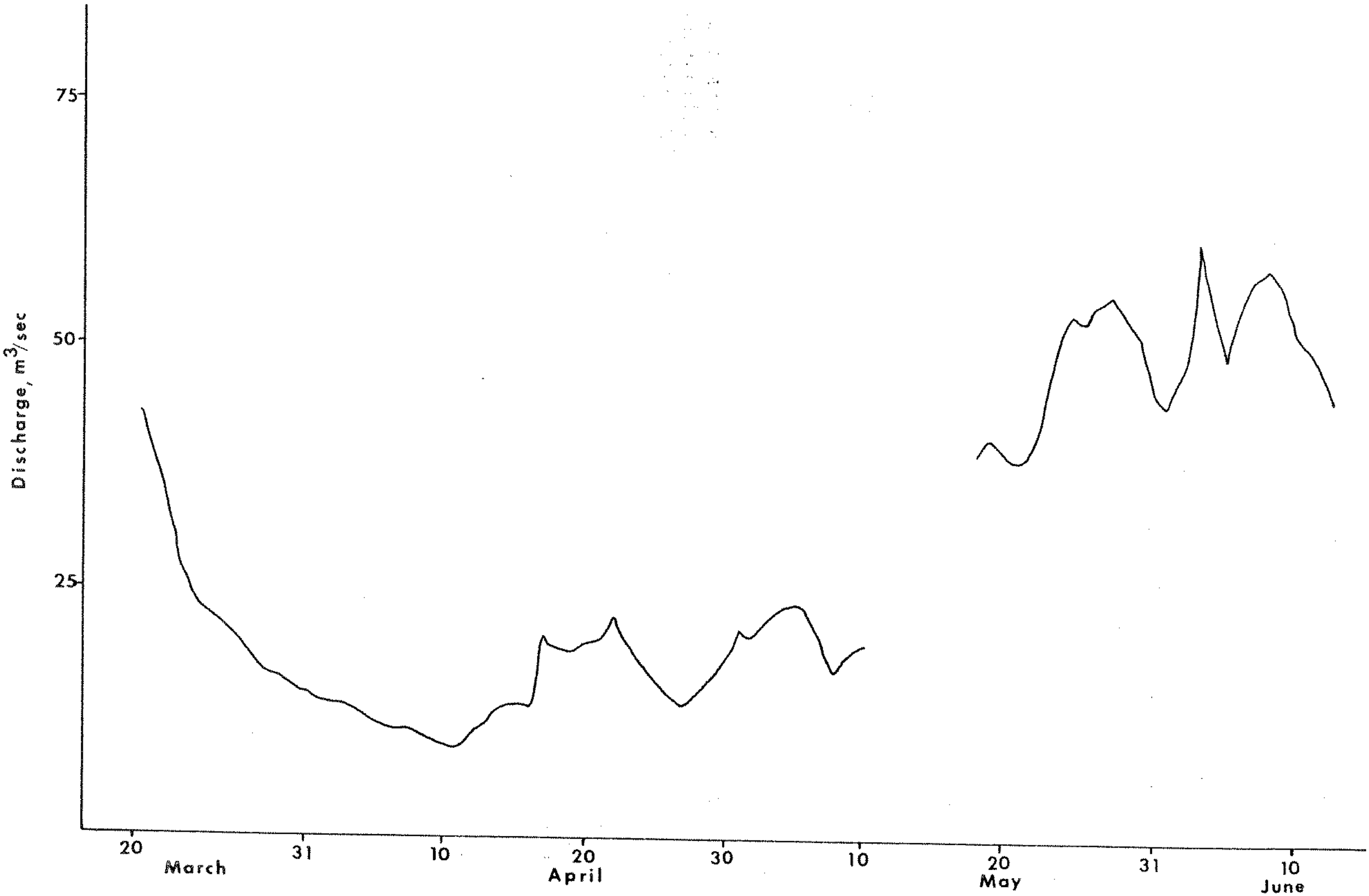

Figure 7. Discharge of Powder River at Locate, Spring 1976.

Channel Catfish

Classified as a game fish by the Montana Legislature in 1975, the channel catfish (*Ictalurus punctatus*) is a popular sport fish in the lower Yellowstone drainage system. Adult channel catfish are evidently highly migratory and may ascend tributary streams to spawn (Trautman 1957). Fisherman interviews indicated that channel catfish provided the major contribution to the Powder River sport fishery and suggested the Yellowstone River was the probable source since catfish are only caught in the late spring and early summer. Channel catfish are caught by anglers as far upstream as Arvada, Wyoming (Fred Dabny, personal communication), 434 km upstream from the mouth of the Powder River.

From April 5, 1976 to May 21, 1976, 95 channel catfish averaging 614 mm in length and 2660 gr in weight were captured in the Powder River. Of these, eighty-seven of these fish were captured in Section 1 as they moved up the Powder River and eight were captured in the Little Powder River, a tributary entering the Powder 249 km upriver. Greatest numbers of channel catfish were captured on April 9, 1976, when river temperatures were rising and flow was increasing (Figure 16). While channel catfish were being collected in 1976 at Section 1, the Powder River discharge averaged 747 cfs (range 332-1440) and the average daily temperature was 11.6 C (range 6.1 - 17.5).

During the 1977 season a total of 174 channel catfish was sampled in two study sections. Section 1 was the source of 118 catfish between March 25 and May 4. These fish averaged 620 mm in length and 2660 gr in weight. The 56 remaining catfish were taken from the Little Powder River (previously addressed). During the 1977 catfish run, the average discharge and average temperature was 731 cfs (range 490-1100) and 9.6 C (range 1.4-16.4°), respectively.

A total of 21 channel catfish was sampled during the spring of 1978. These fish had a mean length of 586 mm and a mean weight of 2490 grams. The period of catfish collection in 1978 (April 6 - May 4) had a mean discharge of 714 cfs (range 438 to 480) and a mean temperature of 9.1°C (range 4.2 to 13.6°). Stream discharge had been found to be major factor influencing adult catfish migrations, with increases in spring expediting migration (Van Eeckhout 1974).

Age determination was accomplished in 30 channel catfish pectoral spines in 1976 and 51 in 1977. These catfish represented age class II-XVI. Age IX and older catfish made up 90 percent or more of the sample from both years which further indicates a spawning migration.

A creel census of the entire Powder River (Montana portion) was conducted in 1977. All data was based on entries made in log books that were distributed to all fisherman that could be located. These logs were intentially kept simple to encourage regular records. No confidence intervals were calculated. The results are shown on Table 26. Logs were given to 41 anglers with 28 (68.3%) returned. A total of 629.4 hours of effort were expended on the river producing 329 catfish. The average number of catfish per angler in 1977 was 8.04.

Channel catfish catch rates for all three springs were calculated for each day (Figure 16, 17, and 18). These values (1976 and 1977) were correlated with Powder River discharge, Powder River daily maximum water temperatures, Powder River mean daily water temperatures, and degrees difference in mean daily water temperature between the Yellowstone River and the Powder River. A linear regression and a quadratic regression were used. Only the 1976 discharge was found to account for a significant amount of the variation in catch rate (54%). This regression supports the hypothesis that the magnitude of the channel catfish movement was partially dependent upon spring discharge patterns in 1976.

No ripe (sex products easily extrudable) channel catfish were collected in the Powder River. Of six fish taken by fishermen in Section 1 in late April, four were females with ovaries in the later stages of development. During fall sampling, young-of-the-year channel catfish were captured in most sections.

Seining conducted during August 1976 showed a much higher catch rate of young channel catfish in the Little Powder River. On the basis of that observation the spring 1977 work was initiated. During May and June 1977, three ripe channel catfish were captured in the Little Powder River. No sites of reproduction were located.

Burbot

Classified as a game fish by the Montana Legislature in 1975, the burbot (*Lota lota*) represents a very important fishery in early spring in the lower Yellowstone drainage system. Contact with a Powder River fisherman in the Powderville area indicated that a burbot fishery did exist in this river. The 1976 spring sampling produced three burbot averaging 341 mm in length and 250 gr in weight. During 1977, 10 burbot were taken averaging 380 mm in length and 380 gr in weight. The 1978 sampling yielded 1 specimen, 791 mm long and 870 grams in weight taken on April 24. The mean daily temperature during the periods of

Four channel catfish tagged in Section 1 of the Powder River were recaptured upstream by anglers in 1976. Two fish were returned from Powderville (145 km) 32 and 38 days following tagging. The third fish was caught at the mouth of the Little Powder River, representing a movement of 249 km in 33 days. The last 1976 channel catfish tag return was taken 30 km up the Little Powder River, 57 days after tagging for a total movement of 279 km. During the spring fish tagging in 1977, three channel catfish tagged in 1976 were returned from the same general area they were tagged. Considering that this rate of return approximates fisherman returns of the previous year, a homing tendency is implied.

A total of eleven catfish tags were returned in 1977. Six of these were fish tagged in 1976. Of these 6, four were caught at the mouth of the Powder River while the other two were taken at Mizpah Bridge and Powderville. Of the catfish tagged in 1977, five fisherman returns were received in 1977. Four of these were caught in the Broadus vicinity by early July while the last tagged channel catfish was caught in mid-August in Miles City.

