# INSTREAM FLOW REQUIREMENTS

# FOR THE MARIAS RIVER FISHERY DOWNSTREAM OF TIBER DAM

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## ABSTRACT

An instream flow study was conducted on a 34 kilometer reach of the Marias River below Tiber Dam from March through November 1983. Relationships between the habitat conditions of selected fish life cycles and flow levels were determined. The aquatic macroinvertebrate communities were studied to correlate their distribution and abundance with mountain whitefish food habits.

Although several species of warm water fish were sampled in low numbers, water temperature monitoring indicated this stretch of river is most suitable for a cold water fishery.

Mountain whitefish was the most numerous fish species found in the river. A population estimate completed in the spring of 1982 indicated a standing crop of 337 mountain whitefish (age II and older) weighing 90.5 kg per 300 m was found in a typical study section in the Marias River below Tiber Dam. Age and growth comparisons with other Montana river whitefish populations indicate whitefish growth rates and sizes are exceptional in the Marias River.

Rainbow trout were the most prevalent species of trout, but were found in low numbers throughout the study area. Age and growth analyses indicated excellent growth rates. Water releases from Tiber Dam during portions of the low base flow period have probably been below the minimum level required to maintain adequate instream flow for development of a good trout fishery in the river below the dam.

Seasonal spawning migrations of shovelnose sturgeon, bigmouth and smallmouth buffalo and blue suckers from the Missouri River were monitored in the study area. There was considerable use of the study area by these migratory fish, and the initiation of their use was correlated with rising spring run-off flows.

Minimum instream flow recommendations were based on maintenance of riffles and pools, providing adequate flows for secure Canada Goose nesting, and providing high flows for sustaining migratory fish spawning runs in the Marias and Missouri rivers and maintenance of channel morphology.

## INTRODUCTION

The Marias River is the largest tributary entering the Wild and Scenic segment of the Missouri River. The Wild and Scenic segment is administered by the Bureau of Land Management (BLM). Because it contributes a significant amount of flow and bedload material, the Marias not only has an effect on the physical features of the Missouri, but it also influences its fish fauna. Berg (1981) reported large numbers of shovelnose sturgeon, sauger, bigmouth and smallmouth buffalo and blue suckers migrate from the Missouri to spawn in the Marias River.

In addition to influencing physical and biological characteristics of the mainstem Missouri, the Marias contains substantial resident fish, wildlife and recreational values. Five years after the Marias River was impounded at Tiber Dam for flood control, Posewitz (1962) reported that a substantial cold water fishery was developing in the river below the dam. Gardner and Berg (1982) surveyed the fishery in the 105 km reach of the river from Tiber Dam to the confluence with the Missouri River and reported an excellent mountain whitefish population existed in a 30 km reach below the dam along with a moderate rainbow trout population. For the remaining 95 km reach, sauger was the predominant sport fish, occurring in high numbers. These studies indicate the present and potential fisheries values of the Marias River.

The BLM is the principal land owner along the corridor of a 34 km reach of the Marias River below Tiber Dam. Within this corridor, the BLM controls approximately 7 km of riverfront land. The remainder of the bottomland within the corridor is privately owned. The BLM was concerned with management of its lands adjacent to the river and determining the instream flows necessary for maintenance of a variety of resource values within this area. The Montana Department of Fish, Wildlife and Parks (MDFWP) was also concerned with maintaining fish and wildlife values of the area. Therefore, it was decided that the BLM and MDFWP would cooperate to determine the instream flow requirements for the fishery and waterfowl within this reach.

This study, funded by the BLM and conducted by MDFWP, was initiated on March 1, 1982.

## DESCRIPTION OF THE STUDY AREA

The study area consists of a 34 km reach of the Marias River in northcentral Montana from Tiber Dam near Chester to the Circle Bridge at Highway 223 (Figure 1). The hydrogeology of the Marias Basin has been described thoroughly by Garvin and Botz (1975). The drainage area's geology has been influenced by past glacial activities from both alpine and continental glaciation. Therefore, much of the ground strata is a mass of consolidated gravels, sand, silt and clay. There does not appear to be a great amount or types of geologic formations suitable for an extensive groundwater supply; consequently, the water runoff storage capacity within the ground strata is probably limited.

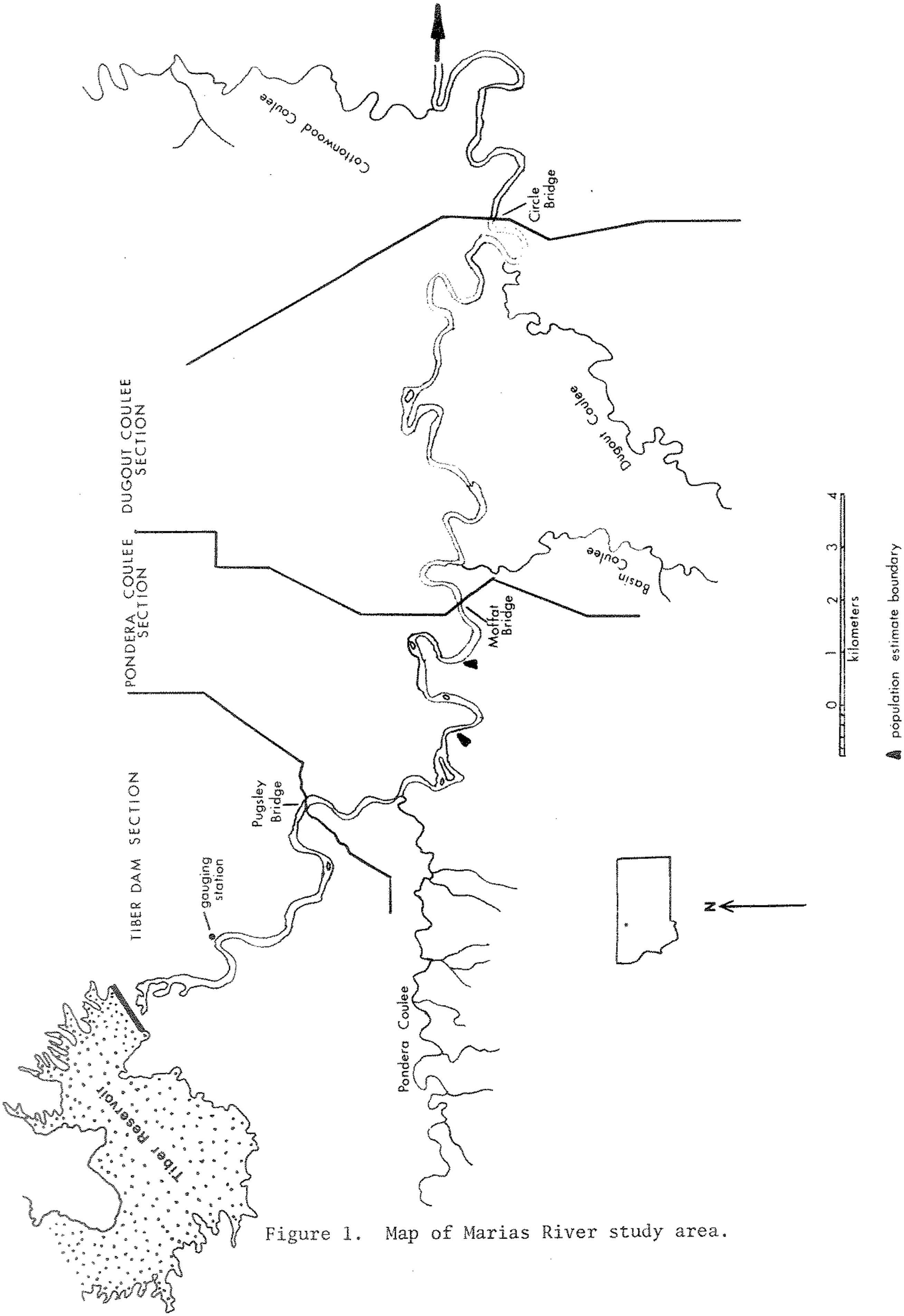


Figure 1. Map of Marias River study area.

At the head of the study reach is Tiber Dam, which impounds a reservoir with a storage capacity of 1,555,898 acre ft (Figure 2). The reservoir was completed in 1956 to provide flood control, irrigation, recreational uses and municipal water supply. The possibility of hydroelectric power generation is currently being considered. Its actual uses, however, have been principally limited to flood control, recreation and municipal water supply.

The Marias River's flow and temperature regime are completely controlled by the operation of the dam. In general, spring runoff in the Marias River below Tiber Dam has been reduced since the dam was constructed, while flows during the fall and winter have been augmented (Missouri River Basin Commission 1978). Stober (1962) reported that the effects of cold water releases from Tiber Dam on the temperature regime of the Marias River were manifested as thermal constancy along with reduced summer water temperatures. He reported these effects were evident at least 38 kilometers below the dam.

Water quality of the Marias River in this reach is similar to the Missouri River at Virgelle, Montana. Conductivity usually ranges from 500-600 micromhos/$cm^2$ and bicarbonate alkalinity ranges from 150-200 mg/l (Garvin and Botz 1975). Suspended sediments carried by the river are greatly reduced because of Tiber Reservoir (Stober 1962). The river meanders through a floodplain ranging from 1-2 km wide, flanked on the sides by steep buttes up to 60 m high. River gradients are gradual and the channel in many places is wide and shallow. The channel bottom throughout the study area is generally comprised of small cobble in the swift current areas. The reach of river below the confluence of Pondera Coulee, an intermittent tributary, has a greater amount of sedimentation within the gravel substrate. Bank vegetation cover is limited because of severe bank erosion. Presently, water use of the Marias River below Tiber Dam is confined to irrigation of approximately 2,104 hectares of small grain and hay-meadow fields. This irrigation requires diversion of approximately 9.25 cubic hectometers (7,500 acre-feet) of water annually (personal communication, Soil Conservation Service).

The study area was divided into three study sections to enable the results to be analyzed along a longitudinal gradient according to physical differences between the sections. The locations and dimensions of each station are presented in Table 1.

The Tiber Dam section is located immediately below the dam and extends 7.9 km downriver to the Pugsley Bridge. Effects of the dam are most obvious in this section. Because water releases from the dam are normally taken from the hypolimnion of the reservoir, water temperatures are cooler and the water is probably enriched by nutrients from the bottom. Wright (1958) observed a similar situation for the Missouri River below Canyon Ferry Dam. The result of this nutrient enrichment of the river is the exceptional aquatic vegetation growth found in the river channel. Immediately below the dam during the summer, large amounts of filamentous green algal mats (mostly Cladophora) form in the river channel and smaller amounts of rooted Potamogeton (pondweed) develop in backwaters and pools. Further down river, substantial amounts of Chara (Stonewort) grow throughout the river channel in large shallow pools in addition to the aquatic vegetation previously mentioned. Smith (1950) described Chara as thriving in clear, hard waters which are characteristic of this study area.

The Pondera Coulee section, located between the Pugsley and Moffat bridges,

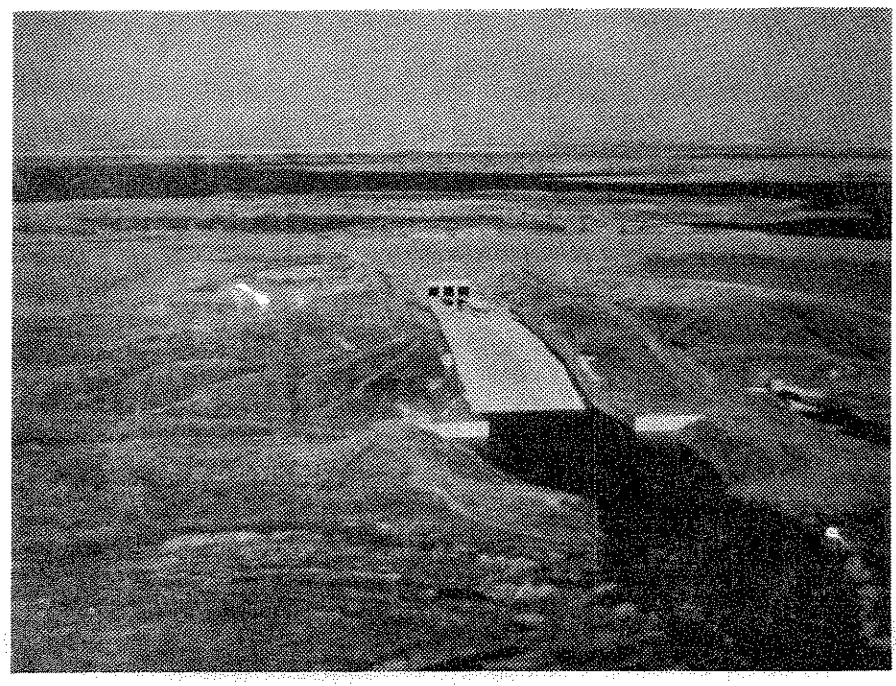

Figure 2. Tiber Dam is a large earth-core dam which entirely regulates the flow of the lower Marias River.

Table 1. Locations and stream gradients of Marias River from base of Tiber Dam to Circle Bridge.

| Study Section | Approximate Location | River km | Elevation meters-msl | Gradient m/km | Gradient ft/mi |
|---|---|---|---|---|---|
| Tiber Dam | Base Tiber Dam T30N R5E Sec. 33 | 0 | 861.0 | | |
| | Pugsley Bridge T29N R5E Sec. 11 | 7.9 | 856.5 | 0.70 | 3.7 |
| Pondera Coulee | Moffat Bridge T29N R6E Sec. 17 | 18.4 | 847.3 | 0.87 | 4.6 |
| Dugout Coulee | Circle Bridge T29N R6E Sec. 24 | 33.7 | 837.3 | 0.66 | 3.5 |

extends 10.5 km. THis section is similar to the Tiber Dam section except the amount of aquatic vegetation is substantially reduced. Pondera Coulee, which enters in the upper third of the section, usually flows heavily with turbid water in the spring resulting from snow melt on the prairies. The effect on the Marias below the confluence of Pondera Coulee is a decline in water clarity and increased sedimentation in the river channel. This environment is noticeably less favorable for growth of aquatic vegetation.

The lowest study section, Dugout Coulee, 15.3 km in length, has a reduced gradient especially in the lower third of the section where increasingly wide meanders are apparent.

# METHODS

## Water Temperature

Thirty-day continuous recording thermographs were used to monitor water temperatures. The recorder box was positioned on the streambank. A thermocouple lead, varying in length from 8-23 m, was extended into the water through flexible plastic sewer pipe.

## Macroinvertebrates

Aquatic macroinvertebrate samples were taken using a rectangular framed 20x45 cm conical kick net sampler with fine mesh (300 micron) pores. The net was positioned on the streambed so the current flowed into it. Macroinvertebrates were washed into the net by a person standing in front of the net kicking into the substrate. All samples were collected in riffle areas comprised of similar assortments of cobbles and gravels. Samples were transferred to jars containing an identifying label and preserved with a solution of 10 percent formaldehyde.

In the laboratory, the samples were washed on a US Series No. 30 screen. Material retained by the screen was transferred to an enamel sorting pan where the organisms were separated from other debris. Macroinvertebrates were identified to the lowest taxon practical using taxonomic keys by Edmondson (1959), Merritt and Cummins (1978), Baumann (1977) and Pennak (1953).

### Young-of-Year Fish and Minnows

Young-of-the-year (YOY) fish and minnows were sampled with a 15.2x1.2 m beach seine with 3.2 mm square mesh. The seine was operated by two persons and worked in as many different habitat types as the current and bottom characteristics allowed. Collected fish were identified, and associated habitat type was recorded. All comparisons between study areas or habitat types for fish sampled by seining were based on catch per unit effort. A mobile electrofishing system was used to sample YOY northern pike and rainbow and brown trout along the channel borders. This system consisted of a hand-held mobile positive electrode, a stationary negative electrode floated beside a small jon-boat and a portable 3,000 watt, 220-volt AC generator. A Coffelt VVP-10 rectifying unit was used to change the alternating current to pulsed direct current. The electrofishing system was carried in a 4.2 m aluminum boat.

### Adult Fish

Adult fish were collected by boom electrofishing in a 4.2 m fiberglass boat powered by a 35 hp outboard motor equipped with a jet propulsion lower unit (Figure 3). Fish captured were measured to the nearest mm in total length and weighed to the nearest 10 g. Sex and spawning condition (gravid, ripe or spawned) were recorded for fish captured during their spawning season. Scales of sport fish were taken from the area between the dorsal fin and lateral line. Mountain whitefish were marked with a fin punch through the lobe of the caudal fin during mark/recapture population estimates.

## Fish Population Estimates

Population estimates for mountain whitefish in the Pondera Coulee section were made using the Pete sen mark/recapture formula as modified by Chapman (1951):

$$N = \frac{(M+1)\ (C+1)}{(R+1)} - 1$$

Where: N= population estimate
M= number of marked fish
C= number of fish in the recapture sample
R= number of marked fish in the recapture sample

Multiple marking and recapture runs were needed to collect an adequate sample size. A minimum of two weeks was allowed before recapture runs were made.

Standing crops, age structures, mortality rates and confidence limits were computed using methods summarized by Vincent (1971 and 1974).

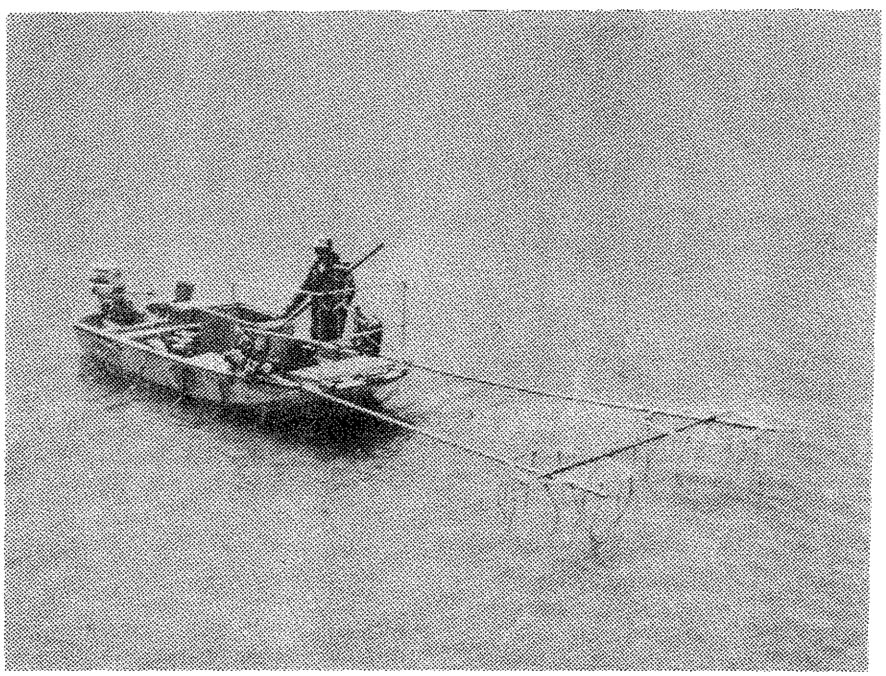

Figure 3. Electrofishing was done from a 4.2 m fiberglass boat.

## Age and Growth Analysis

Impressions of the scales were made on cellulose acetate slides and examined on a scale projector at magnifications of 30X and 70X. Annuli measurements for back calculations of age and growth were made from the center of the focus of each scale along the central radius to the anterior edge of the scale. Calculations of length at previous annuli for fish 0-10 years old were made at the Montana State University computer center using a modified version of FIRE 1, an age and growth analysis program. This program employs the Dahl Lea, Rosa Lea and corrected Rosa Lea linear back calculation equations and the Monastyrsky logarithmic equation (Tesch 1971). FIRE 1 was also used to summarize empirical data concerning length, weight, percent composition and condition factors of assigned age groups. It also calculated length-weight and length-scale radii relationships. Condition factors ($K_{TL}$) were calculated by the formula:

$$K_{TL} = \frac{W x 10^5}{L^3}$$

Age and growth analyses were conducted on mountain whitefish, rainbow and brown trout.

## Mountain Whitefish Food Habits

Food habits were determined for mountain whitefish. The entire stomach was extracted and stored in a labeled plastic package containing a 10% solution of formaldehyde. Stomach contents were sorted, identified and tallied. To facilitate a measure of comparison of general importance of a food item, percent of occurrence, percent of total number and average volumetric rank were calculated. The ranking scheme was an approximate visual assessment of the food items based on their volumetric appearance. A volumetric rank of 5 indicated a food item which ranked first in the sample in terms of volume content. This statistic enabled the food habits analyses to incorporate volume, an essential measure of a food item's importance.

## Instream Flow Assessment

To evaluate the minimum instream flow necessary for maintenance of important fish habitat areas in the Marias River, the wetted perimeter (WETP) hydraulic simulation computer program was employed. This program is described in detail by Nelson (1980). Using standard surveying techniques, water surface elevations at three discharges were measured with a level and stadia rod (Figure 4). Channel profiles were measured at low flows using a range finder and fathometer in conjunction with the level and stadia rod.

Methods used to evaluate instream flow requirements for Canada goose nesting and the high flow period are described in the results section of this report. Since the methods are an integral part of the result for each of these parameters, the methods and results are described together rather than in separate sections of the report.

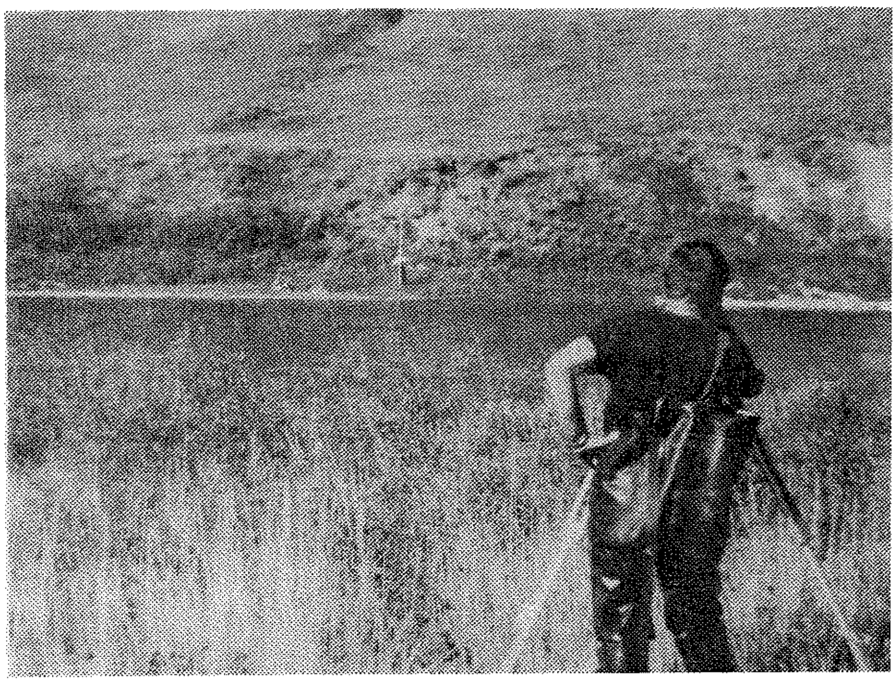

Figure 4. Using standard surveying techniques, the river channel water elevations were measured at a low, mid and high instream flow. This information was then used by the computer hydraulic simulation model to predict the channel conditions at various flows.

## RESULTS

### Water Temperatures and Flow Patterns

Water temperatures of the Marias River were monitored during 1982 using continuous recording thermographs located in the Tiber Dam and Dugout Coulee sections. The Tiber Dam thermograph, located 5 km below Tiber Dam, was operative from July 20 through November 20, while the Dugout Coulee thermograph, located 33.7 km below Tiber Dam, was operative from March 30 through November 10. Five day averages of maximum temperatures for each station are shown in Figure 5.

The maximum temperature recorded during 1982 at both stations was 19.4 C (67 F). At the Tiber Dam station, this temperature was reached on September 25. The maximum temperature at the Dugout Coulee station was recorded on July 29 and 30. The highest maximum temperature at the Tiber Dam station was 19.4 C (67 F) and occurred on September 25, 1982. Peak water temperatures occurring this late in the season are related to the operation of Tiber Dam. From September 24 to October 6, water releases were changed from the low level coool hypolimnion to the upper level warmer epilimnion.

The relatively cool temperatures recorded during this study period were due to release of cold water from the hypolimnion of Tiber Reservoir. The temperatures recorded at both stations were suitable for good growth and survival of cold water fish species, such as trout and mountain whitefish.

The normal pattern for water releases from Tiber Dam during late fall to early spring is to discharge appropriate amounts of water to maintain a reservoir pool elevation of 907.1 m (2,976 ft - bottom of active conservation pool) yet generally maintaining water releases at a minimum of 250 cfs (7.08 $m^3/s$). Since the reservoir's chief function to date has been for flood control use, active storage begins during the major run off period and is gradually released throughout summer. Summer water releases are generally targeted to being three times the winter flow in order to evacuate the stored water (Bureau of Reclamation personal communication - Appendix Table 1).

The pattern of flow releases from Tiber Dam for water year 1982 was not normal (Figure 6). For several years immediately prior to this study, the water level of Tiber Reservoir was held below normal operating water elevations while extensive repairs were made on the dam. Beginning the winter of 1981-82, the Bureau of Reclamation began filling the reservoir which contributed to the decreased flow releases from Tiber. The flow releases from the dam were substantially less than the flow into the reservoir from February 15 to May 20, 1982. The average flows entering the reservoir during the months of March, April and May were 400 cfs (11.33 $m^3$/sec), 940 cfs (26.62 $m^3$/sec) and 2,291 cfs (64.89 $m^3$/sec), respectively, compared to the average monthly flow releases from the dam, during this same period, of 216 cfs (6.12 $m^3$/sec), 241 cfs (6.83 $m^3$/sec) and 964 cfs (24.19 $m^3$/sec), respectively. The peak flow of 3,300 cfs (93.68 $m^3$/sec) released from Tiber was also less than the peak influent flow of 5,140 cfs (145.58 $m^3$/sec). Flow releases from Tiber after August 1 were essentially similar to inflow into the reservoir.

The flow releases from November 1, 1981 to May 20, 1982 and from October 10, 1982 through the winter of 1982-83 ranged between a 70 and 100 percentile flow, indicating these were well below normal base flows.

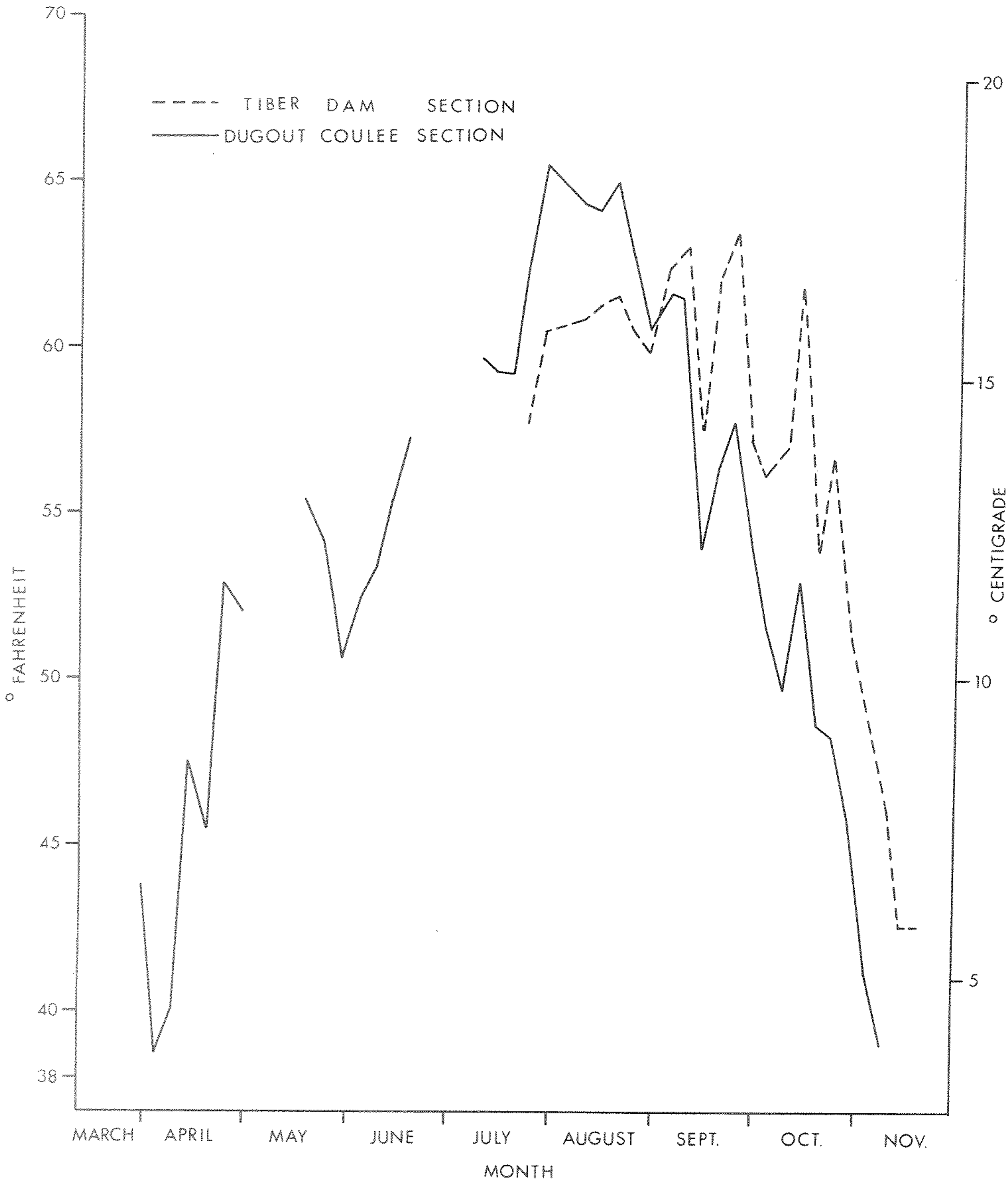


Figure 5. Five day average maximum water temperatures of the Marias River in 1982 in the Tiber Dam (5 km below dam) and Dugout Coulee (33.7 km below dam) sections.

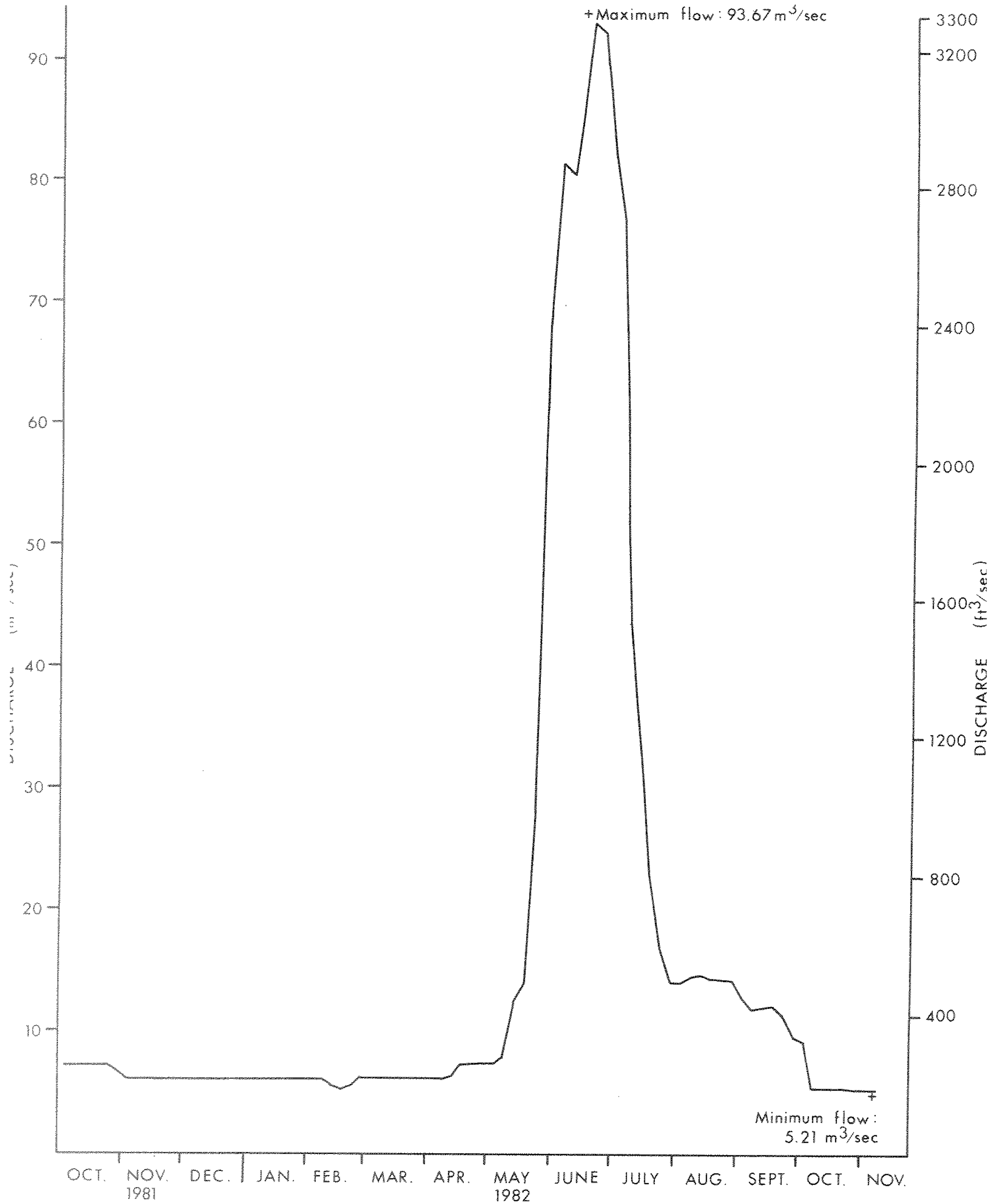


Figure 6. Marias River hydrograph recorded at USGS gaging station 2 km below Tiber Dam, 1981-82.

## Macroinvertebrates

Aquatic macroinvertebrate sampling was conducted at four stations on the Marias River from early November 1981 through mid-July 1982. THe stations were located at the Tiber Dam area, Pugsley, Moffat and Circle bridges. All stations were sampled four times, once each during fall, winter, spring and summer.

A total of 8,848 macroinvertebrates, representing 11 orders and at least 39 genera, was collected during the study. The number of macroinvertebrates collected per kick sample ranged from 61 to 1,455 (Appendix Tables 4-7). Ephemeroptera, Trichoptera, Diptera and Plecoptera comprised an average of 56, 22, 10 and 9 % of the macroinvertebrates collected, respectively (Table 2). The average number of subordinal taxa ranged from 9.4 at the uppermost station, Tiber Dam, and then increased downstream to an average of 22.1 at the lowermost station, Circle Bridge.

Table 2. Percent composition (by order) and average number of taxa (in parentheses) of the aquatic macroinvertebrate communities in the Marias River, November through July 1981-82.

| | Stations | | | |
|---|---|---|---|---|
| Order | Tiber | Pugsley | Moffat | Circle |
| Plecoptera | 4.5 (0.8) | 12.3 (1.5) | 12.8 (2.2) | 5.6 (2.8) |
| Ephemeroptera | 74.8 (2.5) | 61.0 (4.5) | 51.6 (5) | 36.4 (5.5) |
| Trichoptera | 7.0 (2.5) | 22.6 (4.2) | 30.8 (4.5) | 29.0 (6.8) |
| Diptera | 12.2 (1.8) | 3.5 (1.2) | 2.9 (1.5) | 19.5 (1.8) |
| Others | 1.5 (1.8) | 0.6 (2.0) | 1.9 (2.8) | 9.9 (5.2) |
| Total average No. of subordinal taxa | 9.4 | 13.4 | 16.0 | 22.1 |

Table 3 describes the distribution and diversity of macroinvertebrates collected at each sampling site.