Catfish sampling on the Little Powder River in 1977 yielded 4 returns of 1977 tags. Those recaptured fish made the 258 km movement in an average of 58 days.

Increased interest in the Powder River water prompted an attempt to enumerate the strength of the channel catfish run in 1977. Sampled recaptures added to angler returns constituted the pool of recaptured fish. In order to meet the requirements for a valid Petersen estimate, it was assumed that there was not a resident population of channel catfish in the Powder River. The Petersen estimator was used:

$$T = \frac{m}{x/n}$$ (Adams, 1951)

m = number initially marked (118)

n - total number of recaptures (240)

x = number of marked recaptures (9)

T = 3147 (1656 to 7080)

Based on the estimate, 3,147 channel catfish migrated up the Powder River to spawn during the spring of 1977. Confidence intervals at the 95 percent level were calculated and were $P(1656 \leq N \leq 7080)$. It is thus apparent that the Powder contributes to the channel catfish population of the Yellowstone River.

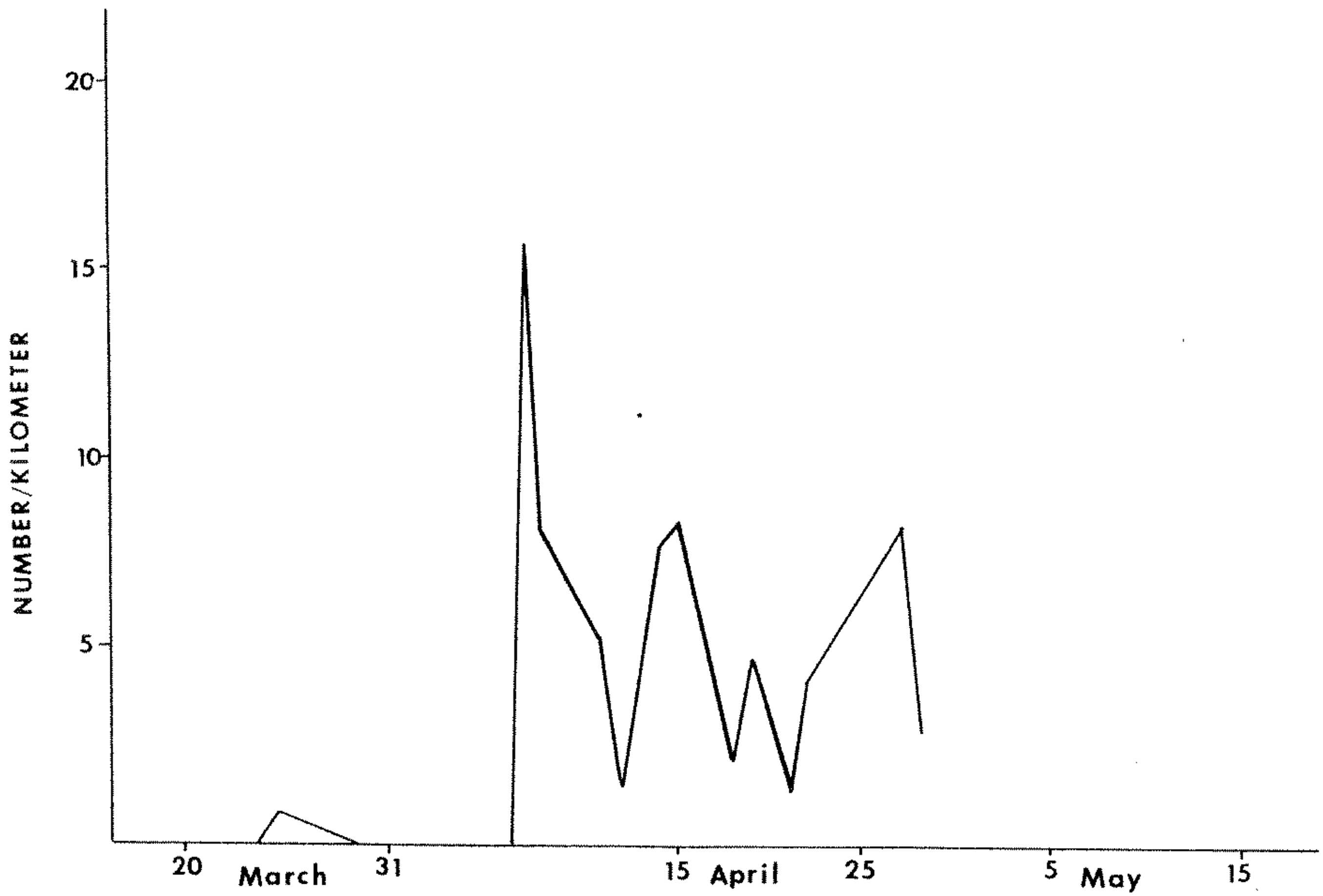

Figure 17. Daily catch rate of channel catfish at section 1, Spring 1977.

Table 26. Voluntary creel census of the Powder River, 1977.

Total known anglers	41
Number accounted for in creel census	28 or 68.3%
Total known number of setline sets	281
Mean number setline sets/angler	10.04
Total estimated setline sets for river	411
Total known pole hours	289.5
Mean pole hours/fisherman	10.3
Total estimated pole hours for river	423.9
Total known number of fisherman trips	355
Mean number of trips per fisherman	12.68
Total number estimated fisherman trips	520
Total setline fisherman hours expended during season (assuming 30 minutes time required to check and reset)	205.5
Total hours expended (pole and setline)	629.4
Number of fish per fisherman	8.04
Total number of catfish caught (estimate)	329
Weight of catfish harvested (2.66 km x estimate)	875

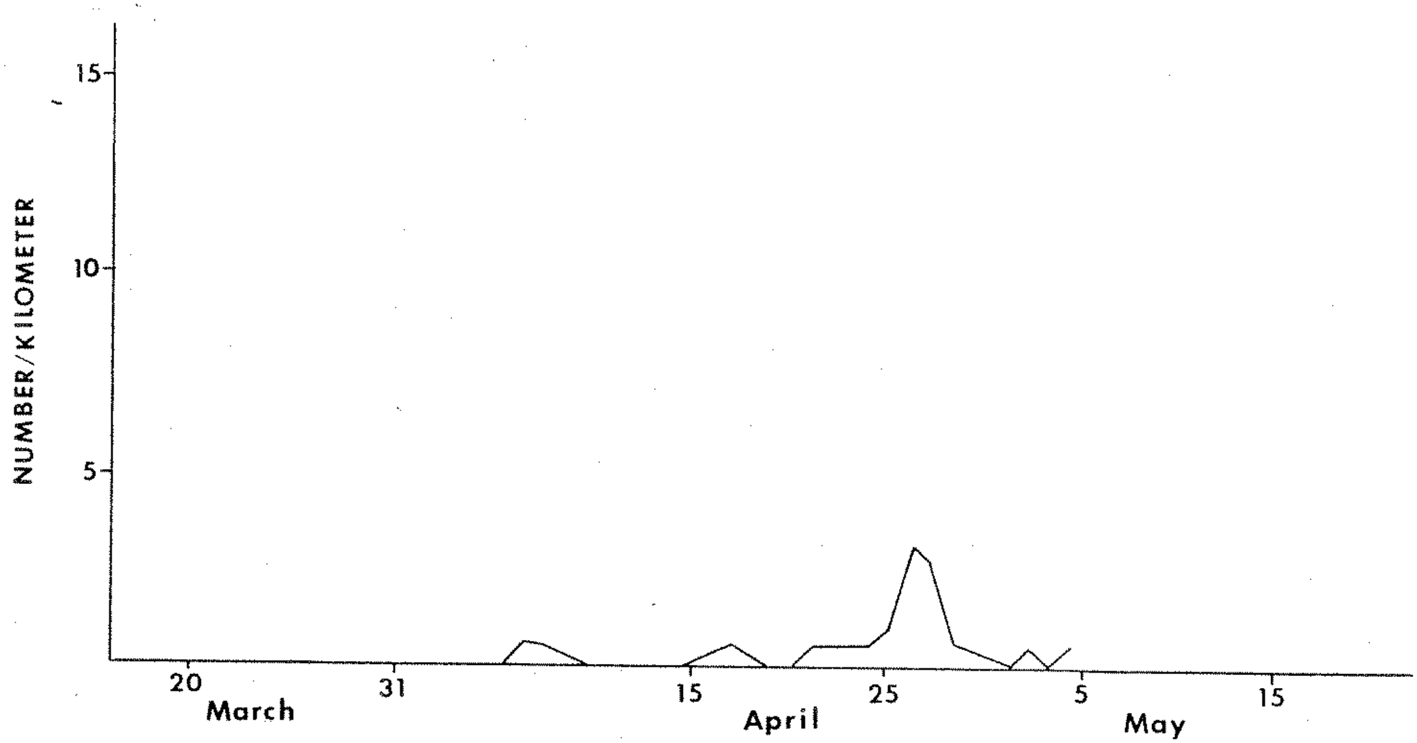

Figure 18. Daily catch rate of channel catfish at section 1, Spring 1978.

burbot collection averaged 10.0 C in 1976, 8.2 C in 1977, and 9.2 in 1978.

Age and growth information was not obtained since the use of otilithes is required which means the fish must be sacrificed. No sex determinations were made and no other reproductive data was collected.

One burbot tagged on March 24, 1977 was taken by a fisherman at the Forsyth diversion on June 1, 1977. This was a 142 km movement in 70 days.

Shovelnose Sturgeon

Shovelnose sturgeon (*Scaphirhynchus platorynchus*) are also native to Montana. Shovelnose sturgeon evidently ascend tributary streams of the Yellowstone River to spawn and large concentrations of them have been noted in the Tongue River by McFarland (Elser, McFarland, and Schwehr 1977). These fish provide a fishery for those fishermen who have learned where and how to catch them.

Shovelnose were first captured in Section 1 of the Powder River on April 13, 1976; April 8, 1977; and April 3, 1978.

The mean length and weight of the sturgeon captured in the Powder River during 1976 were 761 mm and 2420 g, respectively. In 1977 the mean length and mean weight were 756 mm and 2450 g, respectively. While in 1978 the average length was 790 mm and the average weight was 2571 grams. A total of 203 shovelnose sturgeon was collected in 1976, 231 in 1977 and 109 in 1978. The daily catch per km of river is shown in Figures 19, 20, and 21. In general, flow was increasing and water temperature was rising throughout the shovelnose sturgeon sampling period.

On May 11, 1976 shovelnose were first captured at sampling sections further upriver with 8 being taken in Section 2, 48 km upstream from Section 1 (787 cfs).

On May 13, 1976, 4 shovelnose sturgeon were captured in Section 3, 74 km upstream from Section 1. Sampling sections further upriver failed to produce shovelnose for the remainder of the 1976 season.

Two sturgeon tagged in the Powder River have been taken by fisherman. One tagged on May 3, 1977 in Section 1 was recaptured at Fairview, MT., a downstream distance of 217 km in 21 days. The other was tagged in May 1976 and caught at

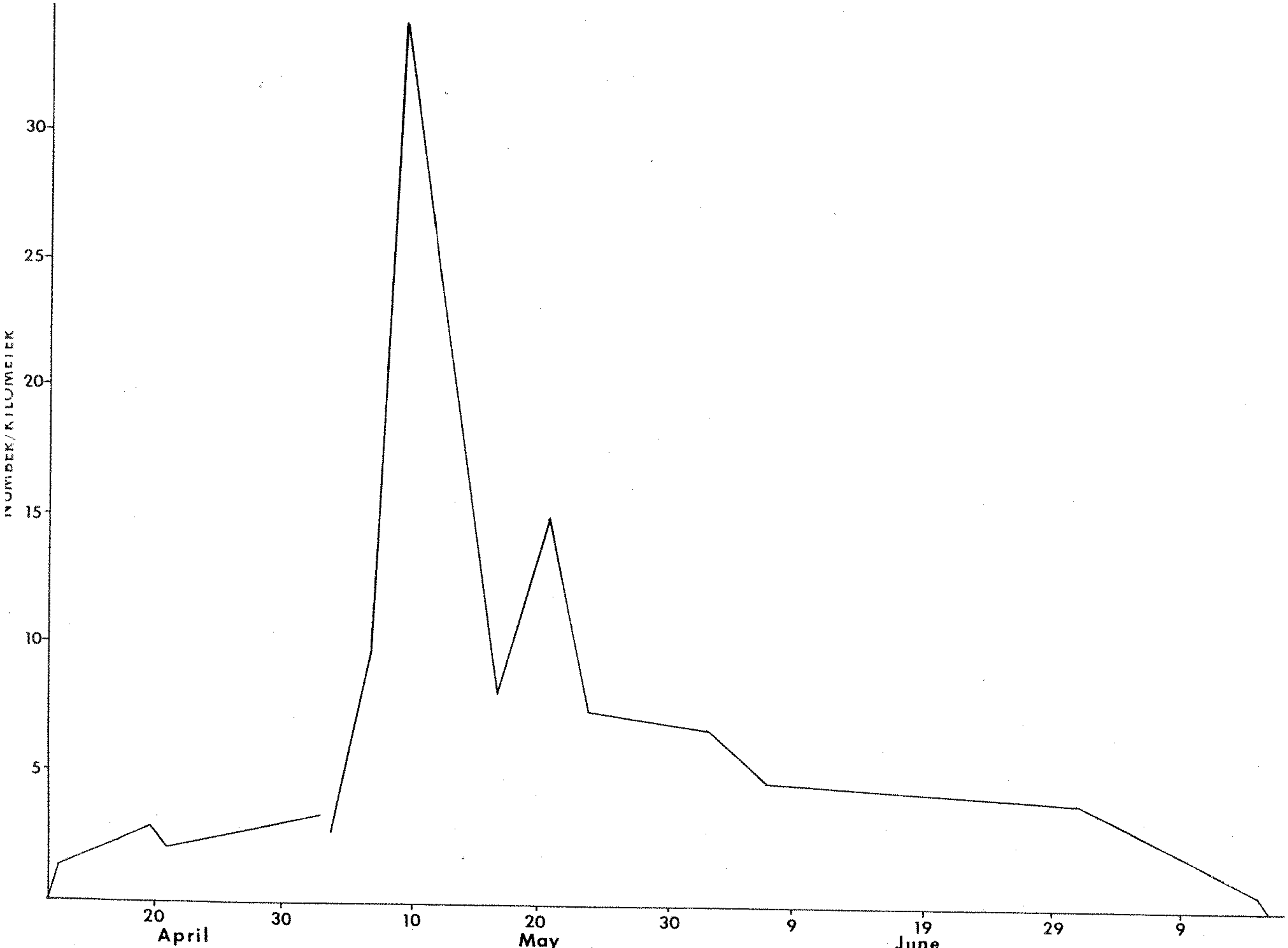

Figure 19. Daily catch rate shovelnose sturgeon at the mouth section of the Powder River, Spring 1976.

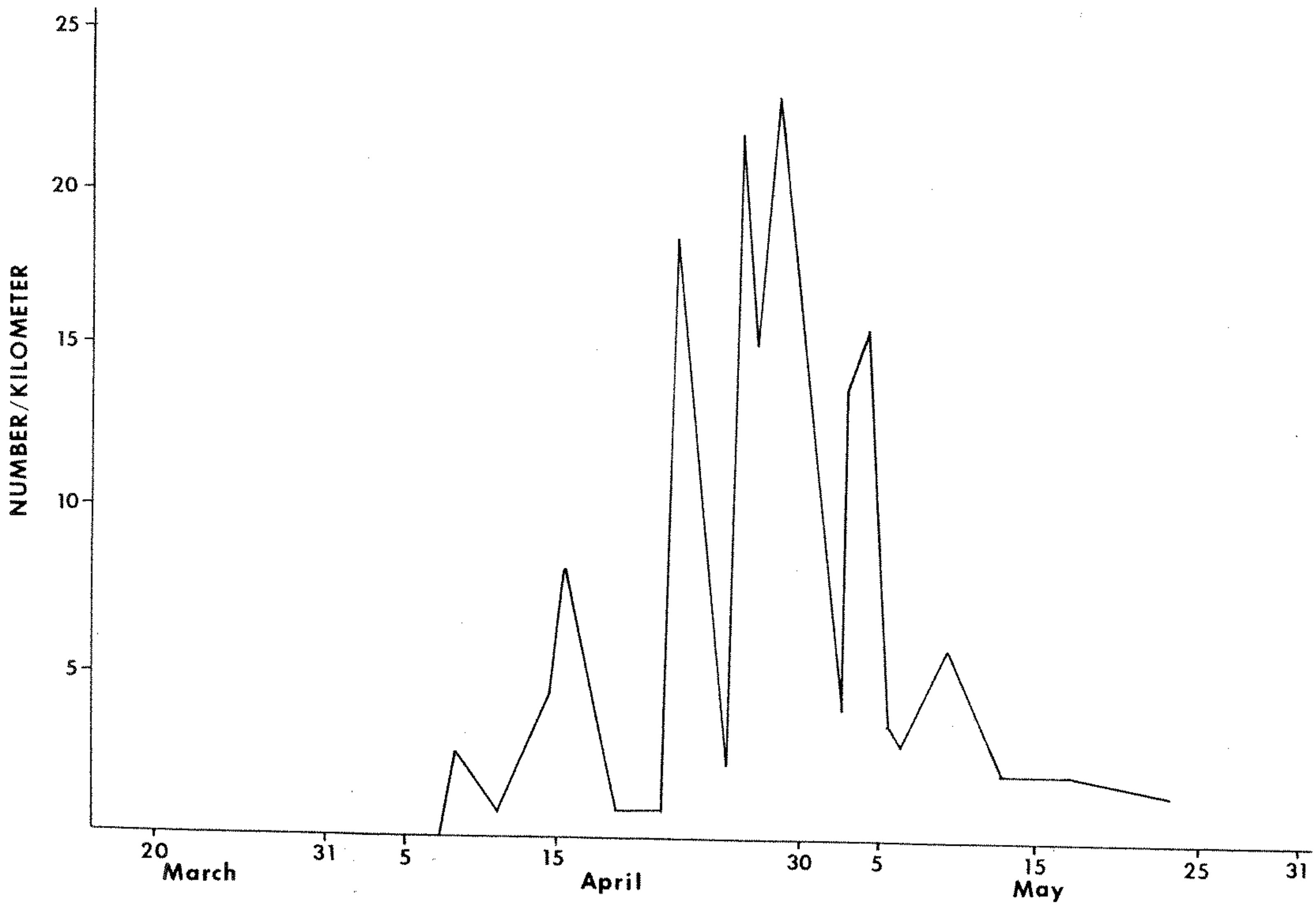

Figure 20. Daily catch rate of shovelnose sturgeon at the mouth section of the Powder River, Spring 1977.