Table 3. Longitudinal distribution of aquatic macroinvertebrates in the Marias River, November through July 1981 - 1982.

| Taxa | Tiber Dam | Pugsley Bridge | Moffat Bridge | Circle Bridge |
|---|---|---|---|---|
| Plecoptera | | | | |
| Capniidae | | | | * |
| *Pteronarcys* | | | * | |
| *Isoperla* | * | * | * | * |
| *Isogenoides* | | * | * | * |
| *Claassenia* | | | * | * |
| Chloroperlidae | | * | * | * |
| Ephemeroptera | | | | |
| *Baetis* | * | * | * | * |
| *Heptagenia* | | * | * | * |
| *Rhithrogena* | * | * | * | * |
| *Stenonema* | | * | | * |
| *Ephemerella* | * | * | * | * |
| *Tricorythodes* | * | * | * | * |
| *Choroterpes* | | * | | * |
| *Leptophlebia* | | * | | * |
| *Ephemera* | | | | * |
| *Ameletus* | | | * 1/ | |
| *Traverella* | | | * 1/ | |
| Trichoptera | | | | |
| *Cheumatopsyche* | * | * | * | * |
| *Hydropsyche* | * | * | * | * |
| *Glossosoma* | * | * | * | * |
| *Agraylea* | * | * | | * |
| *Brachycentrus* | | * | * | * |
| *Lepidostoma* | | | | * |
| *Helicopsyche* | | | * | * |
| *Leptocerus* | | | | * |
| *Oecetis* | * | * | * | * |
| Diptera | | | | |
| *Tipula* | * | * | * | |
| *Simulium* | * | | * | * |
| Chironomidae | * | * | * | * |
| *Chrysops* | * | | | |
| Odonata | | | | |
| *Ophiogomphus* | | | * | * |
| Heteroptera | | | | |
| Corixidae | | | * | |

Table 3 continued.

| | Stations | | | |
|---|---|---|---|---|
| Taxa | Tiber Dam | Pugsley Bridge | Moffat Bridge | Circle Bridge |
| Coleoptera | | | | |
| Elmidae | | * | * | |
| Oligochaeta | * | * | * | * |
| Gastropoda | | | | |
| *Physa* | * | * | * | * |
| *Gyraulus* | * | | * | * |
| *Ferrissia* | | | | * |
| Pelecypoda | | | | * |
| Amphipoda | | | | |
| *Hyalella* | * | * | * | * |

1/ Collected from a mountain whitefish stomach sample.

## Plecoptera (Stoneflies)

The numerical percentage of stoneflies, averaging all sampling dates, ranged from 4.5% at Tiber Dam to 12.8% at Moffat Bridge. Average numbers of subordinal taxa ranged from 0.8 at Tiber Dam to 2.8 at the lowest station, Circle Bridge.

A total of six subordinal taxa was collected in the study area, with the greatest diversity exhibited in the lower two stations (Table 3). *Isoperla*, the most widely distributed genus, was common at all sites. *Isogenoides* was common only at the lower three stations.

## Ephemeroptera (Mayflies)

Mayflies were the predominant macroinvertebrate taxa sampled in the study area. Numerically, they constituted the greatest average percentages of the macroinvertebrates sampled, ranging from 36% at the lowermost station to 75% at Tiber Dam. Their diversity was high with 10 genera sampled in the study area. The average number of genera collected per sampling date ranged from a low of 2.5 at Tiber Dam to 5.5 at Circle Bridge.

*Baetis*, *Rhithrogena*, *Ephemerella* and *Tricorythodes* were collected at all stations. Burrowing and sediment tolerant mayflies were sampled only at the lower three stations. Because of their habits, burrowing and sediment tolerant mayflies were difficult to sample, and their numerical importance in the study area was probably underestimated.

## Trichoptera (Caddisflies)

Caddisflies were also an important macroinvertebrate order, particularly at the lower three stations. Overall, they were the second most common order in the study area, in terms of average numbers of organisms sampled and diversity. The numerical percentage of this order, averaging all sampling dates, ranged from 7% at Tiber Dam to 31% at Moffat Bridge. The average number of subordinal taxa ranged from 2.5 at Tiber Dam to 6.8 at Circle Bridge. Nine genera were sampled in the study area. *Cheumatopsyche*, *Hydropsyche*, *Glossosoma* and *Oecetis* were distributed throughout the study area while *Lepidostoma*, *Helicopsyche* and *Leptocerus* were confined to the lower end of the study area.

## Diptera (True flies)

The numerical percentage of dipterans, averaging all sampling dates, ranged 2.9% at Moffat Bridge to 19.5% at Circle Bridge. Dipterans were generally low in number and variety at all stations. *Tipula*, *Simulium* and Chironomidae were the three most widely distributed taxa. However, Chironomidae was numerically, by far, the predominant taxa in most of the samples (Appendix Tables 4-7).

### Discussion

The structure of the aquatic macroinvertebrate community at Tiber Dam was relatively simple compared to stations down river. Community diversity and balance increased progressively in a down river direction. A similar situation was observed in the Missouri River below Morony Dam (Berg 1981). Since the reservoir above a dam constitutes a barrier to recolonization, diversity of the macroinvertebrate community is usually reduced in the stream reach immediately below the dam. Recolonization by drift is an important mechanism whereby a macroinvertebrate community maintains its diversity (Hynes 1970). In the study area, only the common macroinvertebrates sampled throughout the river were found at the Tiber Dam station. Less common macroinvertebrates were unable to recolonize at this station because of the barrier created by Tiber Reservoir. A simplified table depicting the common members in the macroinvertebrate communities at the four stations in the study area is given in Table 4.

Posewitz (1962) also studied the aquatic macroinvertebrate communities of the Marias within the present study area. His findings were almost identical to those in the present study. The only significant difference reported during this study was the presence of plecopterans at the Tiber Dam station. Berg (1981) studied the macroinvertebrate community near the mouth of the Marias River. This community was somewhat different than the communities in this study. The basic difference was the addition of more silt-tolerant forms. Ephemeropterans such as Baetisca, Hexagenia, Ephron, Heptagenia and the large plecopteran Acroneuria were not sampled in the present study area, but were sampled 95 km down river by Berg. Posewitz (1962) also reported a community shift toward more depositional habitat forms in the lower reaches of the Marias.

Composition in terms of numbers, balance and diversity, indicate healthy macroinvertebrate communities are presently found in the study area.

Table 4. A simplified assemblage of the most common macroinvertebrates sampled at four stations on the Marias River, November through July 1981-82. 1/

| Order | Tiber Dam | Pugsley Bridge | Moffat Bridge | Circle Bridge |
|---|---|---|---|---|
| Ephemeroptera | *Baetis* | *Baetis*<br>*Rhithrogena* | *Baetis*<br>*Rhithrogena* | *Baetis*<br>*Rhithrogena*<br>*Stenonema* |
| | *Ephemerella* | *Ephemerella* | *Ephemerella* | *Ephemerella* |
| Plecoptera | | | *Isogenoides* | *Isogenoides* |
| | *Isoperla* | *Isoperla* | *Isoperla* | *Isoperla* |
| Trichoptera | | *Cheumatopsyche* | *Cheumatopsyche* | *Cheumatopsyche* |
| | *Hydropsyche*<br>*Glossosoma* | *Hydropsyche*<br>*Glossosoma*<br>*Oecetis* | *Hydropsyche* | *Hydropsyche*<br>*Brachycentrus* |
| Diptera | Chironomidae | Chrironomidae | Chironomidae | Chironomidae |
| Others | | | Oligochaeta | Oligochaeta |

1/ For this study a common macroinvertebrate must have occurred in samples on two of the four sampling dates and averaged five or more organisms per sampling date.

## RESULTS - FISH POPULATIONS

### Species Distribution

Sampling of the fish fauna was accomplished throughout all three sections of the study area from March 25 through November 12, 1982. A total of 9,579 fish, representing 29 species, was sampled during the study (Table 5). Of the twenty-nine species, three were considered to be abundant, twelve species were classified as common, and seven were rare. Four were found in the study area only during their spawning season and were probably migrants from the Missouri River. Three of the species listed have been known to occur in this section, but were not sampled during this study. This species list is similar to that reported by Gardner and Berg (1982), who surveyed the fish fauna throughout the entire length of the Marias River below Tiber Dam. The only species not sampled in this study, which was reported for the 1982 survey study, was the mountain sucker. However, this species was collected only in the lower Marias near the confluence with the Teton River.

### Resident Fish Populations

#### Mountain Whitefish

Mountain whitefish were numerically the most abundant fish sampled throughout the study area. The whitefish had an overall average length of 359 mm and weight of 429 g (Figure 7). There was a decrease in average size of whitefish in a down river direction from Tiber Dam, but numbers appeared to increase (Tables 6, 7 and 8).

##### Population Estimates

The mountain whitefish population was estimated in a 4.5 km reach of the Pondera Coulee section (Figure 1). This reach was chosen for the estimate because it was located in the middle of the study area and contained a good variety of habitats. Four marking and four recapture electrofishing runs were required to obtain an adequate sample size. An attempt was made to obtain spring and late summer estimates but only the spring estimate was valid. The late summer estimate indicated an unusually large number of fish in age classes IV and older were present in the study section. This may have been due to a major movement of older fish into the study section to forage or spawn in the area. This movement would violate basic assumptions essential for a legitimate population estimate. Therefore, the late summer estimate was considered invalid. The estimates of whitefish for age classes II and older are presented in Table 9.

##### Age and Growth

In 1982, 490 mountain whitefish sampled on the Marias River were assigned ages ranging from 0-10 years (Table 10). Mean lengths, weights and condition factors of each year class indicate conditions in the Marias River are favorable for growth of mountain whitefish. Calculated lengths of mountain whitefish at annuli 1 through 10 are given in Table 11. The growth rate of whitefish in the Marias River is generally superior to growth rates in other Montana rivers (Table 12).

Table 5. Fish species occurring in the Marias River between Tiber Dam and 33.6 km down river.

| Species | Abundance 1/ |
|---|---|
| Shovelnose sturgeon | 2/ |
| Paddlefish | 3/ |
| Goldeye | C |
| Mountain whitefish | A |
| Rainbow trout | C |
| Brown trout | C |
| Brook trout | R |
| Northern pike | C |
| Carp | C |
| Flathead chub | C |
| Lake chub | R |
| Emerald shiner | R |
| Western silvery minnow | R |
| Fathead minnow | R |
| Longnose dace | A |
| River carpsucker | C |
| Blue sucker | 2/ |
| Smallmouth buffalo | 2/ |
| Bigmouth buffalo | 2/ |
| Shorthead redhorse | C |
| Longnose sucker | A |
| White sucker | C |
| Channel catfish | 3/ |
| Burbot | R |
| Yellow perch | C |
| Sauger | C |
| Walleye | C |
| Freshwater drum | 3/ |
| Mottled sculpin | R |

1/ R=rare in numbers; sampled <50 specimens,
C=common in numbers; sampled 50-300 specimens,
A=abundant numbers; sampled >300 specimens.

2/ Occurs in study area only as a migrant during spawning season.

3/ Not sampled during this study but has been reported to be found in the study area.

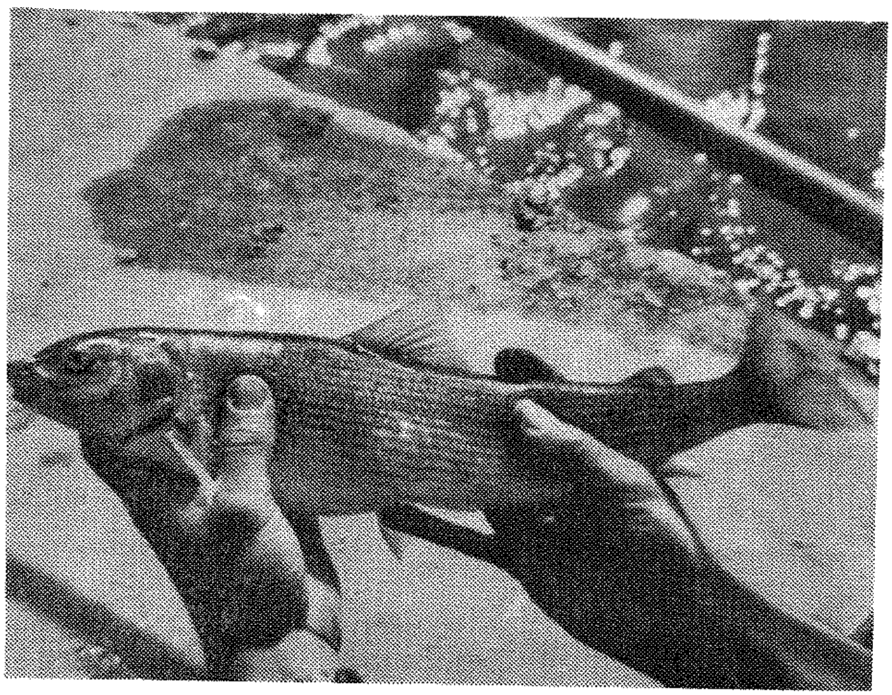

Figure 7. Mountain whitefish were the most numerous species sampled in the study area, and they exhibited excellent growth rates.

Table 6. Catch statistics of resident fish sampled by electrofishing in the Tiber Dam section of the Marias River during 1982.

| Species | Number Sampled | Average Length (mm) | Length Range (mm) | Average Weight (gm) | Weight Range (gm) | Catch Per Unit Effort |
|---|---|---|---|---|---|---|
| Goldeye | 13 | 1/ | | | | <1 |
| Mountain whitefish | 401 | 381 | 146 - 498 | 507 | 40 - 1220 | 20.4 |
| Rainbow trout | 57 | 333 | 104 - 550 | 549 | 10 - 1450 | 2.4 |
| Brown trout | [illegible] | 431 | 370 - 512 | 795 | 410 - 1370 | <1 |
| Northern pike | 26 | 684 | 560 -1200 | 2/ | 950 - 4000+ | 1.2 |
| Carp | 79 | 474 | 384 - 563 | 1312 | 770 - 2150 | 5.4 |
| River carpsucker | 30 | 440 | 390 - 500 | 1089 | 650 - 1520 | 1.8 |
| Shorthead redhorse | 35 | 443 | 373 - 491 | 950 | 580 - 1320 | 2.4 |
| Longnose sucker | 97 | 443 | 275 - 520 | 953 | 280 - 1500 | 6.0 |
| White sucker | 63 | 390 | 119 - 480 | 805 | 20 - 1500 | 4.2 |
| Burbot | 24 | 431 | 270 - 750 | 569 | 120 - 2350 | 1.2 |
| Sauger | 29 | 395 | 313 - 526 | 467 | 210 - 1140 | 1.2 |
| Walleye | 34 | 363 | 204 - 522 | 427 | 60 - 980 | 1.8 |

1/ Fish not measured.

2/ Not all fish were weighed.

Table 7. Catch statistics of resident fish sampled by electrofishing in the Pondera Coulee section of the Marias River during 1982.

| Species | Number Sampled | Average Length (mm) | Length Range (mm) | Average Weight (gm) | Weight Range (gm) | Catch Per Unit Effort |
|---|---|---|---|---|---|---|
| Goldeye | 17 | 327 | 306 - 345 | 286 | 240 - 360 | 1.2 |
| Mountain whitefish | 581 | 352 | 146 - 508 | 405 | 30 - 1310 | 29.4 |
| Rainbow trout | 87 | 308 | 102 - 549 | 369 | 10 - 1520 | 4.2 |
| Brown trout | 21 | 394 | 141 - 750 | 728 | 20 - 3440 | 1.2 |
| Brook trout | 1 | 297 | - | 300 | - | <1 |
| Northern pike | 4 | 560 | 309 - 691 | 1315 | 170 - 2050 | <1 |
| Carp | 67 | 487 | 404 - 640 | 1543 | 810 - 3440 | 4.2 |
| River carpsucker | 4 | 483 | 408 - 504 | 1262 | 1000 - 2020 | <1 |
| Shorthead redhorse | 42 | 437 | 282 - 491 | 941 | 220 - 1380 | 2.4 |
| Longnose sucker | 73 | 428 | 155 - 507 | 840 | 40 - 1450 | 4.8 |
| White sucker | 20 | 336 | 142 - 445 | 662 | 30 - 1220 | 1.2 |
| Burbot | 8 | 541 | 450 - 820 | 1018 | 490 - 3650 | <1 |
| Sauger | 13 | 453 | 364 - 563 | 789 | 330 - 1450 | <1 |
| Walleye | 6 | 419 | 302 - 580 | 763 | 160 - 1960 | <1 |

Table 8. Catch statistics of resident fish sampled by electrofishing in the Dugout Coulee section of the Marias River during 1982.

| Species | Number Sampled | Average Length (mm) | Length Range (mm) | Average Weight (gm) | Weight Range (gm) | Catch Per Unit Effort |
|---|---|---|---|---|---|---|
| Goldeye | 70 | 328 | 298 - 360 | 277 | 200 - 360 | 3.6 |
| Mountain whitefish | 792 | 343 | 143 - 498 | 376 | 30 - 1460 | 34.8 |
| Rainbow trout | 47 | 292 | 127 - 462 | 277 | 20 - 810 | 1.8 |
| Brown trout | 19 | 453 | 308 - 547 | 914 | 240 - 1300 | <1 |
| Northern pike | 17 | 694 | 495 - 978 | 1/ | 650 - 4000+ | <1 |
| Carp | 96 | 463 | 384 - 523 | 1324 | 880 - 2130 | 4.8 |
| River carpsucker | 28 | 465 | 411 - 545 | 1379 | 860 - 2330 | 1.2 |
| Shorthead redhorse | 106 | 435 | 322 - 499 | 860 | 340 - 1500 | 5.4 |
| Longnose sucker | 186 | 423 | 176 - 500 | 796 | 60 - 1220 | 9.6 |
| White sucker | 55 | 379 | 231 - 452 | 674 | 150 - 1160 | 3.0 |
| Burbot | 4 | 465 | 355 - 540 | 572 | 280 - 790 | <1 |
| Sauger | 57 | 368 | 261 - 550 | 413 | 130 - 1300 | 2.4 |
| Walleye | 25 | 353 | 248 - 435 | 406 | 130 - 700 | 1.2 |

1/ Not all fish were weighed.

Table 9. Estimated mountain whitefish populations and age structure in the Pondera Coulee section of the Marias River during the early spring of 1982.

| | | | Estimated Number | | Estimated Weight (kg) | |
|---|---|---|---|---|---|---|
| Age Class | Average Length (mm) | Average Weight (g) | For 4.5 km Section | For 300 m | For 4.5 km Section | For 300 m |
| II | 262 | 150 | 2,362 (±1200)[1/] | 157 | 349.4 (±177.8) | 23.3 |
| III | 315 | 259 | 1,100 (± 284) | 73 | 284.2 (±71.2) | 18.9 |
| IV | 363 | 381 | 754 (±256) | 50 | 288.7 (±96.6) | 19.2 |
| V+ | 406 | 513 | 854 (±114) | 57 | 437.3 (±60.8) | 29.1 |

1/ Confidence intervals for estimated numbers and biomass expressed at the 80 % level shown in parentheses.