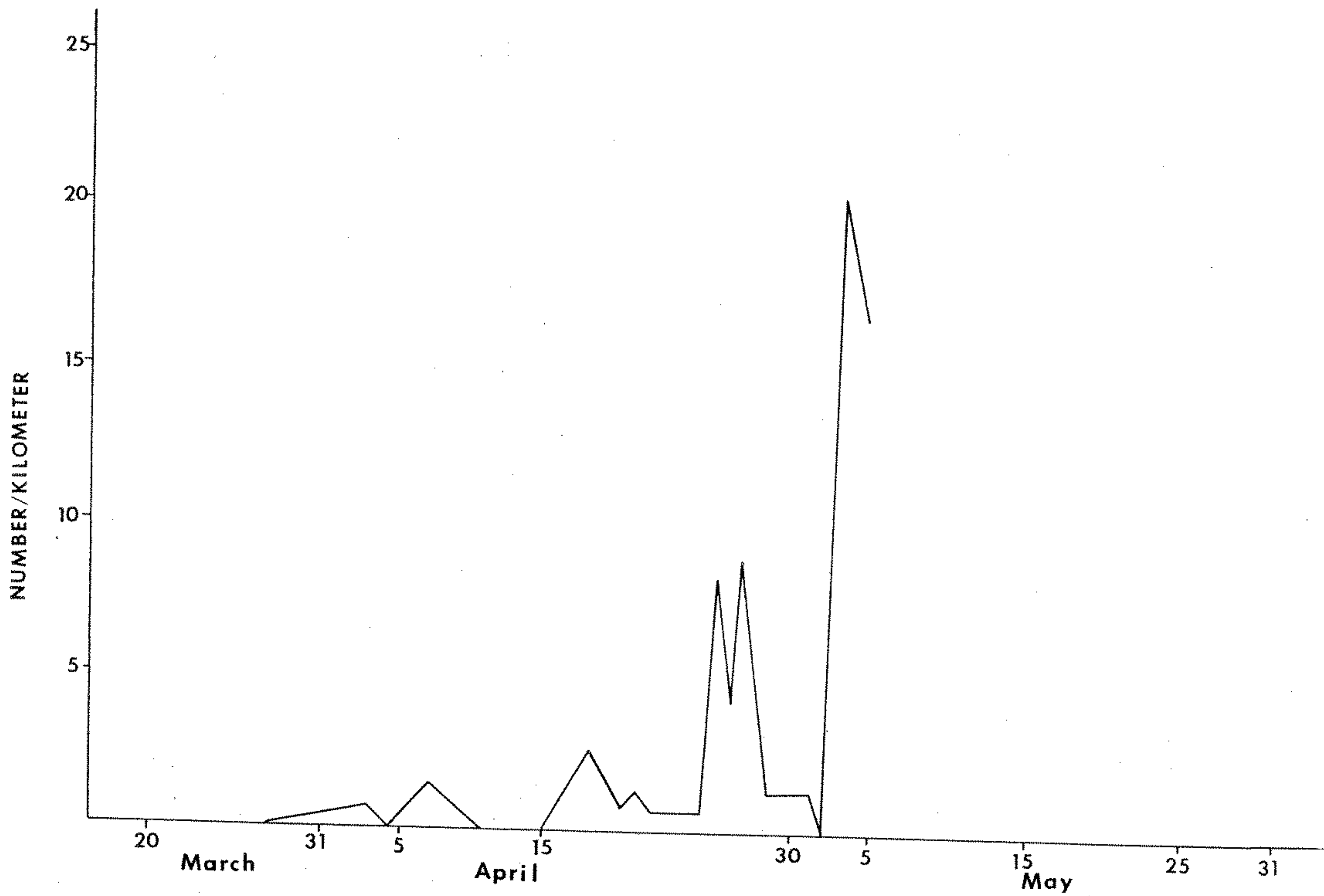

Figure 21. Daily catch rate of shovelnose sturgeon at the mouth section of the Powder River, Spring 1978.

Sheffield (just above Miles City on Yellowstone River) in April 1978.

One shovelnose captured in Section 1 on June 2, 1976 was tagged May 10, 1974 in the Tongue River at Miles City. Two other tagged sturgeon were recaptured in the Powder during spring 1978. One had been tagged there in May 1976, and the other in April 1977.

Age and growth information was not obtained since previous work suggests that pectoral fin ray sections are of dubious value and other techniques require sacrificing the fish. Sex determination was not accomplished since no females were "ripe" and the opaque fluid considered to distinguish males was found to be extrudable from both sexes.

Attempts were made to correlate catch rates with water temperatures and discharges (1976 and 1977) and no significant amount of the catch rate variation was accounted for by these parameters.

Paddlefish

The paddlefish (*Polyodon spathula*) is an annual migrant in the lower Yellowstone River. A large population exists on Garrison Reservoir and each spring moves up the Yellowstone River (Robinson 1966). One paddlefish was taken at the mouth of Clear Creek, Wyoming in the early 1970's (Fred Dabny, personal communication) . During the spring of 1977, another paddlefish was taken in the Powder River in Section 1. This male fish was collected on May 31, 1977. It's "eye to fork of tail" length was 837 mm and weighed 9.45 km. The presence of this relic makes it imparative to identify flow levels necessary to protect the integrity of the Powder.

Non-Sport Fish

Incidental to the spring sport fish monitoring, cursory observations were made on "non-sport" fish use of the Powder River at Section 1 in 1977. Four species were included in this category.

Goldeye (*Hiodon alosoides*) began using the Powder before the first sampling day of March 14, 1977. Their movement into the river closely parallels that of the sauger. The peak number observed was April 7, 1977. However, the goldeye continued to be present in Section 1 until late May. The magnitude of this movement exceeded that of any other fish migrating into the Powder River.

Carp (*Cyprinus carpio*) were only rarely observed until late April and were not commonly observed after June 1. The number of carp that moved into the Powder River appeared to be quite minimal.

River carpsuckers (*Carpoides carpio*) migrated into the Powder River mainly during the last week in April. Lesser numbers were still present in mid-May. The number of carpsuckers that made this movement appeared to be approximately the same as carp.

Shorthead redhorse (*Moxostoma macrolapidotum*) were noted to move into Section 1 for a very short period (April 10-20, 1977). These fish were never observed to be extremely abundant.

DISCUSSION AND CONCLUSIONS

Discharge Recommendation

The instream discharge needs for existing Powder River fish species and the flow needs for game species that could result from mainstem dam construction are all of the same substance. Though the specific species involved could require more or less water in any given month, all require flow in the channel below the point of the proposed development.

The important game fish species presently utilizing the Powder River extensively are the sauger, channel catfish, and shovelnose sturgeon. Experience on the Tongue River has shown that all three of these species can thrive even though the river flow is controlled. However, the volume of water, the timing of the discharge and possibly water quality are very important.

Instream discharge needs were determined and supported by three field seasons on the Powder River (Table 27). The spring (March through June) reservation to request a minimum discharge for sustaining this migratory fishery. It was based on the movement of fish into the Powder River and how extensive their movement was.

The stimulus needed for fish movement into the Powder River is not wholly understood. To conclude that discharge alone is responsible for the migration is of course erroneous. Temperature of the river is assuredly involved, but temperature and discharge are interrelated to some extent.

Sauger migration usually began at cold water temperatures (1977, 2.8°C) and moderate spring discharges (1977, 718 cfs). The cessation of this movement was preceded by several days by a mean daily water temperature that exceeded 16.0°C.

The flow recommendation of 500 cfs was based on the discharge at which sauger enter the Powder River and was tempered by other factors. In 1976, the sauger arrival preceded sampling. It was concluded that the migration had begun seven to ten days earlier (484-641 cfs). The discharge at which the sauger first moved into the Powder was documented on March 18, 1977 (718 cfs). The mean discharge for the period of sauger migration monitored at Section 1 was 867 cfs in 1976 and 720 cfs in 1977. The peak catch rate during 1976 and 1977 occurred on April 9 and April 7, respectively. The flows on these dates were 370 and 550 cfs. In addition to this evidence, sauger were collected at Locate and Moorhead, verifying long movements within the system. It was therefore concluded that 500 cfs for the months of March and April was an appropriate discharge to maintain this population at its current level as well as assuring the Yellowstone River sauger numbers.