Table 10. Age-frequency of mountain whitefish sampled from the Marias River during 1982 with mean length, weight and condition factor ($K_{TL}$) of each age class.

| Age | No. of Fish | Mean Length (mm) | Mean Weight (g) | Mean $K_{TL}$ |
|---|---|---|---|---|
| 1 | 53 | 217 | 116 | 1.13 |
| 2 | 73 | 291 | 242 | 0.97 |
| 3 | 114 | 344 | 383 | 0.93 |
| 4 | 58 | 389 | 564 | 0.96 |
| 5 | 57 | 421 | 766 | 1.02 |
| 6 | 61 | 444 | 892 | 1.01 |
| 7 | 40 | 457 | 978 | 1.01 |
| 8 | 20 | 475 | 1077 | 1.01 |
| 9 | 10 | 487 | 1147 | 0.99 |
| 10 | 4 | 488 | 1142 | 0.97 |

Table 11. Calculated length at the end of each year of life and average growth of mountain whitefish sampled from the Marias River in 1982 (Monastyrsky logarithmic method).*

| Age Group | No. Fish | Calculated total length (mm) at end of year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 53 | 125 | | | | | | | | | |
| 2 | 73 | 127 | 247 | | | | | | | | |
| 3 | 114 | 127 | 244 | 310 | | | | | | | |
| 4 | 58 | 124 | 250 | 332 | 365 | | | | | | |
| 5 | 57 | 112 | 246 | 332 | 372 | 399 | | | | | |
| 6 | 61 | 117 | 223 | 302 | 362 | 397 | 424 | | | | |
| 7 | 40 | 117 | 216 | 288 | 348 | 387 | 416 | 440 | | | |
| 8 | 20 | 115 | 201 | 284 | 349 | 391 | 420 | 440 | 460 | | |
| 9 | 10 | 116 | 199 | 281 | 336 | 383 | 415 | 437 | 458 | 473 | |
| 10 | 4 | 99 | 157 | 235 | 298 | 346 | 387 | 411 | 435 | [illegible] | 471 |
| Grand Ave. Calculated Length | | 122 | 236 | 310 | 360 | 393 | 419 | 438 | 457 | 468 | 471 |
| Grand Ave. Length Increment | | 122 | 114 | 74 | 50 | 33 | 26 | 19 | 19 | 11 | 3 |
| No. Fish | | 490 | 436 | 364 | 250 | 192 | 135 | 74 | 34 | 14 | 4 |

*The regression of total length on anterior scale radius was curvilinear (r = 0.948)

Table 12. Calculated growth of mountain whitefish sampled from the Marias River in 1982 compared to calculated growth in other major Montana rivers.*

| River | No. Fish | Average calculated total length (mm) at end of year 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Marias (1982) (Present study) | 490 | 122 | 236 | 310 | 360 | 393 | 419 | 438 | 457 | 468 | 471 |
| Big Hole (1959) | 122 | 79 | 163 | 236 | 274 | 340 | 409 | | | | |
| Still-water (1948) | 193 | 104 | 201 | 264 | 310 | 376 | 419 | 411 | | | |
| Madison (1950) | 256 | 109 | 239 | 307 | 343 | 373 | 373 | | | | |

*Peters 1964

Food Habits

Food habits analyses were completed for 82 mountain whitefish collected by electrofishing in the Pondera Coulee study section during spring, summer and fall 1982. The sampled fish ranged in length between 145 and 500 mm. The mountian whitefish diet was comprised of a wide variety of aquatic macroinvertebrates (Table 13). A total of 3,513 organisms representing 24 subordinal taxa were identified from the stomach contents. For most of the stomach samples, unidentifiable food items dominated the contents, averaging a volumetric rank of 4.33 for all seasons.

The order Ephemeroptera was the most important insect group in the diet of the mountain whitefish during the seasons sampled. Their average volumetric rank, combining all seasons, was 3.41. Baetis, Ephemerella and Tricorythodes were the most common ephemeropterans consistently found in the whitefish diets.

The orders Plecoptera and Trichoptera were also important items in the diet of the mountain whitefish, constituting average volumetric ranks of 1.12 and 1.48, respectively. Isoperla and Hydropsychidae were the common subordinal taxa representing these two orders. Representing the order Diptera, the common subordinal taxon was Chironomidae, a small organism. Although this dipteran only comprised an average volumetric rank of 0.60, it was usually the most numerous organism in the whitefish diet.

Table 14 describes the seasonal mountain whitefish diet. Food organisms common in the whitefish diets were common in the benthic community as a whole, indicating little apparent selectivity. Terrestrial insects and adult insects of aquatic origin comprised a small portion of the identifiable contents in mountain whitefish stomach samples. The importance of adult insects in the whitefish diet may have been underestimated because their body tissue is easily digested and becomes unidentifiable. Unidentifiable stomach contents constituted the greatest amount of food in the whitefish diet, with an average volumetric rank of 4.33. Adult insects of aquatic origin probably comprised a large portion of the unidentifiable contents. Mountain whitefish were observed feeding heavily on adult aquatic insects on the water surface on numerous occasions from early summer to mid-fall.

The food items comprising the chief portion of the mountain whitefish diet are aquatic insects produced in riffle areas of the river channel. To maintain the food base for whitefish and other species, adequate wetted perimeter should be maintained in these important food producing areas.

## Trout

Trout were not endemic to the lower Marias River. However, after construction of Tiber Dam, resulting cold-water releases altered the aquatic environment, favoring cold-water fish species.

Rainbow and brown trout were the most common trout sampled in the study area, although in relatively low numbers. Catch rates for trout were highest in the Pondera Coulee section (Tables 6-8). A total of 191 age I and older rainbow trout sampled in the study area averaged 311 mm in length and 398 g in weight. Forty-nine age I and older brown trout averaged 426 mm in length and 812 g in weight.

Table 13. Percentages of occurrences (O), average total numbers (N) and average volumetric rank values (V) of food items found in the diets of mountain whitefish in the Marias River, 1982.

| | Spring | | | Summer | | | Fall | | |
|---|---|---|---|---|---|---|---|---|---|
| | %O | %N | V | %O | %N | V | %O | %N | V |
| Ephemeroptera | | | | | | | | | |
| *Baetis* | 83 | 21 | 2.4 | 72 | 12 | 0.72 | 54 | 18 | 0.82 |
| *Heptagenia* | | | | 4 | tr | - | 4 | tr | - |
| *Rhithrogena* | 14 | tr | - | 12 | 2 | - | | | |
| *Traverella* | | | | | | | 7 | 2 | - |
| *Ephemerella* | 52 | 11 | 1.8 | 96 | 44 | 4.0 | | | |
| *Tricorythodes* | 7 | tr | - | | | | 57 | 16 | 0.50 |
| *Ameletus* | 7 | tr | - | | | | | | |
| Adult mayfly | | | | | | | 4 | tr | - |
| Plecoptera | | | | | | | | | |
| Capniidae | | | | 4 | tr | - | | | |
| *Isoperla* | 62 | 10 | 1.14 | 64 | 13 | 1.68 | 18 | tr | - |
| *Isogenoides* | 14 | tr | 0.55 | | | | | | |
| Trichoptera | | | | | | | | | |
| Hydropsychidae | 76 | 14 | 1.72 | 64 | 15 | 1.72 | 43 | 8 | 1.0 |
| *Glossosoma* | 10 | 2 | - | | | | | | |
| *Agraylea* | | | | 8 | tr | - | | | |
| *Brachycentrus* | 10 | tr | - | 8 | tr | - | 11 | tr | - |
| *Oecetis* | 37 | 3 | - | | | | | | |
| *Leptocerus* | 7 | tr | - | 4 | tr | - | | | |
| *Lepidostoma* | | | | | | | 7 | tr | - |
| Diptera | | | | | | | | | |
| *Tipula* | 28 | 2 | 0.93 | | | | | | |
| *Simulium* | | | | | | | 43 | 18 | 0.46 |
| Chironomidae | 93 | 33 | 0.66 | 44 | 7 | 0.28 | 79 | 31 | 0.54 |
| Others | | | | | | | | | |
| Corixidae | | | | 32 | 2 | - | [illegible] | 2 | - |
| *Physa* | 10 | tr | - | | | | 11 | tr | - |
| *Hyalella* | 7 | tr | - | | | | 4 | tr | - |
| Terrestrial Insects | | | | 4 | tr | - | 4 | tr | - |
| Unidentifiable Contents | | | 4.17 | | | 4.40 | | | 4.43 |
| Number of Fish Sampled | 29 | | | 25 | | | 28 | | |
| Total Number of Organisms | 1,426 | | | 853 | | | 1,234 | | |

Table 14. Common food organisms found in mountain whitefish stomachs, Pondera section, 1982.

| Order | Spring | Summer | Fall |
|---|---|---|---|
| Ephemeroptera | Baetis<br>Ephemerella | Baetis<br>Ephemerella | Baetis<br>Tricorythodes |
| Plecoptera | Isoperla | Isoperla | |
| Trichoptera | Hydropsychidae | Hydropsychidae | |
| Diptera | Chironomidae | | Chironomidae |

Age and Growth

In 1982, 176 rainbow trout sampled in the Marias River were assigned ages ranging from 0-6 years (Table 15). Ages 0 and I comprised only 17.6 % of the sample; however, these two age classes were probably under-represented because of the sampling gear's selectivity toward larger fish. Ages II through IV constituted 78.4% of the sample. The mean lengths, weights and condition factors of each year class indicate conditions in the Marias are favorable for rainbow trout growth. Calculated lengths of rainbow trout at annuli 1 through 6 are given in Table 16. The length increment of 167 mm between ages I and II represents an excellent growth rate during this period. The growth rate of rainbow trout in the Marias is superior to most other Montana rivers (Table 17 and Figure 8).

Table 15. Age-frequency of rainbow trout sampled from the Marias River during 1982 with mean length, weight and condition factor ($K_{TL}$) of each age class.

| Age | No. of Fish | % of Sample | Mean Length (mm) | Weight (g) | Mean $K_{TL}$ |
|---|---|---|---|---|---|
| 0 | 2 | 1.1 | - | - | - |
| 1 | 29 | 16.5 | 146 | 39 | 1.04 |
| 2 | 70 | 39.8 | 298 | 259 | 0.95 |
| 3 | 32 | 18.2 | 376 | 505 | 0.93 |
| 4 | 36 | 20.4 | 438 | 765 | 0.90 |
| 5 | 6 | 3.4 | 486 | 1012 | 0.95 |
| 6 | 1 | 0.6 | - | - | - |

Table 16. Calculated length at end of each year of life and average growth of rainbow trout sampled from the Marias River in 1982 (Monastyrsky logarithmic method).*

| Age Group | Fish | Calculated total length (mm) at end of Year 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1 | 29 | 122 | | | | | |
| 2 | 70 | 109 | 277 | | | | |
| 3 | 32 | 115 | 267 | 355 | | | |
| 4 | 36 | 112 | 296 | 377 | 424 | | |
| 5 | 6 | 92 | 273 | 347 | 416 | | |
| 6 | 1 | 135 | 265 | 334 | 396 | 450 | 483 |
| Grand Ave. Calculated length | | 112 | 279 | 364 | 423 | 459 | 483 |
| Grand Ave. Length Increment | | 112 | 167 | 85 | 59 | 36 | 24 |
| No. Fish | | 165 | 136 | 67 | 36 | 5 | 1 |

*The regression of total length on anterior scale radius was curvilinear (r = 0.964)

Table 17. Calculated growth of rainbow trout sampled from the Marias River in 1982 compared to calculated growth in other major Montana rivers.*

| River | No. of Fish | Average calculated total length (mm) at end of Yr | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Marias 1982 (Present study) | 165 | 112 | 279 | 364 | 423 | 459 | 483 |
| West Gallatin 1948-49 | 182 | 81 | 165 | 226 | 307 | 396 | |
| Marias (below Tiber D.) 1961 | 35 | 86 | 226 | 307 | 338 | | |
| Stillwater (Yell. 1948) | 184 | 84 | 185 | 262 | 343 | 411 | |
| Missouri (below Holter D.) 1948 | 472 | 89 | 218 | 297 | 361 | 404 | 434 |
| Madison 1950 | 436 | 109 | 239 | 321 | 378 | 470 | |

*Peters 1964

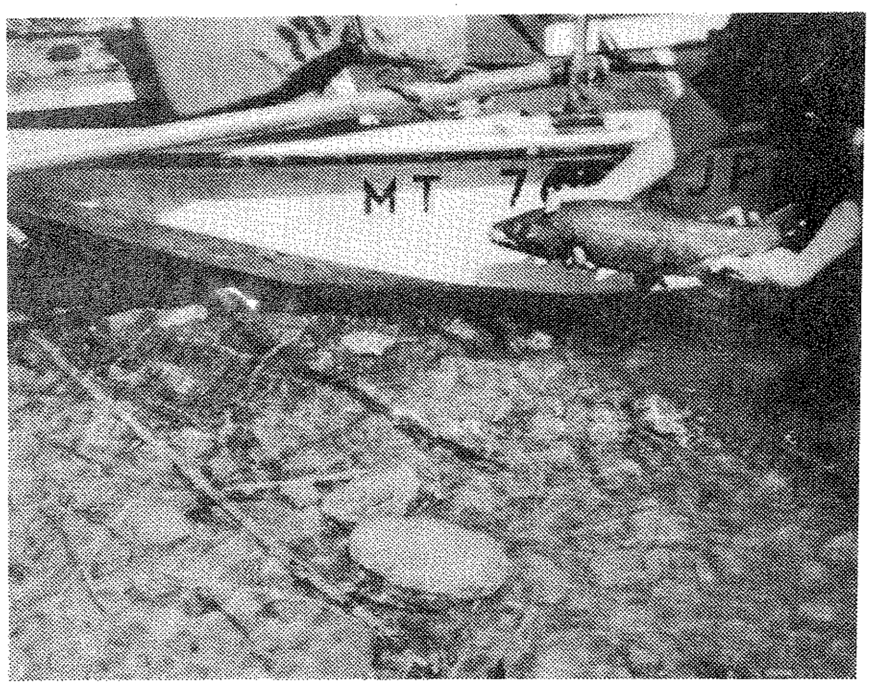


Figure 8. Rainbow trout were sampled in low numbers; however, they exhibited an excellent growth rate.

Forty-two brown trout sampled in 1982 were assigned ages ranging from 0-8 years (Table 18). Average annual growth of brown trout was less than rainbow trout for yearling fish but greater for YOY and two-year-old and older fish.

Table 18. Calculated length at end of each year of life and average growth of brown trout sampled from Marias River in 1982 (Monastyrsky logarithmic method).*

| Age Group | No. Fish | Calculated total length (mm) at end of Year 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 124 | | | | | | | |
| 2 | 2 | 149 | 243 | | | | | | |
| 3 | 3 | 133 | 205 | 304 | | | | | |
| 4 | 10 | 133 | 219 | 294 | 368 | | | | |
| 5 | 13 | 127 | 212 | 304 | 371 | 413 | | | |
| 6 | 7 | 120 | 216 | 315 | 388 | 461 | 509 | | |
| 7 | 3 | 87 | 167 | 257 | 334 | 402 | 454 | 498 | |
| 8 | 1 | 112 | 166 | 227 | 314 | 366 | 432 | 468 | 500 |
| Grand Ave. Calculated length | | 125 | 211 | 297 | 368 | 424 | 487 | 491 | 500 |
| Grand Ave. Length Increment | | 125 | 86 | 86 | 71 | 56 | 63 | 4 | 9 |
| No. Fish | | 42 | 39 | 37 | 34 | 24 | 11 | 4 | 1 |

*The regression of total length on anterior scale radius was curvilinear (r = 0.936)

## Spawning

Spawning and incubation are probably the most vulnerable stages in the life cycle of trout. Spawning and incubation activities occur in shallow riffles which are the most sensitive to instream flow changes (Bovee 1974). Spawning site selection is specific for water current velocities and depth and for clean gravel of suitable size.

From late March through late may 1982, the study area was searched for rainbow trout redds. Fourteen redds were located in the first 10 km of the study area. The lower 24 km of river contained many riffle areas, but it appeared that siltation from the coulees which drain into the river within this area affect the quality of spawning gravel. The physical dimensions of the redds measured are given in Table 19. Based on redd counts and examination of rainbows for spawning condition, the major rainbow spawning period extended from April 13 through April 21. Maximum water temperatures during this period ranged from 5 to 7.2 C (Table 20). When water releases approximately doubled beginning May 11, a resumption of redd construction occurred, indicating the low flow during April was below the minimum required for normal rainbow trout spawning.

Spawning intensity in 1982 was probably below the potential for this section of river. Moreover, the few redds which were constructed during the low flows were dug far from the stream edge toward the center of the channel where good spawning gravel was lacking. The overall poor success of rainbow trout spawning in 1982 was probably due largely to the abnormally low water releases from Tiber Dam during their spawning season.

Table 19. Physical dimensions of rainbow trout redds measured in the Marias River, April 13-21, 1982.

| Section | No. Redds | Length (m) | Width[1] (m) | Depth[2] (m) | Velocity[3] 1(cm/s) | Velocity[4] 2(cm/s) |
|---|---|---|---|---|---|---|
| Tiber Dam | 8 | 1.42 | 0.85 | 0.29 | 53 | 63 |
| Pondera Coulee | 5 | 1.68 | 0.64 | 0.26 | 55 | 63 |
| | Ave. | 1.52 | 0.76 | 0.28 | 54 | 63 |
| | Range | (1.0-2.0) | (0.5-1.1) | (0.2-0.4) | (23-77) | (30-85) |

1 - Measured across widest point of redd
2 - Measured immediately above redd pit
3 - Measured above redd pit at bottom of channel
4 - Measured above redd pit at 0.6 of depth (average velocity)

Table 20. Water temperatures during rainbow spawning period 1982 measured 1 km below Tiber Dam.

| Period | Minimum Temperature (C) | Maximum Temperature (C) |
|---|---|---|
| 4/13 | Installed | 5.0 |
| to 4/15 | 2.2 | 6.1 |
| to 4/20 | 1.1 | 7.2 |
| to 4/21 | 1.1 | 7.2 |
| to 4/26 | 1.7 | 8.3 |
| to 4/30 | 1.7 | 8.9 |
| to 5/3 | 2.8 | 8.9 |
| to 5/11 | 3.3 | 10.0 |
| to 5/17 | 3.9 | 8.9 |

From mid-October through November 1982, the study area was searched for brown trout redds. A total of 8 redds was located, all within a 20 m channel segment in the upper reach of the Tiber Dam section. River flows were again at a near record low, and it appeared that the site where the redds were located was the only location in the entire study area suitable for brown trout spawning at that low flow.

Rearing

During the late summer, an attempt was made to locate preferred rainbow trout rearing areas. The channel border was randomly sampled throughout the study area with the electrofishing equipment. Most of the YOY rainbow trout were found in the Tiber Dam and Pondera Coulee sections (Table 21). Within the Pondera Coulee section, 80% of the YOY rainbows sampled were found in the upper 2 km of the section, indicating that YOY rainbow trout rearing was limited below river km 10. Therefore, only the upper third of the study area appears to be used extensively for rearing. The longitudinal distribution of YOY rainbow trout corresponds closely with the distribution of rainbow trout redds throughout the study area (Figure 9).

Table 21. Numbers and sizes of young-of-year rainbow trout sampled in Marias River during Aug. 31-Sept. 2, 1982.

| Section | No. Fish Sampled | Ave. Length (mm) | Length Range (mm) |
|---|---|---|---|
| Tiber Dam | 89 | 60.0 | (30-80) |
| Pondera Coulee | 40 | 66.1 | (52-86) |
| Dugout Coulee | 3 | 82.0 | (78-84) |
| Total | 132 | | |

Young-of-the-year rainbow trout prefer interstitial spaces of large cobble areas within a slight water current for rearing (pers. obs.). This type of rearing habitat is scarce in the Marias River, and the rainbows here utilize a more prevalent cover type. The majority of YOY rainbows were associated with the large filamentous algal mats anchored along the channel borders. THese mats provided excellent cover areas because they existed along riffle and run borders, were available at the onset of rainbow rearing, occurred in large numbers and were fairly extensive in distribution. The algal mats were present during the summer from the dam downriver approximately 10 km to the confluence with Pondera Coulee. Below this point the mats were considerably smaller and less frequent. The scarcity of algal mats below Pondera Coulee may be related to the slightly decreased water clarity and general depletion of essential nutrients. The lack of suitable rearing habitat is probably a significant factor limiting the downriver distribution of YOY rainbow trout. As mentioned in the

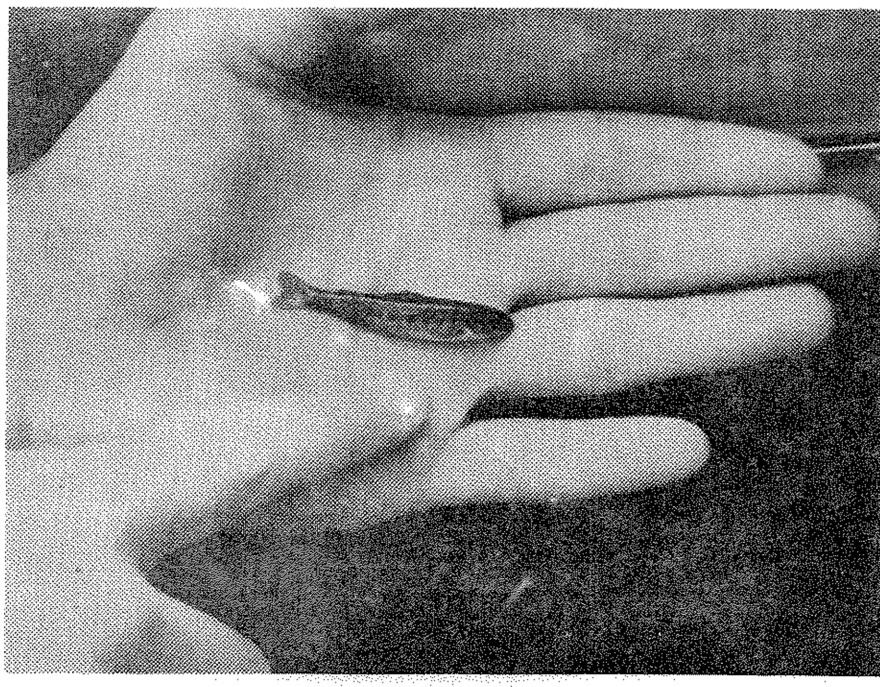

Figure 9. Young-of-the-year rainbow and brown trout reared only in the first 10 km of the Marias River and used the extensive growths of filamentous algal mats as shelter areas.

previous section, poorer quality spawning habitat below Pondera Coulee related to siltation of gravels may also hinder trout reproduction in downstream areas.

Young-of-the-year brown trout also preferred the upper 10 km of the study area for rearing. Most of the YOY brown trout sampled were associated with the filamentous algal mats (Table 22). Numbers of YOY brown trout sampled were approximately half of the total numbers of rainbows sampled.

Table 22. Numbers and sizes of young-of-year brown trout sampled in Marias River during Aug. 31-Sept. 2, 1982.

| Section | No. Fish Sampled | Ave. Length (mm) | Length Range (mm) |
|---|---|---|---|
| Tiber Dam | 38 | 83.6 | (72-94) |
| Pondera Coulee | 18 | 82.6 | (65-90) |
| Dugout Coulee | 4 | 82.8 | (80-85) |
| Total | 60 | | |

## Other Sport Fish

Northern pike, burbot, sauger and walleye are the most common warmwater sport fish found in the study area ((Tables 5-8). Catch rates for these species ranged from less than 1 to 2.4 fish per hour, which was considered to be indicative of low population numbers. Northern pike were usually sampled in off-channel areas, such as the dredge ponds immediately below the dam or in coulee embayments in the Dugout Coulee section. In these areas, a fair number of YOY pike were also found, indicating their preference for this habitat for rearing. YOY burbot and walleye were also collected in the study area.

Although sauger are a major sport fish in the lower Marias (Gardner and Berg 1982), they were uncommon in the study area. During spring 1962, Posewitz (1962) found high numbers of sauger in the Dugout Coulee section. The exceptionally low flows experienced during spring 1982 may have limited up river spawning movements of sauger into this section.

## Migratory Fish

The importance of the Marias River as a spawning stream for resident Missouri River fish has been reported by Berg (1981). Until the present study, the extent of migratory use in the upper reach of the Marias was unknown.

Migratory fish from the Missouri River found in the study area during the high water period (June-early July) included shovelnose sturgeon, blue sucker and bigmouth and smallmouth buffalo (Tables 23-25). Prior to, during and after the high water period, electrofishing runs were conducted throughout the study area to determine the seasonal distribution of migratory fish (Table 26).

Table 23. Sizes of migratory fish species sampled by electrofishing in the Tiber Dam section of the Marias River during 1982.

| Species | Number Sampled | Average Length (mm) | Length Range (mm) | Average Weight (gm) | Weight Range (gm) |
|---|---|---|---|---|---|
| Shovelnose sturgeon | | | | | |
| Blue sucker | 11 | 685 | 630 - 765 | 2711 | 1950 - 3950 |
| Bigmouth buffalo | 12 | 758 | 656 - 880 | 1/ | 4000+ |
| Smallmouth buffalo | 5 | 534 | 432 - 645 | 1/ | 2270 - 4000+ |

Table 24. Sizes of migratory fish species sampled by electrofishing in the Pondera Coulee section of the Marias River during 1982.

| Species | Number Sampled | Average Length (mm) | Length Range (mm) | Average Weight (gm) | Weight Range (gm) |
|---|---|---|---|---|---|
| Shovelnose sturgeon | 2 | 850 2/ | 790 - 910 | 1/ | 2000 - 4000+ |
| Blue sucker | 6 | 673 | 635 - 727 | 2675 | 2150 - 3260 |
| Bigmouth buffalo | 4 | 732 | 688 - 755 | 1/ | 4000+ |
| Smallmouth buffalo | None measured | | | | |

Table 25. Sizes of migratory fish species sampled by electrofishing in the Dugout Coulee section of the Marias River during 1982.

| Species | Number Sampled | Average Length (mm) | Length Range (mm) | Average Weight (gm) | Weight Range (gm) |
|---|---|---|---|---|---|
| Shovelnose sturgeon | 32 | 887 | 774 - 1041 | 1/ | 1640 - 4000+ |
| Blue sucker | 5 | 675 | 600 - 789 | 1/ | 1760 - 4000+ |
| Bigmouth buffalo | 5 | 782 | 737 - 826 | 1/ | 4000+ |
| Smallmouth buffalo | 1 | 597 | | 2760 | |

1/ Not all fish could be weighed.

2/ Represents total length.

Table 26. Seasonal distribution of migratory fish in the study area as determined by seven electrofishing runs taken during 1982.

| Study Section | May 11 | May 24 | June 1 | June 24 | June 30 | July 7 | Aug 2 |
|---|---|---|---|---|---|---|---|
| | Number of Shovelnose Sturgeon Observed | | | | | | |
| Tiber Dam | | | | | | | |
| Pondera Coulee | | | | | 4 | 1 | |
| Dugout Coulee | | | | 24 | 11 | 33 | |
| | Number of Blue Suckers Observed | | | | | | |
| Tiber Dam | | | 20 | 2 | | | |
| Pondera Coulee | | 4 | | 1 | 1 | | |
| Dugout Coulee | | 1 | 2 | 4 | | 1 | |
| | Number of Bigmouth Buffalo Observed | | | | | | |
| Tiber Dam | | | 3 | 56 | 4 | 23 | |
| Pondera Coulee | | | 3 | 6 | | 3 | |
| Dugout Coulee | | 1 | 5 | 19 | 22 | 12 | |
| | Number of Smallmouth Buffalo Observed | | | | | | |
| Tiber Dam | | | | 18 | 1 | 1 | |
| Pondera Coulee | | | | | | 1 | |
| Dugout Coulee | | | | | 6 | 3 | |

Shovelnose sturgeon were sampled from June 24 through July 7 in the lower two study sections. Sturgeon increased in abundance in a downriver direction. Most of the sturgeon were in spawning condition, ripe males or gravid females. For spawning migratory fish such as the shovelnose, water temperature and rising flow are probably the most important environmental factors necessary to induce the run (Purkett 1961, Berg 1981 and Peters 1982). These factors appeared to stimulate the shovelnose sturgeon migrating up the Marias. The first observation of sturgeon in the study area occurred when the flow increased substantially and water temperatures warmed up to about 15 C (60F). Berg (1981) reported a depressed sturgeon run in response to low flows in the Marias River during their spawning season. During years with good spring flows, he reported peak spawning occurred at temperatures of 16.1-20.6 C.

Blue suckers were sampled from May 24 through July 7 throughout the study area. Blue suckers were the first migratory fish to move into the study area, arriving before the high flows occurred.

Bigmouth and smallmouth buffalo were also sampled during the migration period throughout the study area. Bigmouth buffalo were more numerous and arrived on May 24. Smallmouth buffalo were first sampled on June 24.

During the peak flow period from June 20 through June 30, electrofishing survey runs were continued downstream from the study area to the confluence with the Teton River. Within this 90 km reach, 118 shovelnose sturgeon, 3 blue suckers, 19 bigmouth and 14 smallmouth buffalo were found, indicating these migratory fish were distributed throughout the lower Marias. During this survey run, two tagged shovelnose sturgeon were captured. One sturgeon tagged in the Missouri River in 1978, 11 km upstream from the Marias/Missouri confluence, was recaptured June 21, 1982, in the lower end of the study area at Marias River km 30. This fish moved a distance of 103 km. The other shovelnose tagged in 1977 in the Missouri River 120 km below the Marias/Missouri confluence was recaptured on June 23, 1982, in the Marias River 82 km downstream of Tiber Dam. This fish had moved at least 128 km since it was tagged.

These findings indicate the Marias River within the study area is used by spawning fish from the Missouri River. Migrants move into the Marias during the spring when the river is flowing at normal high flow levels.

## Nonsport Fish

The predominant nongame fish sampled were longnose sucker and carp. The average catch rates for all sections combined were 6.8 and 4.8, respectively, compared to the catch rates for shorthead redhorse and whitesuckers of 3.4 and 2.8, respectively (Tables 6-8). River carpsuckers were uncommon. Goldeye occurred in the study area mostly during the summer.

## Forage Fish

The forage fish community of the Marias River provides a food base for piscivorous fish species such as northern pike, sauger, walleye and brown trout. For purposes of this study, a forage fish was broadly defined as any fish utilized by another fish as a food source. This would include most age 0 fish and nearly all minnows.

Off-channel habitat areas (side channels and backwaters) in the study area are scarce; consequently the forage fish communities were sparse in numbers and diversity. The most common forage species found throughout the study area were YOY suckers (mostly longnose and white suckers and shorthead redhorse), longnose dace, flathead chubs and yellow perch (in backwater habitat-Tables 27-29). The lowest section, Dugout Coulee, had the greatest number of forage fish groups, probably because of the greater quality and quantity of off-channel habitat.

## Pesticide Analyses

In Montana, pesticide contamination of fish is becoming an item of increasing concern. It is important to determine the current status of pesticide contamination in the fishery resources for the protection of the public and as a general baseline for future comparative purposes. For this study, the mountain whitefish was selected for evaluation because it is the predominant sport fish and, therefore, commonly harvested and consumed. The muscle tissue from each of 10 specimens was filleted, frozen and later sent to Hazelton Raltech Laboratories for pesticide analysis.

None of the chemicals were present in concentrations to warrant concern at this time (Table 30). It was noted that the presence of DDE (a degradation product of DDT) and PCB's (polychlorinated biphenyls) were present at detectable levels in fish sample numbers 3, 5 and 8. It is apparent these chemical are present in the drainage. The chemicals were detected only in the whitefish samples with the highest percent lipid content.

From past studies, it has been reported that endrin does not persist at high levels in fish tissues, while DDT and PCB's are long-lasting in the aquatic environment (Henderson et al. 1969 and Veither 1975).

## Canada Goose Nesting

Rivers are important to Canada goose populations because they fulfill essential habitat requirements necessary throughout their life cycle. Canada geese were common in the study area and used the river for staging, loafing, nesting and rearing. This area has a high potential for Canada goose production because the river is fairly isolated from human activities and there are several islands and gravel bars which could be used as goose nesting sites.

The life cycle stage most affected by river flow is nesting. Most Canada goose nesting occurs on islands because of the protection the side channel provides against mammalian predators (Hook 1981). When flows are high enough, water depths, width and velocities in side channels form a barrier against a predator's attempt to cross onto the island. However, at lower flows the barrier imposed by the side channel becomes ineffective, exposing the goose nests to predation.

During spring 1982, the nesting activities of Canada geese in the study area were monitored (Figure 10). Eleven nests were located during the initial ground survey on April 19. The subsequent survey on May 17 revealed only two

Table 27. Catch rates (number of fish per seine haul) of forage fish species in Tiber Dam study section, Marias River, 1982.

| Species | Habitat Type<br>Main Channel Border | Main Channel Pool | Side Channel Pool | Backwaters |
|---|---|---|---|---|
| Mtn. whitefish | 1.5 | | | |
| Buffalo1/ | | | | 3 |
| Suckers2/ | 7.5 | | 136 | 0.3 |
| Longnose dace | | | 10 | |
| Emerald shiner | | | 1 | |
| Northern pike3/ | | 0.5 | | 2 |
| Yellow perch | | 0.5 | 1 | 24 |
| Number hauls | 2 | 2 | 2 | 3 |

1 - No differentiation between bigmouth and smallmouth buffalo
2 - Includes shorthead redhorse, longnose and white suckers
3 - Includes YOY and/or yearling fish

Table 28. Catch rates (number of fish per seine haul) of forage fish species in Pondera Coulee study section, Marias River, 1982.

| Species | Habitat Type<br>Main Channel Pool | Side Channel Pool |
|---|---|---|
| Suckers1/ | 22 | 80 |
| Longnose dace | 22 | |
| Flathead chub | 235 | 0.5 |
| Lake chub | | 18 |
| Emerald shiner | | 0.5 |
| Northern pike2/ | | 2 |
| Yellow perch | | 2.5 |
| Walleye2/ | | 0.5 |
| Number hauls | 2 | 2 |

1 - Includes shorthead redhorse, longnose and white suckers
2 - Includes YOY and/or yearling fish

Table 29. Catch rates (number of fish per seine haul) of forage fish species in Dugout Coulee study section, Marias River, 1982.

| Species | Main Channel Border | Main Channel Pool | Side Channel Pool | Backwaters |
|---|---|---|---|---|
| Mountain whitefish | | 1 | | |
| Suckers 1/ | 10 | 104 | 62 | 20.2 |
| Longnose dace | 8 | 83.6 | 69.2 | |
| Fathead minnow | | | 3.8 | 3 |
| Flathead chub | | 4 | 4.8 | 7.5 |
| Lake chub | | | 0.5 | |
| Emerald shiner | | | 1.2 | 1.2 |
| Western silvery minnow | | | | 1 |
| Northern pike 2/ | | | 0.8 | 0.8 |
| Yellow perch | | 0.3 | 25 | 52.8 |
| Number hauls | 2 | 5 | 4 | 4 |

1 - Includes shorthead redhorse, longnose and white suckers
2 - Includes YOY and/or yearling fish

Table 30. Concentrations of chlorinated hydrocarbons in mountain whitefish collected from the Marias River, November 20, 1982.

| Sample No. | Fish Size Length (mm) | Fish Size Weight (g) | % Lipid | Chemical Conc. (ug/g) DDE[1] | DDD[2] | DDT | PCB | Diel-drin | BHC[3] | Lin-dane | HCB[4] | En-drin | HE[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 415 | 560 | 3.31 | 0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 2 | 423 | 760 | 1.39 | <0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 3 | 400 | 875 | 5.79 | 0.03 | <0.01 | <0.01 | 0.16 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 4 | 420 | 540 | 0.60 | <0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 5 | 426 | 780 | 7.35 | 0.03 | <0.01 | <0.01 | 0.15 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 6 | 375 | 480 | 0.28 | <0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 7 | 418 | 670 | 4.14 | <0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 8 | 395 | 620 | 7.87 | 0.02 | <0.01 | <0.01 | 0.14 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 9 | 300 | 300 | 1.19 | <0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 10 | 331 | 350 | 2.21 | <0.01 | <0.01 | <0.01 | <0.10 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

1 - Degradation product of DDT
2 - Dichloro diphenyl dichlorethane
3 - Benzene hexachloride
4 - Hexachlorobenzene
5 - Heptachlor epoxide

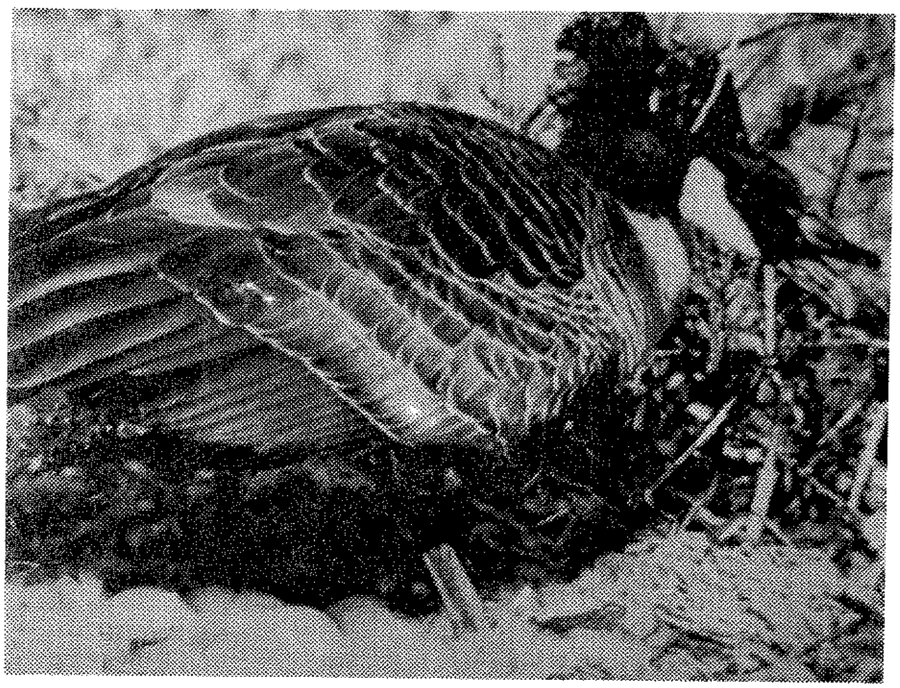

Figure 10. Canada geese prefer to nest on river islands protected by side channels with good deep flows.

nests were successful, yielding a nest success of only 18% (Table 31 and Figure 11). Compared to other Canada goose nesting surveys, the Marias experienced an abnormally low nest success during 1982. The most obvious reason for the low number of geese nesting and poor nest success in the study area was low flow during the nesting season from mid-March to mid-May. Water releases from Tiber Dam during 90% of this period ranged from 215 to 265 cfs (6.09 to 7.51 $m^3$/sec). The effects of these low flows on the Canada goose population were reduced nest initiation and reduced nest security.