Channel catfish movements into the Powder River begin later than sauger. The majority of this migration passes through Section 1 in a short period of time (1-2 weeks). An attempt to explain the channel catfish ingression was partially successful. Regressions were calcualted for both 1976 and 1977 with daily catch rates as the dependent variable and water temperature and discharge as the independent variables. It was assumed that the catch rate (number per kilometer) reflected actual movement. A significant correlation was drawn for 1976 data where 54 percent of the variation in catch rate was explained by discharge. However, once within the system, the channel catfish used side channels and tributaries (Little Powder River, June 1977) for passage and reproduction. The 120 cfs figure was concluded to be sufficient for these uses. The channel catfish use period was overlaid with both the sauger and shovelnose sturgeon recommendation which required greater mainstream discharges.

Shovelnose sturgeon have been shown to migrate great distances. During this movement, the sturgeon exclusively uses the stream thalweg (Elser, McFarland and Schwehr, 1978). Such dependence upon the deepest and fastest part of the channel makes the shovelnose very vulnerable to alterations in the flow regimen. Within the Powder River the following generalization appears to be true, the greater the discharge and the longer it lasts, the greater the magnitude of the run and the more extensive the movement. However, the data do not conclusively show this.

The magnitude and length of the run also appears to partially depend on the early increasing stages of spring runoff as well as the presence of a high and stable "plateau" in the hydrograph (1976, catch rate increased dramatically at 725 cfs; 1977, 690 cfs; 1978, approximately 3,000 cfs). In 1977 the high plateau was not maintained and the run ended over 1 month earlier than in 1976. In 1978, the flow pattern was very high early and late while the mid-period discharges were low. This caused a complete cessation of the migration on May 2. When the flow did increase due to heavy rains, the river could not be sampled as it had before. A boom shocking boat worked at the mouth of the Powder and noted large concentrations of sturgeon present.

Passage of the shovelnose sturgeon to the upper river was monitored in 1976 and noted on May 11. U. S. Geological Survey provided provisional data for that spring but it included a seven day void where linear interpolation was used. This yielded a discharge of 787 cfs. This was the "backbone" of the sturgeon passage flow needs. When final data was available from U.S.G.S., the actual discharge was 655 cfs. The 1977 work did not allow continuous sampling at Locate but creel census catch data substantiated a flow of between 781 and 1160 cfs for passage.

During 1978, the Locate Section was again monitored to determine this flow of passage. The first sturgeon was sampled at Locate on April 25, 1978 at a discharge of 515 cfs. Subsequent sampling yielded 6 more sturgeon, one of which had been tagged on April 5 at Section 1. The assumption that 800 cfs is needed for passage is therefore incorrect, as shown by the 1978 data. However, the data also show that low flow will completely stop the run (May 2). The mean daily temperatures for May 2 and May 3 were both 12.5°C. The only difference is discharge (438 cfs on May 2 and 816 cfs on May 3). The catch rate for May 2 was 0.0 and for May 3 was 20.51/km. Peak catch rate data supports this need for minimum discharges of approximately 800 cfs. It is concluded that 800 cfs is the flow essential to maintaining this population during May and June.

Water Surface Profile data applied to the indicator species method (Bovee 1975), yield discharge requirements that were far in excess of those known to be sufficient. It was concluded that this methodology did not apply in the Powder River.

During 1977, attempts were made to quantify the habitat requirements of the five most abundant resident fish species (flathead chub, sturgeon chub, longnose dace, plains minnow, and goldeye). Due to sampling difficulties correlation were not achieved. The wetted perimeter method (White 1975) was not found to be applicable. Therefore discharge figures calculated for the Northern Great Plains Resource Program (1974), based on the naturally occurring hydrograph, were accepted as most appropriate (Table 27).

Table 27.

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
State Line to Little Powder	120	30	30	100	100	100	100	100	400	400	600	750
Little Powder to Yellowstone	200	47	40	85	80	80	80	75	500	500	800	800

Fishery Resulting From Powder River Impoundment

Potential Tail Water Fisheries

The single most important point on this subject is the need for sizeable discharges from the reservoir. During the 1976 water year in the Bighorn River (St. Xavier) the lowest mean monthly discharge was 2610 cfs (Sept). The lowest mean monthly flow below the Tongue River dam during that same year was 153 cfs (Oct. 1975). Both of these streams support good tailwater fisheries.

The maximum fishery potential appears to be related to the volume of discharge. Stevenson (1975) working on the Bighorn River found high fishing pressure and high rates of success in that trout fishery. Work done on the Tongue River tailwater area (Elser, McFarland, and Schwehr,1977) indicated that a reproducing trout population does exist, yet it is not of the magnitude of the Bighorn fishery.

It must be emphasized that both of these reservoirs are the mainstream type. A review of literature did not reveal any publication where an off-stream storage facility made sizeable enough releases to create a documented tailwater fishery. Therefore, all recommendations are confined to mainstem reservoirs with sizeable water releases.

Such a reservoir on the Powder River in the Moorhead area could produce a tailwater fishery that would be a real asset to the area. Flow patterns like those of the Tongue River would insure a similar fishery. The Tongue River tailwater fishery is characterized by a "remnant" reproducing brown trout population, walleye and northern pike as "spill overs" from the reservoir, and reproducing populations of black and white crappie. This sport fishery requires high summer discharges. Instream flow recommendations given by Elser, McFarland and Schwehr (1977) show 150 cfs required from mid-July through March except for the brown trout spawning period (Oct.-Nov.) when the minimum flow was determined to be 190 cfs. These recommendations were based on data collected by the Water Surface Profiles method and preferred spawning depths (0.5-0.8 ft.) and velocities (1.30-1.70 ft/sec) for brown trout. This was the same method used for crappie. Rearing and incubation discharges were based on the wetted perimeter method (White 1975).

The Tongue River also maintains a reproducing population of smallmouth bass, rock bass, northern pike, sauger and walleye.

These species are found in the reach of the Tongue River immediately below the tailwater fishery. The minimum flow at which these fish are able to sustain themsleves as a sport fishery was determined to be 150 cfs (mid-July through March).

Since the Tongue River is similar to the Powder River in water quality (Powder - higher in salt concentrations) and similar flows are possible for the Powder River, it is concluded that such a stream fishery is possible if minimum flow releases are guaranteed.

Dam Design and Its Impact on Future Fisheries

An evaluation of the predicted fishery resulting from different types of dams and reservoirs must be based on older impoundments and the associated fishery data. There exists one major difference between the two proposed Powder River reservoirs and the vast majority of older impoundments. That difference is in the function and management of these bodies of water. Typically, the release is manipulated through the dam by the use of a stationary penstock. Water is commonly drawn off from a depth below the thermocline level. This has definite impacts on stratification, nutrient mixing, primary production and finally fish production. This cold water discharge usually results in the salmonid tailwater fishery.

However, in the Powder River, virtually all water will be pumped from or near the reservoir surface (Mt. DNRC File 3763-s42J and File 1004-s42J) with minimal or non-existent releases through the dam. This type of water withdrawal would have less immediate impact on the hypolimnion (the nutrient trap) as well as reducing the effect on destratification.

Mainstem dams designed with a single stationary deep water outlet have resulted in numerous cold water fisheries (Green River, Utah; White River, Ark; Bighorn River, MT.). However in the case of Flaming Gorge, the extreme cold water discharge has been determined to inhibit good salmonid growth. This has resulted in a dam modification which has the effect of a variable depth or multiple level release. Biologically this type of design is undoubtedly more desireable. Such modifications allow far greater control of reservoir nutrient release, water temperature, and stratification. Such design modification would be controlled by economics and water release.

The only other design feature of fisheries importance has already been included by both proposed Powder River projects. The use of extensive riprap and bedding gravel on the face of the earthfill dam has been shown to be used as spawning substrate by walleye (Jenkins 1973). This might insure significant walleye reproduction when other spawning substrate is unavailable.

Reservoir Fishery Forecast

Both the off-stream and mainstream reservoirs proposed for the Powder River have two important characteristics in common: (1) water chemistry and (2) continuous water withdrawal.

The water chemistry and its affect on a reservoir fishery has been addressed by Jenkins (1970). He found that the reservoirs total dissolved solids (T.D.S.) divided by the mean depth yielded a useful index of fish production. Maximum standing crops of fish were realized at index values between 5 and 30. This index accounted for 62 percent of the variability in hydropower storage reservoir fish standing crops (all fish, not just game fish).

The determination of the mean water depth requires knowledge of the water use patterns which is unknown at this time on the Powder River proposals. However, the T.D.S. of the Powder River presently ranges between 970 and 2050 (1976). Predictions for T.D.S. levels in the reservoir show a steady increase due to evaporative loss to a maximum of 3000 microhons/cm^3 (Mt. DNRC, 1977).

Jenkins (1972) noted that the total quantity of nutrients passing through a reservoir appear to be of greater importance to fish production than the concentration of nutrients per unit volume. This flow of nutrients is closely related to storage ratio (ratio of reservoir volume at average pool to annual discharge volume).

Optimum fish production and standing crop have been analyzed by Jenkins (1973 and 1976). The T.D.S. levels should not exceed 350 ppm and are preferred at around 100 ppm. At concentrations above this, a predominance of "rough fish" is probable.

Another index of water quality to fish production is that of carbonate-bicarbonate to sulfate-chloride relationship. The better fisheries studied, always have higher carbonate-bicarbonate concentrations (Jenkins 1976). The Powder River has the reverse of this situation (U.S.G.S. 1976). In general, Jenkins concludes that Great Plains Reservoirs will produce large rough fish fisheries.

The physical environment of a reservoir is also very important in the eventual realization of a fishery. The single most important factor in this category is that of water level management, with the spawning period the most crucial time.

Reservoir northern pike traditionally have strong year classes each year until the reservoir reaches maximum pool (Hassler 1970). The wave and ice action rapidly destroy the needed vegetative spawning substrate and water level fluctuations prevent the establishment of aquatic plants and emergents. This usually eliminates natural reproduction by northern pike. Another species similarly affected appears to be the yellow perch which decreases in number after maximum pool is achieved (Nelson and Walburg 1976). The yellow perch represents a large part of the forage base in several Missouri River reservoirs. In addition to these two species, all fish using shoreline areas for spawning are vulnerable to severe and extensive draw downs. But other important aquatic organisms are also negatively affected. *Hexagenia*, a burrowing mayfly, is severely reduced by draw down as are the chironomids, zooplanktons, and periphyton (Benson 1973). Conversely, the white crappie and largemouth bass appear to benefit by non-spawning period draw downs. It is thought that dropping the water level removes the forage from security, concentrates them, and thereby increases predation.

Other important physical parameters involved are: (1) reservoir water turbidity (high turbidities appear to retard the sport fish crop), (2) the presence of a thermocline (those reservoir with one tend to have higher standing crops of fish), and (3) climatic factors (determine water level and thereby, reproductive success and forage supplies). These factors were determined by Nelson and Walburg (1976) and Jenkins (1970 and 1973).

The supply of forage fish in a reservoir is all important. The supply may be directly determined by previously mentioned factors, and will account for sport fish year class strength (Nelson and Walburg, 1976). The "rough fish" addressed earlier will offer some use as forage for a relatively short period before these species (carp, carpsuckers, goldeye) grow too large to be utilized. Yellow perch will suffice as a good forage base for the first few years until maximum pool is acheived and they decrease in abundance. The Tongue River Reservoir game fish depend heavily on the golden shiners and young-of-the-year white crappies.

Another possible sport fish that has not been considered is the sauger. This species will confine its distribution to the upper end of the reservoir and will do well as long as turbitities remain quite high (Nelson and Walburg 1976). The sauger requires a tributary to spawn (April and May) and the Powder is commonly high enough to suffice during that period.

Applying all this information. the most realistic management plan appears to be two-fold. The first approach would be, for the most part, short lived (3-5 years). This phase would depend on the increasing water levels for the northern pike and yellow perch. The long range sport fish complex would follow and consist of walleye, sauger, largemouth bass and white crappie with shiners as a forage base. This combination should yield a good fishery for a short time and possibly longer than anticipated. The water chemistry, turbidity, and sedimentation will undoubtedly cause problems as will the rough fish.

The water management plan for either of these reservoirs will have to peak near July 1 and be at its lowest during February. There definitely would be a 2 or 2½ year water use plan as a hedge for dry years. This type of management, during a series of wet years would aid stream fish reproduction as well as reservoir fish.

List of Waters:

Powder River
Little Powder River
Mizpah Creek
Ten Mile Creek - Mouth in Prairie County
Coal Creek - Prairie County

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Appendix Table 21. Organisms collected in October 1975.

Station	1				2				3				4				5			
Sample	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																				
Ephemeroptera														2		1				
Rhithrogena													-	2	3	-	3			
Heptagenia													-	1	-	-	1	1	2	-
Leptophlebia													-	2	1		3	3	2	-
Tricorythodes																				
Trichoptera																				
Hydropsyche													-	2	-	-	7	2	-	-
Cheumatopsyche	5	-	1	-	3	11	7	2	-	-	-	1	-	35	106	8	8	7	-	-
Brachycentrus																	9	-	1	-
Plecoptera																				
Perlodidae	1	-	-	-	11	1	-	-									15	1	-	-
Isogenus					-	-	1	-	-	-	-	1	-	-	-	1				
Acroneuria									-	-	-	1	-	1	2	-	1	-	-	-
Diptera																				
Chironomidae					-	1	-	-	-	1	-	1	-	1	1	16	2	-	1	1
Empedidae																	10	-	-	-
Simulium													-	4	39	8	11	1	-	-
Odonata																				
Argia													-	1		-				
Coleoptera																				
Elmidae (adults)																	-	8	4	-
Microcylloepus																	13	-	-	-
Stenelmis																	12	1	1	-

*K - Kick Sample

1 - First Water's Sample

2 - Second Water's Sample

3 - Third Water's Sample

Appendix Table 22. Organisms collected in March 1976.

Station	1				2				3				3T				4				5				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	E*	E	E	E	K	1	2	3	K	1	2	3	K	1	2	3
<u>TAXA</u>																												
Ephemeroptera																												
Rhithrogena																									2	-	-	-
Leptophlebia													-	3	-	-												
gravestella													1	-	-	-												
Caenis													-	1	-	-												
Baetis parvis																									1	1	-	-
Ametropus					1	-	-	-	2	-	-	-									1	-	-	-				
Trichoptera																												
Hydropsyche																									4	10	-	-
Cheumatopsyche	8	11	52	40	-	2	2	-	-	-	2	-	2	-	4	-	18	32	-	4					8	2	-	4
Brachycentrus																												
Plecoptera																												
Brachyptera																					-	1	-	-				
Perlodidae	10	-	6	1					6	2	-	5					-	-	1	-	1	-	-	-	15	-	-	1
Isogenus	1	-	-	-													-	-	3	-								
Acroneuria	3	-	1	1																								
Diptera																												
Ceratopogonidae													-	1	-	-												
Chironomidae*	6	-	1	-									10	8	-	1					2	3	-	-	8	-	2	2
Cricotopus													x	x							x							
Eukiefferiella			x																									
Trissocladius													x															
Conchapelopia	x												x								x							
Dicrotendipes	x												x															
Endochironomus														x														
Pseudochironomus													x		x													
Stitochironomus	x													x														
Dolicopodidae													1	1	-	-												
Empedidae																	2	1	-	-					1	5	-	-
Simulium													29	-	2	-	1	-	-	-					38	-	1	1
Stratiomyidae													1	-	-	-												
Tipulidae													2	-	1	-												
Odonata																												
Gomphus	2	1	-	-																								
Coleoptera																												
Elmidae (adults)																	-	-	1	-					1	-	-	-
Others					3	-	-	2					4	2	-	-												

*E - Ekman Dredge Samples
*X - Denotes the presence of that genus

Appendix Table 23. Organisms collected in April 1976.

.tion	2	3	3T	4	5	5T	6
Sample No.	K 1 2 3	K 1 2 3	E E E E	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3
<u>TAXA</u>							
Ephemeroptera							
Stenonema						- 8 1 1	
Leptophlebia gravestella						- 4 3 5	
Caenis			3 - 74 -			- 2 - -	
Baetis parvis						- 1 - -	
Ametropus	2 - - -						
Trichoptera							
Polycentropus						- - 1 -	
Hydropsyche						- - 1 -	
Cheumatopsyche	- 3 - 1	- - 2 -	- - 3 -	- - 9 4		- 7 3 3	- 1 - -
Plecoptera							
Perlodidae	- 2 - 3	- 3 3 1		- - 3 2	- 1 - 3		- 1 - -
Acroneuria	- 1 - -			- - - 1			
Diptera							
Ceratopogonidae		1 - - -	2 - - -				
Chironomidae	- - 1 1	- 1 2 1	11 - 23 -		- - 4 -	- - 1 -	
Cricotopus			x				
Conchapelopia			x				
Paratendipes			x				
Stitochironomus		x x					
Empedidae					- - 1 -		
Simulium				1 7 1 -		- - 97 57	
Tipulidae			- - 1 -				
Odonata							
Argia			- - 1 -				
Omphidae					- 2 - -		
Coleoptera							
Dubiraphia						- 7 - -	
Stenelmis				- 1 - -		- 6 - 5	
Others			- - - 1		- - 1 -	- - 2 2	

Appendix Table 24. Organisms collected in May 1976.

Station	1				2				3				3T				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																																
Ephemeroptera																																
Anepeorus																																
Stenonema																																
Epeorus																													6	2	-	-
albertae																									3	1	-	2				
Leptophlebia																					2	-	-	-					8	1	-	-
gravistella																									30	3	1	6				
Caenis													-	13	18	16									1	-	1	2	-	4	-	-
Baetis parvis																									2	-	-	1				
Ametropus									-	-	-	1									1	-	-	-								
Trichoptera																																
Polycentropus													-	-	-	1																
Hydropsyche																									-	1	-	-				
Cheumatopsyche	1	1	3	-									-	3	-	-	-	1	3	-	1	-	-	1	4	3	-	7				
Plecoptera																																
Perlodidae	2	-	2	1					12	1	5	-					-	1	-	-	3	-	-	2					14	2	-	1
Acroneuria	1	-	-	-													2	1	-	-												
Diptera																																
Chironomidae																	-	-	1	-					20	2	7	-	1	-	3	-
Conchapelopia																													x			
Dolicopodidae																					-	2	-	-								
Empedidae									1	-	-	-													2	-	-	-	1	-	-	-
Simulium																					-	1	-	-	4	-	-	-				
Tipulidae									1	-	-	-													4	-	-	-	1	-	-	-
Odonata																																
Argia													-	1	-	-																
Gomphidae													-	1	-	-									1	-	-	-	1	-	-	-
Coleoptera																																
Dubiraphia																					-	-	-	3	3	2	3	4				
Stenelmis																									19	1	-	-				
Hemiptera																																
Ambrysus mormon																									1	-	-	-				
Others																					-	-	-	34	2	-	1	-	-	-	-	1

Appendix Table 25. Organisms collected in June 1976.