Table 31. Canada goose nest survey results from Marias River, 1982 with comparisons to other river surveys.

| River | No. Islands/ km | Goose Nests/ km | Average No. Eggs/ Nest | Percent Nest Success |
|---|---|---|---|---|
| Marias | 0.89[1/] | 0.33 | 6.0 | 18.2 |
| Missouri[2/] | 0.58 | 0.50 | 5.94 | 91.7 |
| Yellowstone[3/] | - | 0.37 | 5.45 | 57.5 |

1 - This figure includes larger gravel and sand bars which were not included in the other studies.
2 - Hook (1981)
3 - Hinz (1977)

Flows necessary for providing side channel water barriers for goose nesting islands were evaluated during this study (Figure 12). Five of these ten side channels of the nesting islands were monitored at medium and low flow to investigate changes in side channel features as flow receded. Cross-sections were established at the shallowest channel crossing because this is probably the most vulnerable access point to the island.

Physical characteristics of the side channels predicted by WETP computer simulation are presented in Table 32. Side channel flow, average current velocity and maximum depth were most affected by reduced flows. Channel width was least affected, averaging a 39% change between a medium and a low flow. Side channel numbers 23 and 26 were associated with the only two islands which successfully hatched a brood. These two side channels had the greatest predicted maximum depths at the lower instream flow. The projected low flow was similar to the low flow actually experienced during the nesting season. Based on this information, a maximum depth between 0.16 m (the greatest maximum depth which

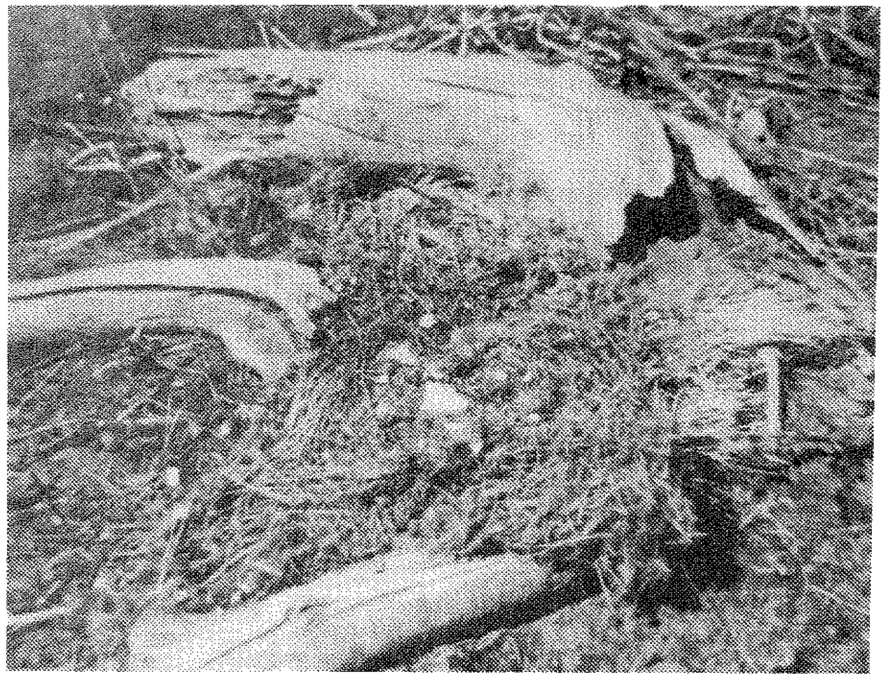

Figure 11. A destroyed goose nest. Because of the abnormally low flow on the Marias River during the spring of 1982, there was a low hatching success of only 17 percent.

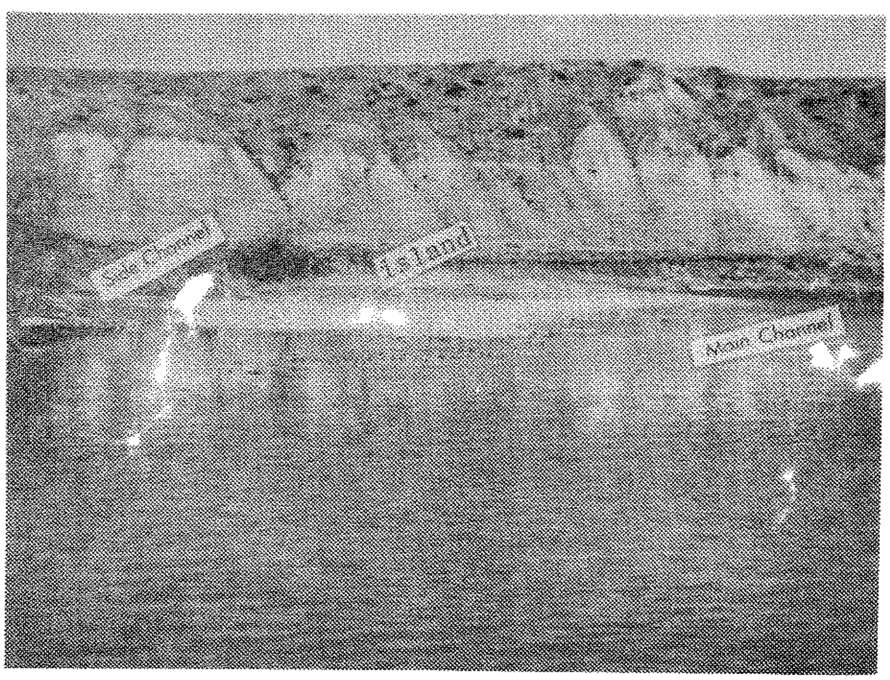


Figure 12. A typical goose nesting island.

Table 32. Physical characteristics of side channels of goose nesting islands in the study area compared to flow of the Marias River in 1982.

| Number | Marias River Flow (m3/s) | Side Channel Flow (m3/s) | Width (m) | Maximum Depth (m) | Average Current Velocity (cm/s) |
|---|---|---|---|---|---|
| | 5.92 | 0.46 | 23.77 | 0.24 | 1.4 |
| 23 | 15.12 | 3.91 | 31.39 | 0.43 | 4.5 |
| | 5.92 | 0.21 | 18.29 | 0.12 | 1.9 |
| 24 | 15.12 | 1.95 | 27.71 | 0.27 | 4.1 |
| | 5.92 | 0.08 | 2.71 | 0.01 | 0 |
| 25 | 15.12 | 1.70 | 22.40 | 0.27 | 5.9 |
| | 5.92 | 0.50 | 14.02 | 0.31 | 2.1 |
| 26 | 15.12 | 2.32 | 15.85 | 0.45 | 4.8 |
| | 5.92 | 0.29 | 19.32 | 0.16 | 2.4 |
| 27 | 15.12 | 2.65 | 30.21 | 0.33 | 4.7 |
| Average Change (Percent) | 60.8 | 87.8 | 38.8 | 55.7 | 65.6 |

allowed access to the nest on the island) and 0.24 m (the least maximum depth which apparently thwarted predator access to islands) is required to maintain the water barrier. Assuming that 0.24 m is the least maximum depth which provides a side channel barrier, a flow of 534 cfs (15.12 $m^3$/sec) is the approximate minimum flow required to maintain effective barriers in the five measured side channels. Based on a general examination of the river, it is believed about the same minimum flow is required to secure barriers in unmeasured side channels protecting islands from predator access to goose nests.

## Instream Flow Assessment for Channel Morphology

### Dominant Discharge/Channel Morphology Concept

It is generally accepted that the major force in the establishment and maintenance of a particular channel form in view of its bed and bank material is the annual high flow characteristics of the river. It is the high spring flows that determine the shape of the channel rather than the average or low flows.

The major functions of the high spring flows in the maintenance of channel form are bedload movement and sediment transport. It is the movement of the bed and bank material and subsequent deposition which form the mid-channel bars and, subsequently, the islands. High flows are capable of covering already established bars with finer material which leads successively to vegetated islands. Increased discharge associated with spring runoff also results in a flushing action which removes deposited sediments and maintains suitable gravel conditions for aquatic insect production, fish spawning and egg incubation.

Reducing the high spring flows beyond the point where the major amount of bedload and sediment are transported would interrupt the ongoing channel processes and change the existing channel form and bottom substrates. A significantly altered channel would affect both the abundance and species composition of the present aquatic populations by altering the existing habitat types.

Several workers adhere to the concept that the form and configuration of river channels are shaped by and designed to accommodate a dominant discharge (Leopold et al. 1964, U. Bureau of Reclamation 1973, Emmett 1975). The discharge which is most commonly referred to as a dominant discharge is the bankful discharge (Leopold et al. 1964, Emmett 1975). Bankful discharge is defined as that flow when water just begins to overflow onto the active floodplain.

Bankful discharge tends to have a constant frequency of occurrence among rivers (Emmett 1975). The recurrence interval for bankful discharge was determined by Emmett (1975). The recurrence interval for bankful discharge was determined by Emmett (1975) to be 1.5 years and is in close agreement with the frequency of bankful discharge reported by other studies (Leopold et al. 1964, Emmett 1972).

The bankful discharge for the Marias River was estimated by using 1-1/2 year frequency peak flows derived from the USGS gage station located 2 km below Tiber Dam. The dominant discharge was 2,240 cfs (63.44 $m^3$/sec). It is not presently known how long the bankful flow must be maintained to accomplish the necessary channel reformation processes. Until further studies clarify the necessary duration of the bankful discharge, a duration period of 24 hours was chosen.

High Flow Period Assessment

High flows during the normal spring runoff period are essential for maintenance of migratory fish runs up the Marias River. Under suitable flow conditions migratory fish such as shovelnose sturgeon, sauger, buffalo and blue suckers utilize the Marias for spawning (Berg 1981).

The Marias River also provides substantial accretion of flow to the Missouri River. A reduction in the Marias during the high water period decreases the magnitude of the high flow period in the Missouri River. Berg (1981) found migratory paddlefish required a high flow of 14,000 cfs (396.52 $m^3$/sec) gaged at Virgelle to initiate their run up the Missouri to spawn. Other migratory fish also require the high spring flows to induce spawning movements.

The flows required during the high flow period were based on the amount of flow normally contributed by the Marias to raise the flow of the Missouri River to 14,000 cfs. The period extends from May 19 through July 5 when most of the paddlefish spawning and incubation occurs. During this period, other migratory fish also spawn. This flow not only contributes to the paddlefish requirements in the Missouri River, but is also important for maintaining the Marias River migratory fish runs. As mentioned previously, there is a substantial migratory fish run up the Marias, originating from the Missouri River. The Marias River migration coincides largely with the paddlefish run. A flow of 1,144 cfs (32.40 $m^3$/sec) from the Marias River is required to augment the flow of the Missouri River to 14,000 cfs in a normal water runoff year (Table 33).

Instream Flow Assessment for Riffles and Pools

Spring and summer base flow recommendations were determined using the wetted perimeter/inflection point method. Wetted perimeter is the distance along the bottom and sides of a channel cross section in contact with water. As the flow in the stream channel decreases, the wetted perimeter also decreases, but the rate of loss of wetted perimeter is not constant throughout the entire range of flows. There is a point, called an inflection point, on the curve of wetted perimeter versus flow, at which the rate of loss of wett ' perimeter is significantly changed. Above the inflection point, large changes in flow cause only very small changes in wetted perimeter. Below the inflection point, the river begins to recede from the riffle bottom, exposing the bottom at an accelerated rate. The flow recommendation was selected at this inflection point.

The maintenance of suitable flows in riffles and runs during this period is essential for the Marias River fish populations. Three reasons are:

1. Riffles and runs contain substantial standing crops of aquatic macroinvertebrates and forage fish, the principal food organisms of important fish species in the Marias River.

2. The borders of riffles and runs were the major habitat areas used for

Table 33. Normal flow accretion of a segment of the Missouri River system. Based on USGS flow duration hydrograph for a 19 year period between water years 1960 and 1978.

| Location | Normal Percent of Virgelle Flow[1/] | Flow Required to Maintain Paddlefish[3/] at Virgelle | |
|---|---|---|---|
| | | $m^3/s$[4/] | CFS |
| Missouri River at Ft. Benton[2/] | 90.16 | 357.49 | 12,622 |
| Marias River near Chester | 8.17 | 32.40 | 1,144 |
| Teton River near Dutton | 1.36 | 5.38 | 190 |

1/ Nearest USGS gage station below confluence of Marias River with Missouri River.
2/ Nearest USGS gage station above confluence of Marias River with Missouri River.
3/ Paddlefish flow requirement was determined by Berg (1981) to equal 396.52 $m^3/s$ (14,000 cfs) and should be maintained from May 19 through July 5.
4/ These figures do not add up to exactly 396.52 $m^3/s$ due to accuracy of gaging and water loss.

rearing by YOY rainbow and brown trout.

3. Riffle and run areas are essential for trout spawning and incubation.

If flows in the Marias River were reduced below the inflection point, the riffle and run bottom would be exposed at an accelerated rate, causing a decrease in riffle and run area and channel depth.

Riffles are also the area of a stream most affected by flow reductions (Bovee 1974, Nelson 1977). Consequently, the maintenance of riffles should ensure the maintenance of the pool areas.

The wetted perimeter/inflection point method was applied to 11 typical riffle/run sites located in the three study sections. Two, four and five riffle/run cross-sections were established in the Tiber Dam, Pondera Coulee and Dugout Coulee sections, respectively. Water level elevations of the Marias River were measured at flows of 1,183 cfs (33.51 $m^3$/sec), 534 cfs (15.12 $m^3$/sec) and 209.9 cfs (5.94 $m^3$/sec). The $R^2$ values (correlation coefficients) for the cross-sections ranged between 0.985 and 1.000. The high $R^2$ values imply there were excellent linear correlations between water elevations and flows for all cross-sections.

The relationship between wetted perimeter and flow for a composite of two riffle/run cross-sections in the Tiber Dam section is depicted in Figure 13. The inflection point is at 450 cfs (12.75 $m^3$/sec). For the composite of four riffle/run cross-sections in the Pondera Coulee section the inflection point occurred at 550 cfs (15.58 $m^3$/sec, Figure 14). In the lowest section, Dugout Coulee, based on a composite of five riffle/run cross-sections, the inflection point was at 500 cfs (14.16 $m^3$/sec, Figure 15). A flow of 500 cfs, an average of the three composite curves, is the flow necessary for the maintenance of the riffle and run habitat areas during the spring and summer period.

A desirable target instream flow for the fall and winter periods would also be 500 cfs, and is based on the flow necessary for the maintenance of the riffle and run habitat areas.

An analysis of historic flow records, however, revealed median flow during fall and winter was usually below the minimum required to maintain adequate wetted perimeter of riffle areas. This deficiency may be related to the abnormally wide dimensions of the river channel which necessitates a substantial riffle maintenance flow. Although maintenance of riffles during the fall and winter are important for the aquatic fauna existing in this habitat, most production and critical life cycle stages occur in the riffles during the spring and summer periods (Hynes 1970). Because of possible water availability constraints during the fall and winter months, an alternate methodology was used to determine a base or minimum flow. During the relatively inactive fall and winter period it is important that pools be maintained for cover and protection of fish populations from severe ice conditions. The base flow level for fall and winter is based on maintenance of suitable habitat conditions in pools.