Station	1				2				3				3T			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																
Ephemeroptera																
Anepeorus	-	-	1	-	1	-	-	-					8	-	-	-
Stenonema																
Heptagenia criddlei													5	1	-	3
Epeorus																
albertae					2	-	-	-	-	1	-	1				
Leptophlebia gravestella													-	-	-	1
Caenis									-	-	1	-	12	-	1	-
Baetis parvis																
B. propinquus					-	-	1	-					4	-	-	-
Ametropus																
Trichoptera																
Psychomyiid Genus A	-	-	2	9	-	3	1	-	3	12	1	-				
Hydropsyche																
Cheumatopsyche	4	-	5	2	1	-	1	-	1	2	3	-	70	13	1	3
Plecoptera																
Isoperla	2	-	1	-	10	1	-	-	11	2	-	-				
Acroneuria					-	-	-	1								
Diptera																
Chironomidae													1	-	-	-
Odonata																
Gomphus																
Ophiogomphus																
Coleoptera																
Elmidae (adults)																
Stenelmis																
Hemiptera																
Ambrysus mormon																
Others																

Station	4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																
Ephemeroptera																
Anepeorus	2	-	-	-	2	-	-	2					4	-	2	-
Stenonema					-	1	-	-								
Heptagenia criddlei					1	-	-	-	12	5	1	6				
Epeorus	2	-	1	-									7	-	1	-
albertae																
Leptophlebia gravestella									19	6	2	-				
Caenis																
Baetis parvis									2	-	-	-	1	-	-	-
B. propinquus					-	-	1	4								
Ametropus					-	-	-	1					2	-	-	-
Trichoptera																
Psychomyiid Genus A	-	-	31	1	-	2	12	-	-	-	1	-	-	2	-	1
Hydropsyche									3	3	-	-	-	1	-	-
Cheumatopsyche	2	-	1	-					4	7	1	-				
Plecoptera																
Isoperla	2	-	1	-	3	-	1	-					3	-	-	-
Acroneuria	2	-	-	-												
Diptera																
Chironomidae																
Odonata																
Gomphus									-	2	-	-				
Ophiogomphus	-	1	-	-	1	-	-	-								
Coleoptera																
Elmidae (adults)									1	-	-	-				
Stenelmis					1	-	-	-	13	1	-	-	-	1	-	-
Hemiptera																
Ambrysus mormon									9	1	-	-				
Others									-	-	-	3				

1.4366	2.000	1.7533	0.4854	0.7254	1.5196	2.4180	1.8112
1.9999	2.3219	2.3219	1.0000	2.3219	1.9999	2.9999	1.9999
.8475	2.000	1.0144	.2974	.7254	.7416	1.1828	1.5487
.4888	1.000	.4348	.7324	.9999	.3817	.3202	.4182
.7183	.8613	.7551	.4854	.3124	.7598	.8060	.9056
.3324	.6666	.3875	.1142	.1403	.3314	.4574	.6037
1.1042	1.3333	1.3657	.3711	.5851	1.1882	1.9605	1.2075
[illegible]		[illegible]	[illegible]	[illegible]	1.8112	2.2194	1.2896

Appendix Table 26. Organisms collected in July 1976.

Station	1				2				3				3T				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																																
Ephemeroptera																																
Ephoron album																									2	-	-	-				
Anepeorus					1	-	-	-									4	-	-	-	5	-	-	-					7	-	-	-
Heptagenia criddlei													3	-	2	-	1	-	-	-					2	2	-	-				
Epeorus albertae																													1	-	-	-
Traverella albertana	3	1	-	3	6	1	2	1	-	1	-	-					30	1	1	-	61	-	-	-					11	-	2	-
Leptophlebia gravestella													2	-	-	-									2	4	1	2				
Tricorythodes minutus																					1	-	-	-					2	-	-	-
Brachycercus																					6	-	-	-					3	-	-	-
Caenis									-	1	-	-	5	1	-	-																
Baetis parvis																	1	-	-	-									-	-	2	-
B. propinquus									-	-	-	1	-	1	-	-	-	1	-	-	8	-	-	-	2	-	-	-	2	-	-	-
Ametropus																									5	2	-	-				
Trichoptera																																
Psychomyiid Genus A	2	-	-	1					-	-	1	-									3	1	-	1					2	-	-	-
Hydropsyche													2	-	-	-									-	1	-	-	1	-	-	-
Cheumatopsyche	1	-	-	-	-	1	-	-	-	1	2	-	33	-	1	-	4	-	1	-	3	-	-	-	1	11	1	-	10	-	1	2
Plecoptera																																
Perlodidae					-	1	-	-																								
Acroneuria	3	-	-	3	-	2	-	-	1	1	-	-					3	-	-	-	5	-	-	-								
Diptera																																
Chironomidae													8	1	-	4																
Cricotopus													X																			
Orthocladius														x		x																
Calopsectra																x																
Conchapelopia													x			x																
Cryptochironomus													x																			
Dicrotendipes													x																			
Simulium	-	-	2	-													1	-	-	-												
Odonata																																
Gomphidae					-	-	1	-													5	-	-	-								
Gomphus													1	-	-	-									1	-	-	-				
Ophiogomphus					-	1	-	-									3	-	-	-									1	-	-	-
Coleoptera																																
Stenelmis																									2	7	2	1				
Hemiptera																																
Ambrysus mormon																									-	-	1	-				

Appendix Table 26 continued.

Station	1	2	3	3T	4	5	5T	6
Sample No.	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3	K 1 2 3
Megaloptera								
Sialis				1 - - -				
Others		- 1 - -			3 - - -		2 1 - -	1 - - -
	1.8464	2.3219	1.8112	1.7609	0.8112	0	2.0628	0.9852
	1.9999	2.5849	1.9999	1.9999	1.0000		2.5849	1
	1.3567	2.1609	1.5487	1.3567	.8112		.9038	.5916
	.2387	.6203	.4182	.3716	1.0000		.3105	.0361
	.9232	.8982	.9056	.8804	.8112		.7980	.9852
	.5558	.6989	.6037	.5301	.4056		.3990	.3509
	1.2906	1.6229	1.2070	1.2308	.4056		1.6638	.6342
	1.8910	.5916	0	1.6371	1.6673	1.2475	2.1148	1.8441
	2.0418	2.0157	1.8910	1.8014	1.6390	1.3158	2.2968	1.7798

Appendix Table 27. Organisms collected in August 1976.

Station	1				2				3				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	2	K	1	2	3
TAXA																												
Ephemeroptera																												
Ephoron albertae																					-	-	-	2				
Heptagenia criddlei																					10	6	8	10				
Cinygma																	2	-	-	-								
Isonychia																					1	-	-	-				
Traverella albertana	1	-	-	-	-	-	1	-	2	2	2	-	32	7	2	6									86	12	1	20
Leptophlebia gravestella																					10	2	-	8				
Tricorythodes minutus													2	-	-	-	1	-	-	-					1	1	-	-
Baachycercus	4	-	1	-	-	1	-	-	1	20	7	0	1	-	-	-	2	-	1	-								
Caenis									-	-	1	-																
Baetis parvis																					2	-	1	-	6	-	1	-
Trichoptera																												
Psychomyiid Genus A	1	-	-	-									1	-	-	-	1	-	-	-								
Hydropsyche													1	1	-	-					5	-	-	-	1	-	-	1
Cheumatopsyche	5	1	21	7	1	-	-	-	7	6	6	3	14	10	5	3					125	-	1	6	-	2	-	-
Plecoptera																												
Acroneuria	1	3	-	-					-	1	-	-	2	2	1	-	-	-	-	1					-	1	-	-
Diptera																												
Chironomidae																	-	1	1	-	1	1	1	-	1	-	-	-
Conchapelopia																					x							
Cryptochironomus																		x										
Dicrotendipes																									x			
Polypedilum																			x		x	x						
Simulium	-	-	2	-					-	-	-	1	19	-	4	5					1	-	-	-	33	4	2	1
Odonata																												
Gomphidae																	1	-	-	1								
Gomphus																	2	-	-	-								
Coleoptera																												
Stenelmis					1	-	-	-													14	-	1	1				
Hemiptera																												
Ambrysus mormon																					6	-	-	1				
Others																					1	-	1	2				

Appendix Table 28. Organisms collected in September 1976.

Station	1				2				3				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Ephemeroptera																												
Rhithrogena																									3	-	-	-
Stenonema									1	-	-	-									3	-	-	-				
Heptagenia criddlei																	-	2	-	-	3	-	-	-	2	-	-	-
Traverella																									9	-	1	-
Leptophlebia gravestella													-	-	1	-	-	1	1	1	9	-	-	-	6	-	1	-
Tricorythodes minutus																	1	-	-	-								
Brachycercus					1	-	-	-	1	-	-	-	-	1	-	-	3	1	-	-					-	-	1	1
Caenis																					1	-	-	-				
Baetis parvis					1	-	-	-									-	1	-	-					25	-	2	-
Ametropus									5	-	-	-	-	1	-	-	1	-	-	-	1	-	-	-				
Trichoptera																												
Hydropsyche																									2	-	-	-
Cheumatopsyche	-	1	-	19	37	2	4	2	2	3	-	-	-	3	-	-	1	-	12	6	2	-	-	-	20	26	37	12
Plecoptera																												
Perlodidae	1	-	-	-	6	-	-	-																				
Acroneuria	-	-	1	3	-	-	-	1	1	1	-	-					1	-	-	-					2	-	-	-
Diptera																												
Chironomidae																	5	1	-	-								
Chironomus																	x	x										
Simulium	33	1	-	1	-	1	-	-	1	-	-	-					1	-	-	-	2	-	-	-				
Odonata																												
Gomphidae									1	-	-	-					1	-	-	-								
Gomphus																					6	-	-	-				
Ophigomphus																									1	-	-	-
Coleoptera																												
Elmidae (adults)	1	-	-	-																								
Stenelmis					1	-	-	-													1	-	-	-	2	-	-	-
Hemiptera																												
Corixidae																					5	-	-	-				

Appendix Table 29. Organisms collected in October 1976.

Station	1				2				2				4				5				5T				6			
Sample No.	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3	K	1	2	3
TAXA																												
Stenonema																					5	2	4	15				
Heptagenia elegantula																					-	-	-	1				
Leptophlebia gravestella													1	-	-	-	-	1	-	-	41	18	85	270				
Caenis																					-	-	2	-				
Ametropus									2	-	-	-																
Trichoptera																												
Hydropsyche					-	-	1	-													40	-	-	-	4	6	1	-
Cheumatopsyche	23	6	31	1	14	30	27	3	19	-	55	-	-	7	-	-	5	-	-	-	218	8	18	45	60	64	19	7
Plecoptera																												
Perlodidae	1	-	-	-	1	-	-	-					2	-	-	-									1	-	-	-
Acroneuria					2	1	-	-	2	-	-	-	1	-	-	-												
Diptera																												
Chironomidae	-	-	6	-	-	-	1	-													4	1	9	3				
Cricotopus																					x							
Conchapelopia																					x		x					
Chironomus																						x	x					
Cryptochironomus																							x	x				
Dicrotendipes			x				x																					
Simulium																					6	-	-	-				
Odonata																												
Hetaerina americana																					-	-	-	1				
Gomphus					-	-	-	1													-	-	-	1				
Ophigomphus					-	1	-	-																	2	-	-	-
Coleoptera																												
Dubiraphia																					-	-	3	-				
Stenelmis																					9	-	10	35				
Hemiptera																												
Ambrysus mormon																					1	-	-	15				
Megaloptera																												
Sialis																					1	-	-	-				
Others																					-	3	8	4				

Appendix Table 30 . Invertebrates collected during April 1977 from Powder River.

	April 13, 1977						
	1K	2K	3K	3TK	4K	5K	5TK
Plecoptera							
Isoperla			1				
Ephemeroptera							
Ametropus		1	1				1
Caenis			1	2			
Choroterpes					1		1
Heptagenia						1	
Odonata							
Amphiagrion				1			
Heteroptera							
Ambrysus mormon		1					
Corixidae nymph							1
Trichoptera							
Hydropsyche	ZERO						1
Cheumatopsyche			1		5		5
Diptera							
Simulium				1	1		30
Endochironomus				1			
Pseudochironomus			1	4			
Stictochironomus							1
Oligochaeta							
Immature Limnodrilus							4
Limnodrilus udekemianus				16			3
Limnodrilus spiralis							1
Amphipoda							
Hyalella azteca				1			

Appendix Table 31. Invertebrates collected during May 1977 from Powder River.

	May 11, 1977						
	1K	2K	3K	4K	5K	5TK	6K
Plecoptera							
Isoperla			21	3	1		4
Ephemeroptera							
Ametropus					3		1
Anepeorus			1				
Caenis						1	
Choroterpes						26	
Heptagenia						11	
Trichoptera							
Hydropsyche							1
Cheumatopsyche	ZERO	ZERO				7	9
Coleoptera							
Stenelmis						1	
Diptera							
Empididae							1
Simulium						31	
Theinemannemyia gr.						2	
Chironomus							1
Polypedilum						1	
Oligochaeta							
Immature Limnodrilus							1

Appendix Table 32. Invertebrates collected during June 1977 from Powder River.

	June 9		June 2, 1977				
	1K	2K	3K	4K	5K	5TK	6K
Plecoptera							
Isoperla		14			3		10
Ephemeroptera							
Ameletus						16	
Ametropus					3		
Anepeorus		4		4	1		5
Baetis		1		1			
Choroterpes						57	
Ephoron album						8	
Heptagenia		2		1		25	
Epeorus							49
Heteroptera							
Ambrysus mormon						3	
Trichoptera							
Hydropsyche						6	1
Cheumatopsyche					1	10	
Nectopsyche		6			19		
Coleoptera							
Stenelmis (*larvae*)						18	
Stenelmis (*adult*)							
Diptera							
Silulium						28	
Chironomid pupae						4	
Theinemannemyia group						22	
Cryptochironomus		1					
Polypedilum						2	
Eukiefferiella						1	
Oligochaeta							
Limnodrilus udekemianus						1	

Appendix Table 33. Invertebrates collected during July 1977 Powder River.

	July 12, 1977			July 13, 1977		
	1K	2K	3K	4K	5K	6K
Ephemeroptera						
Ametropus		2				
Baetis	1					3
Caenis	1	3	1	4	2	1
Heptagenia	1					
Traverella albertana				9		2
Tricerythodes minutus				1		1
Trichoptera						
Cheumatopsyche					1	3
Nectopsyche			1	4	8	4
Coleoptera						
*Dubiraphia minima**					1	
Stenelmis						2
Diptera						
Simulium						3
Chironomid pupae						1

* Adult form

Appendix Table 34. Invertebrates collected during August 1977 from Powder River.

	August 5		August 4, 1977				
	1K	2K	3K	4K	5K	5TK	6K
Plecoptera							
Acroneuria				1			2
Ephemeroptera							
Baetis						36	
Ameletus						7	
Caenis				1			
Choroterpes						91	
Heptagenia						3	
Traverella albertana			1	2			
Tricorythodes minutus							3
Trichoptera							
Cheumatopsyche				1		422	16
Hydropsyche						35	4
Early in star hydropsychids						31	
Hydropsychid pupae						12	
Hydroptilid pupae						4	
Odonata							
Gomphus					1		
Coleoptera							
Microcylloepus (larvae)						3	
*Microcylloepus pusillus**						1	
Stenelmis						33	
Diptera							
Dicranota						1	
Empididae						14	1
Simulium						1	
Theinemannemyia gr						24	
Cryptochironomus						4	
Unknown Chironomid A						3	
Polypedilum						41	
Pelecypoda							
Pisidium						1	

Appendix Table 35. Invertebrates collected during September 1977 from Powder River.

	September 6, 1977						
	1K	2K	3K	4K	5K	5TK	6K
Plecoptera							
Acroneuria	3			1			2
Isoperla							1
Ephemeroptera							
Ametropus			2		1		
Baetis				1		1	3
Caenis		3	1	2		1	
Choroterpes						9	1
Heptagenia						2	
Tricorythodes minutus							3
Heteroptera							
Ambrysus mormon	1					21	
Odonata							
Gomphus					1		
Ophiogomphus						1	1
Trichoptera							
Hydropsyche						21	2
Cheumatopsyche	5	8	4	4		183	9
Coleoptera							
Microcylloepus						1	3
*M. pusillus**						8	2
Stenelmis			2			10	4
Diptera							
Empididae						1	1
Simulium	5	9	10	2		9	1
Theinemannemyia gr.							1
Cryptochironomus		5					
Polypedilum							1
Unknown Chiron. A				1			
Orthocladius							1
Oligochaeta							
Immature Limnodrilus						5	

Appendix Table 36. Invertebrates collected during October 1977 from Powder River.

	October 1977						
	1K	2K	3K	4K	5K	5TK	6K
Plecoptera							
Acroneuria				1			
Isoperla					1		1
Ephemeroptera							
Ametropus		1	1		3		1
Caenis	1	1	1		8		
Choroterpes						99	
Odonata							
Gomphus					1		
Trichoptera							
Hydropsyche						35	1
Cheumatopsyche			9	7		186	56
Diptera							
*Tipulid larva***			1				
Empididae						5	3
Theinemonnemyia gr						3	
Orthocladius						1	
Oligochaeta							
Immature Limnodrilus						2	

** Keys to a group of genera: Gonomyia, Ormosia, Helobia, and Erioptera.