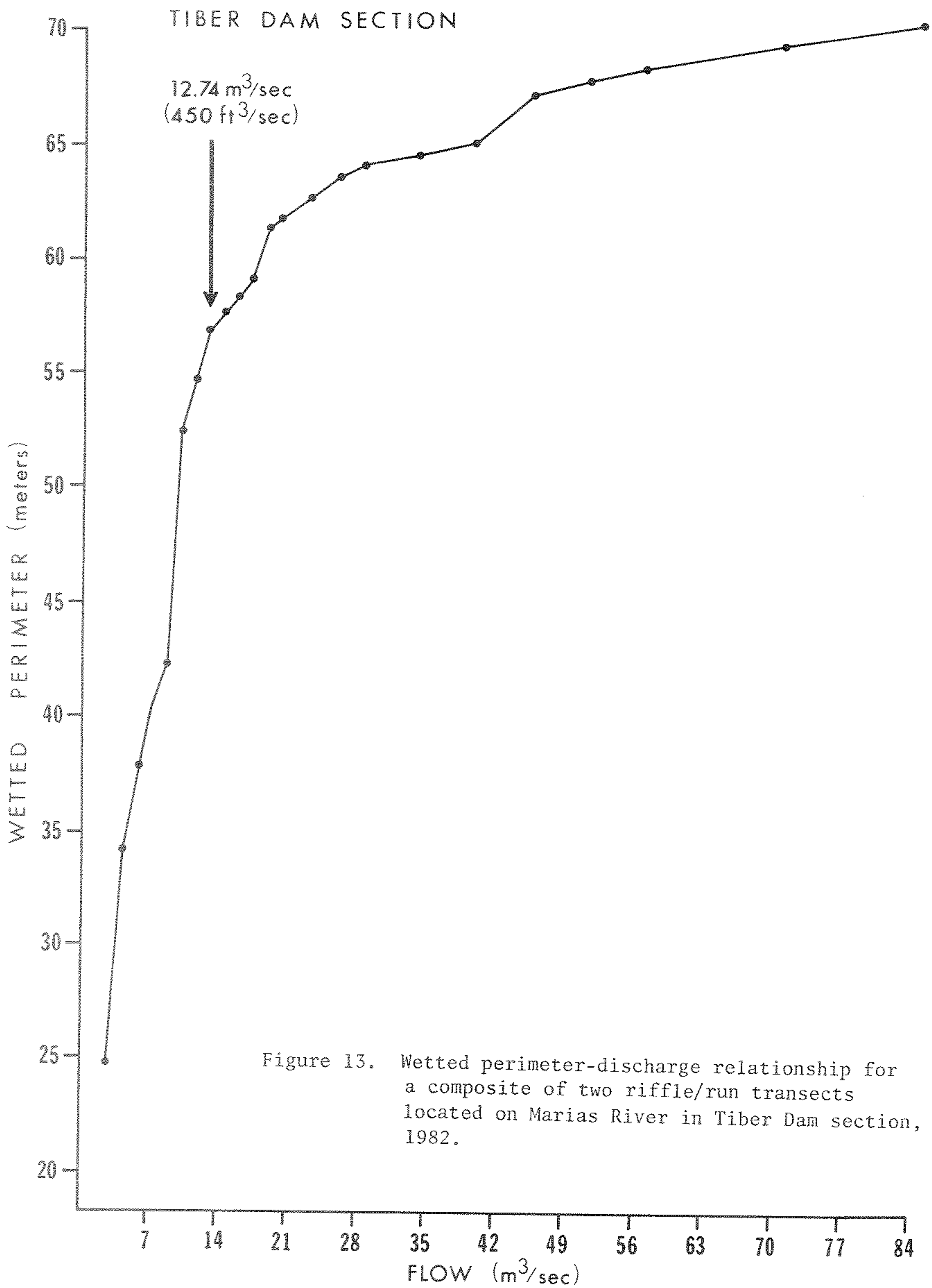


Figure 13. Wetted perimeter-discharge relationship for a composite of two riffle/run transects located on Marias River in Tiber Dam section, 1982.

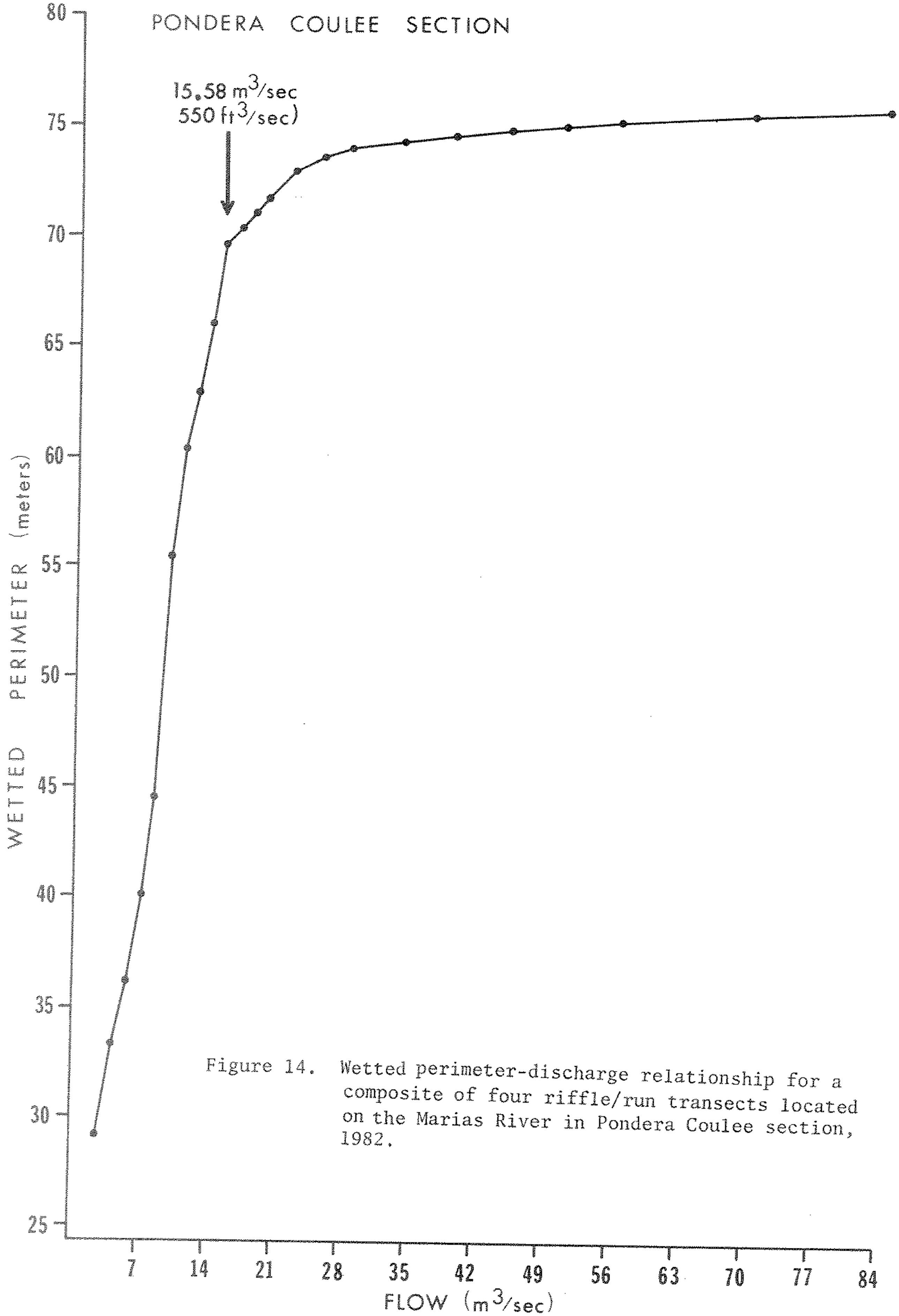


Figure 14. Wetted perimeter-discharge relationship for a composite of four riffle/run transects located on the Marias River in Pondera Coulee section, 1982.

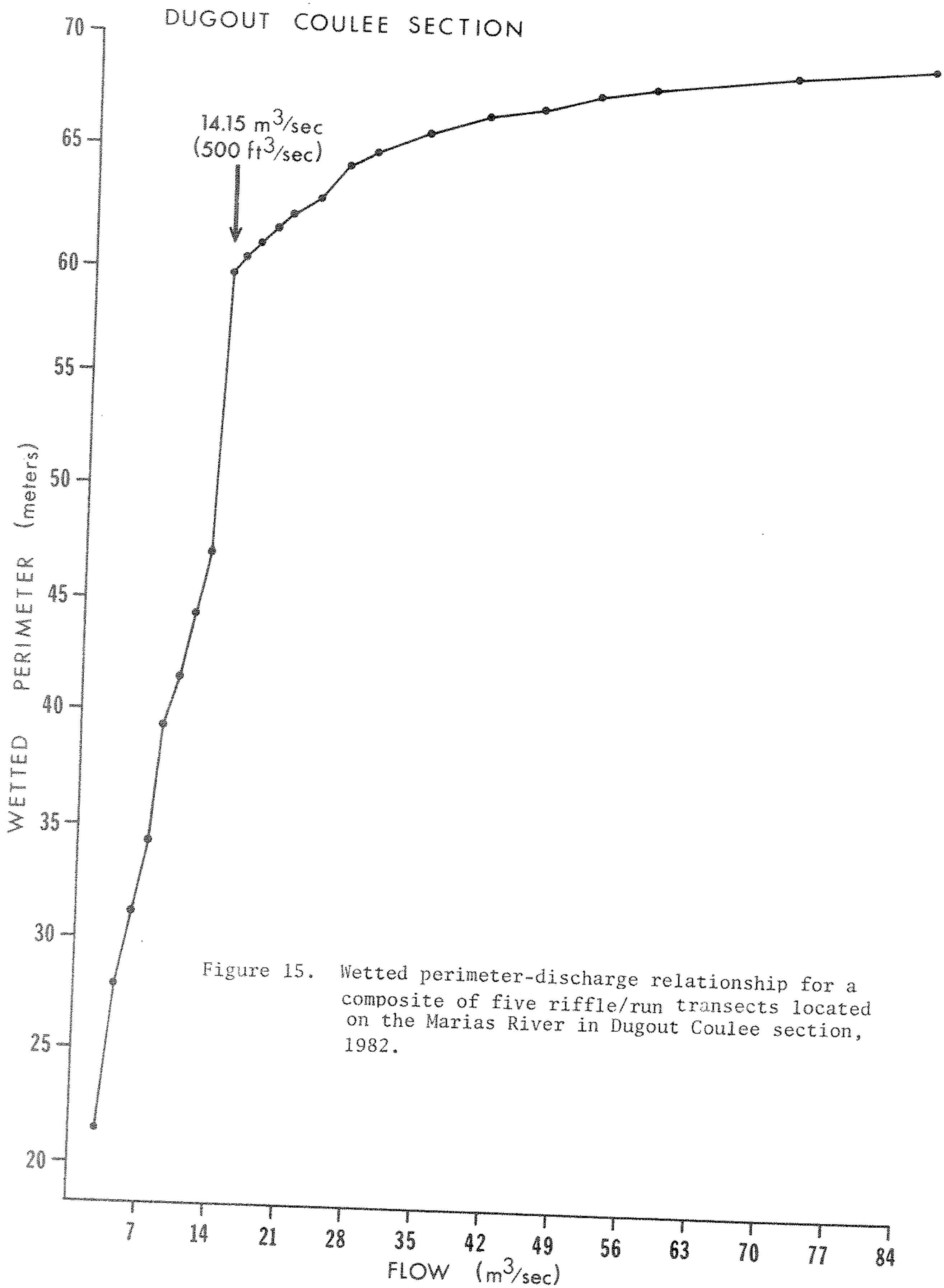


Figure 15. Wetted perimeter-discharge relationship for a composite of five riffle/run transects located on the Marias River in Dugout Coulee section, 1982.

Fall and winter base flow recommendations were based on maintenance of pool habitat. The major fish habitat concerns for pools are depth and size dimensions. The WETP computer program predicted average depth, maximum depth and area of the cross-sections measured in the pool areas of the river. A flow recommendation was selected at the inflection point. If fall and winter flows in the Marias River were reduced below the inflection point, the depth and size of the pools would decrease at an accelerated rate, causing a decrease of space available in the pool habitat areas.

Analysis of pool habitat maintenance was evaluated for five typical pool sites located in the three study sections. Water level elevations of the Marias River were measured at the same flows described previously for the wetted perimeter/inflection point method. The $R^2$ values for the pool cross-sections ranged from 0.975 to 0.985. The $R^2$ values imply there was an excellent linear correlation between water elevations and flows for all transects.

The relationship between the measured pool parameters (average depth, maximum depth and area) and flow for a composite of five pool cross-sections in the study area are depicted in Figure 16. The inflection points are at 300 cfs (8.50 $m^3$/sec), 300 cfs and 350 cfs (9.91 $m^3$/sec) for the average depth, maximum depth and area curves, respectively. A flow of 317 cfs (8.98 $m^3$/sec), an average of the three composite curves, is the minimum flow necessary for the maintenance of the pool habitat areas during the fall and winter period, while a desirable target instream flow for fall and winter is 500 cfs.

## Summary of Target Instream Flow Recommendations

Target flow recommendations for the Marias River are given according to the seasonal schedule in Table 34. The base flow required for pool habitat maintenance is designated from October 16 through March 15. This period was chosen because mid-October is the onset of the brown trout and mountain whitefish spawning season. It is important that the base winter flow of the river is set before the salmonids begin to spawn. This provides stable egg incubation flows throughout the winter. The low flow period should end March 15 because rainbow trout spawning and Canada goose nesting season commences and higher flows are necessary. May 19 through July 5 is the recommended high flow period with the dominant discharge occurring during this time. Several important fish species migrate and spawn in the Marias and Missouri rivers during this period. Normal high flows are necessary to initiate these migratory movements. From July 6 through October 15 salmonid rearing occurs in the riffle/run areas and food production i at a maximum. Suitable flow in riffle areas is necessary during this time period.

Table 34 indicates the flows requested are generally less than the median flows. The median flow (50 percentile rank) provides a measure of water availability during a normal or typical water year. The median is the flow that is equalled or exceeded in 5 of 10 years (Figure 17).

# CONCLUSIONS AND RECOMMENDATIONS

This study found that the Marias River from Tiber Dam to the Circle Bridge supports a cold water fishery consisting primarily of rainbow and brown trout and mountain whitefish. Although rainbow and brown trout population numbers currently appear to be suppressed, mountain whitefish

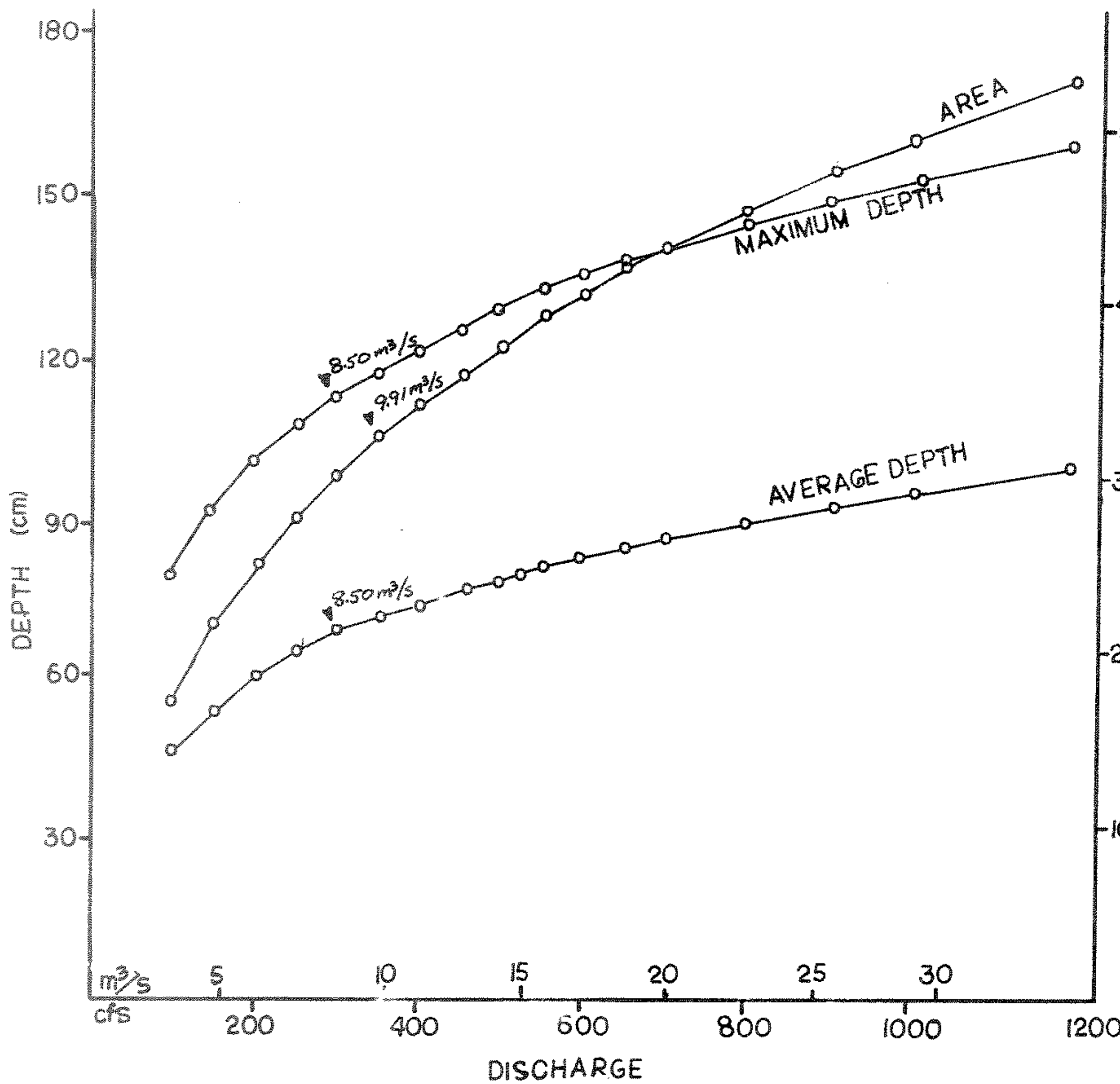


Figure 16. Average depth, maximum depth and cross section area vs. river discharge curves for a composite of five pool cross sections located in the Marias River, 1982.

Table 34. Flow reservation schedule for the Marias River below Tiber Dam.

| Period | Recommended Flow | | Ave. Percentile 1/ | | Fifty Percentile Flow Below Tiber Dam | | Fifty Percentile Flow Above Tiber Reservoir | |
|---|---|---|---|---|---|---|---|---|
| | $m^3/s$ | cfs | Rank | Acre Ft. | $m^3/s$ | cfs | $m^3/s$ | cfs |
| March 1-15 | 8.98 | 317 | 47.0 | 9,429 | 8.44 | 298 | 8.75 | 309 |
| March 16-31 | 14.16 | 500 | 43.5 | 15,864 | 10.82 | 382 | 13.40 | 473 |
| April | 14.16 | 500 | 65.9 | 29,745 | 24.64 | 870 | 30.31 | 1070 |
| May 1-18 | 14.16 | 500 | 86.9 | 17,847 | 37.75 | 1333 | 60.53 | 2137 |
| May 19-31 | 32.40 | 1144 | 76.3 | 29,492 | 39.65 | 1400 | 83.01 | 2931 |
| June | 32.40 2/ | 1144 | 70.8 3/ | 70,233 3/ | 47.87 | 1690 | 71.37 | 2520 |
| July 1-5 | 32.40 | 1144 | 61.9 | 11,343 | 38.92 | 1374 | 43.96 | 1552 |
| July 6-31 | 14.16 | 500 | 78.4 | 25,779 | 38.12 | 1346 | 23.54 | 831 |
| Aug | 14.16 | 500 | 81.1 | 30,736 | 27.11 | 957 | 9.46 | 334 |
| Sept | 14.16 | 500 | 83.8 | 29,745 | 28.323 | 1000 | 7.73 | 273 |
| Oct 1-15 | 14.16 | 500 | 71.1 | 14,872 | 28.07 | 991 | 8.58 | 303 |
| Oct 16-31 | 8.98 | 317 | 70.0 | 10,058 | 26.40 | 932 | 9.57 | 338 |
| Nov | 8.98 | 317 | 73.4 | 18,858 | 15.21 | 537 | 9.40 | 332 |
| Dec | 8.98 | 317 | 61.1 | 19,487 | 11.05 | 390 | 7.02 | 248 |
| Jan | 8.98 | 317 | 49.5 | 19,487 | 8.81 | 311 | 5.98 | 211 |
| Feb | 8.98 | 317 | 48.4 | 17,601 | 8.64 | 305 | 8.16 | 288 |
| | | | | 370,576 4/ | | | | |

1/ From USGS duration hydrograph for 19 year period between water years 1960-1978.
2/ Bankfull flow of 63.44 m3/sec (2240 cfs) for 24 hours should occur during June.
3/ Bankfull flow of 63.44 m3/sec included in this figure.
4/ This figure represents 75 percentile rank in terms of total acre-feet.

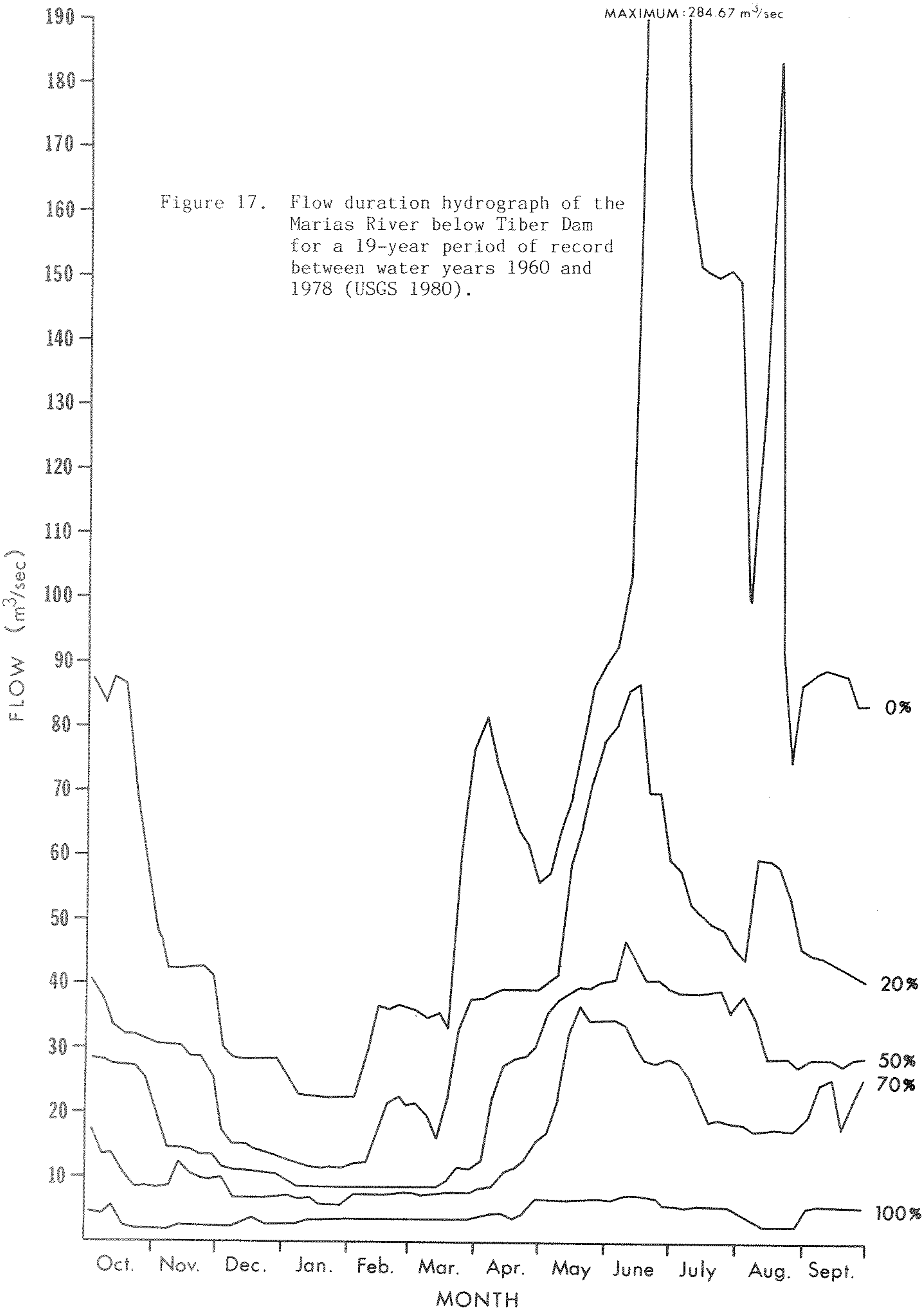


Figure 17. Flow duration hydrograph of the Marias River below Tiber Dam for a 19-year period of record between water years 1960 and 1978 (USGS 1980).

population estimates and age and growth studies for both whitefish and rainbow trout demonstrate that the basic conditions for salmonid growth are excellent. The cold-water releases from the hypolimnion of the reservoir are favorable for brown trout, rainbow trout and mountain whitefish growth. In addition, extensive riffle habitat in the river below the dam is well suited for aquatic insect production, the principal food items for rainbow trout and mountain whitefish. There is little off-channel development, however, and numbers of forage fish are limited.

At present, it appears that poor recruitment of young fish into the population is probably responsible for the low rainbow trout numbers. The primary limiting factor may be related to water release patterns from Tiber Dam which limit recruitment and suppress the fishery. Low flows probably contributed to poor spawning success of rainbow trout in 1982. Additionally, this study found that rearing of young-of-year (YOY) trout was associated with the large mats of filamentous algae anchored along the channel borders. If flows are too low during the summer, water depth and velocity conditions among the algal mats are reduced to the extent that they provide very little rearing habitat for YOY trout. Conversely, when flows are too great, the algal mats may be scoured or poorly developed.

Riverbank erosion appears to be a problem influencing the current fish populations. Stream bank erosion and lack of bank stability inhibit the establishment of good bank cover and limit the variety and abundance of fish populations. In addition, erosion widens the stream channel and necessitates a greater flow to maintain adequate wetted perimeter and depth.

In spite of the factors believed to be limiting the fish populations below Tiber Dam, excellent opportunities exist for the enhancement of the trout fishery in that area. Incorporation of the target instream flows developed from this study into the reservoir operation plan should improve the flow situation and result in increased trout production. It is recommended that this be accomplished. The instream flows identified for the winter period are particularly critical. Maintenance of existing temperature regimes and nutrient content of water released from the dam is necessary for this improvement to take place. If target instream flow releases result in reservoir water levels detrimental to northern pike and forage fish reproduction, alternate means of assuring such reproduction should be explored. Possibilities may include shoreline seeding of suitable vegetation as reservoir water levels recede or alternate operating plans considering periodic reservoir needs.

The riverbank erosion problem should be studied to determine the causative agents responsible for the erosion and to identify flow levels below which bank erosion does not occur. Means to improve the physical habitat in the Marias River below Tiber Dam should also be explored.

River and reservoir fish populations should be monitored to determine population response to target instream flows and any other enhancement measures that are undertaken. After sufficient information is gathered, the target instream flows schedule should be evaluated.

## LITERATURE CITED


Baumann, R. W., A. R. Gaufin and R. F. Surdick. 1977. The stoneflies (Plecoptera) of the Rocky Mountains. Mem. Amer. Entom. Soc. No. 31. 200 pp.

Berg, R. K. 1981. Fish populations of the Wild & Scenic Missouri River, Mt. Mont. Dept. Fish, Wildl. & Parks. Fed Aid to Fish & Wildl. Rest. Proj. FW-3R. Job Ia. 242 pp.

Bovee, K. D. 1974. The determination, assessment and design of "instream value" studies for the Northern Great Plains region. Univ. of Mont. Final Rept. Contr. No. 68-01-2413, Envir. Prot. Agency. 204 pp.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. Univ. of Calif. Pub. in Stat. 1(7):131-160.

Edmondson, W. T. (ed.). 1959. Freshwater biology. John Wiley & Sons, NY. 1248 pp.

Emmett, W. W. 1972. The hydraulic geometry of some Alaskan streams south of the Yukon River. US Geol. Survey open-file rept. 102 pp.

Gardner, W. M. and R. K. Berg. 1982. An analysis of the instream flow requirements for selected fishes in the wild and scenic portion of the Missouri River. Montana Department of Fish, Wildlife and Parks. 111 pp.

Garvin, W. H. and M. K. Botz. 1975. Water quality inventory and management plan Marias River Basin, Montana. Mont. Dept. Health & Environ. Sci. 118 pp.

Henderson, C., A. Inglis and W. L. Johnson. 1971. Organochlorine insecticide residues in fish - fall 1969. Pestic. Monit. J. 5:1-11.

Hinz, T. 1977. The effect of altered streamflow on migratory birds of the Yellowstone River Basin, Montana. Tech. Rept. No. 7, Yellowstone Impact Study. Final Rept. to the Old West Reg. Comm. Mont. Dept. Nat. Res. & Cons., Helena, Mont. 107 pp.

Hook, D. 1981. Middle Missouri River project. Fed. Aid to Fish and Wild. Rest. Proj. No. FW-3-R-7. Job Comp. Rept. Mont. Dept. Fish, Wild. and Parks. Helena. 354 pp.

Hynes, H. B. N. 1970. The ecology of running waters. Univ. of Toronto Press, Toronto, Canada. 555 pp.

Leopold, L. B., G. M. Wolman and J. P. Miller. 1964. Fluvial processes in geomorphology. W. H. Freeman and Co., San Francisco. 522 pp.

Merritt, R. W. and K. W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Pub. Co., Dubuque, Iowa. 441 pp.

Missouri River Basin Commission. 1978. Flow characteristics of selected streams in the upper Missouri River basin. 19 pp.

Nelson, F.A. 1977. Beaverhead River and Clark Canyon Reservoir fishery study. Montana Dept. of Fish & Game, Helena. 118 pp.

______________. 1980. Guidelines for using the wetted perimeter (WETP) computer program of the Montana Department of Fish, Wildlife and Parks. 23 pp.

Pennak, R. W. 1953. Freshwater invertebrates of the United States. The Ronald Press Co., New York, N. Y. 769 pp.

Peters, J. C. 1964. Age and growth studies and analysis of bottom samples in connection with pollution studies. Job. Comp. Rept., Fed. Aid to Fish and Wildl. Rest. Proj. No. F-23-R-6. Jobs I and II. 76 pp.

______________. 1982. Effects on river and streamflow alteration on fishery resources. American Fisheries Society Fisheries Bulletin, 7:20-22.

Posewitz, J. 1962. Central Montana fisheries study - a fish population investigation in the Marias River below Tiber Dam. Proj. No. F-5-R-11, Job IIa. 9 pp.

Purkett, C. A. 1961. Reproduction and early development of paddlefish. Trans. Am. Fish. Soc. 90(2): 125-129.

Smith, G. M. 1950. The fresh-water algae of the United States. McGraw-Hill Book Co. New York, N. Y. 719 pp.

Stober, Q. J. 1962. Some limnological effects of Tiber Reservoir. MS Thesis, Mont. St. Univ., Bozeman. 37 pp.

Tesch, F. W. 1971. Age and growth. In Methods for assessment of fish production in fresh waters. IBP handbook No. 3. Blackwell Scientific Pub., Oxford and Edinburgh, England. 348 pp.

US Bureau of Reclamation. 1973. Appendix H - sedimentation. Pp 789-795 in Design of small dams. US Govt. Print. Off., Washington.

USGS. 1978-1982. Water resources data for Montana. US Dept. of Interior.

_____________. 1980. Flow duration hydrograph for Marias River near Chester, Mt. 19-year period between water years 1960 and 1978.

_____________. 1980. Flow duration hydrograph for Teton River near Dutton, Mt. 19 -year period between water years 1960 and 1978.

Veithe, G. D. 1975. Baseline concentrations of polychlorinated biphenyls and DDT in Lake Michigan fish, 1971. Pestic. Monit. J. 9:21-29.

Vincent, E. R. 1971. River electrofishing and fish population estimates. Prog. Fish. Cult. 33:163-167.

_____________. 1974. Addendum to river electrofishing and fish population estimates. Prog. Fish. Cult. 36:182.

Wright, J. C. 1948. The limnology of Canyon Ferry Reservoir. I. Phytoplankton-zooplankton relationships in the euphotic zone during Sept. and Oct. 1956. Limnol. Oceanogr. 3:150-159.

APPENDIX

Appendix Table 1. Water storage levels in Tiber Dam 1983.

| Purpose | Elevations | Storage in Acre-feet |
|---|---|---|
| Crest | 3026.0 | 389,695 |
| Surcharge | 3012.5 to 3020.2 | 389,695 |
| Flood control | 2993.0 to 3012.5 | 187,740 |
| Conservation | 2966.4 to 2993.0 | 400,838 |
| Inactive | 2870.0 to 2966.4 | 556,043 |
| Dead | 2823.5 to 2870.0 | 21,582 |
| Total Storage Capacity | 2823.5 to 3020.2 | 1,555,898 |

Elevation of:

Auxiliary outlet = 2967 ft
River (hypolimnion) outlet = 2870 ft.

Appendix Table 2. Daily minimum and maximum water temperatures (degrees F) for the Marias River 5 km below Tiber Dam recorded during 1982.

| | July | | August | | September | | October | | November | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| 1 | | | 49 | 60.5 | 50 | 61 | 50 | 54 | 43.5 | 48.5 |
| 2 | | | 49 | 61 | 51 | 63 | 49 | 58.5 | 43.5 | 51 |
| 3 | | | 50 | 59 | 51 | 64 | 50 | 58 | 42 | 48 |
| 4 | | | 50 | 61 | 52 | 62.5 | 48.5 | 54 | 40 | 46 |
| 5 | | | 50 | 62 | 50 | 61.5 | No data | | 42.5 | 50.5 |
| 6 | | | 50.5 | 61.5 | 50 | 64 | No data | | 42.5 | 47 |
| 7 | | | 50.5 | 62 | 50 | 63 | 48 | 53.5 | 40 | 48 |
| 8 | | | 50 | 61.5 | 51 | 64 | 47.5 | 57.5 | 40 | 45 |
| 9 | | | 52 | 57 | 50 | 63 | 46.5 | 58 | 42 | 44 |
| 10 | | | 50.5 | 62 | 52 | 61 | 46.5 | 59 | 41 | 48 |
| 11 | | | 51.5 | 62 | 48.5 | 60 | 48 | 61.5 | 38 | 43 |
| 12 | | | 51 | 60 | 49 | 57 | 50 | 60.5 | 36 | 41.5 |
| 13 | | | 50 | 62 | 48 | 53.5 | 49 | 61.5 | 38 | 43 |
| 14 | | | 51 | 61 | 48.5 | 55 | 50.5 | 63 | 36 | 43 |
| 15 | | | 51 | 61 | 48.5 | 62 | 50 | 62.5 | 38 | 42.5 |
| 16 | | | 51 | 62 | 50 | 60 | 51 | 58 | 38.5 | 42 |
| 17 | | | 51.5 | 62 | 48 | 62.5 | 47.5 | 55 | 39 | 44.5 |
| 18 | | | 52 | 62 | 48 | 62.5 | 53.5 | 47 | 40 | 43 |
| 19 | | | 52 | 61.5 | 49 | 62 | 45 | 54 | 36 | 41 |
| 20 | 48.5 | 57 | 50.5 | 60 | 48 | 63 | 45 | 55.5 | 36 | |
| 21 | 48.5 | 58 | 51 | 61.5 | 50 | 62 | 44 | 55 | | |
| 22 | 48.5 | 58.5 | 51 | 61 | 49 | 62.5 | 47 | 56 | | |
| 23 | 48.5 | 58.5 | 51 | 56.5 | 50 | 62.5 | 48.5 | 58 | | |
| 24 | 48 | 58 | 50.5 | 62 | 50 | 63 | 47 | 57 | | |
| 25 | 49.5 | 57.5 | 50 | 61.5 | 53 | 67 | 46 | 57 | | |
| 26 | 49 | 60 | 50.5 | 56 | 54 | 60 | 48.5 | 54 | | |
| 27 | 48.5 | 60 | 50 | 62 | 51.5 | 56 | 45 | 51 | | |
| 28 | 48 | 61 | 50.5 | 61 | 50 | 55 | 43.5 | 51 | | |
| 29 | 49 | 61 | 50.5 | 60 | 49 | 53 | 45 | 52.5 | | |
| 30 | 49 | 61 | 51 | 59 | 50 | 62 | 43 | 53 | | |
| 31 | 49 | 60 | 50 | 60.5 | | | 43 | 50.5 | | |

Appendix Table 2 continued. Daily minimum and maximum water temperatures (degrees C) for the Marias River 5 km below Tiber Dam recorded during 1982.

| | July | | August | | September | | October | | November | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| 1 | | | 9.5 | 15.9 | 10.0 | 16.1 | 10.0 | 12.2 | 6.4 | 9.2 |
| 2 | | | 9.5 | 16.1 | 10.5 | 17.2 | 9.5 | 14.7 | 6.4 | 10.5 |
| 3 | | | 10.0 | 15.0 | 10.5 | 17.8 | 10.0 | 14.5 | 5.6 | 8.9 |
| 4 | | | 10.0 | 16.1 | 11.1 | 17.0 | 9.2 | 12.2 | 4.4 | 7.8 |
| 5 | | | 10.0 | 16.7 | 10.0 | 16.4 | | | 5.6 | 10.3 |
| 6 | | | 10.3 | 16.4 | 10.0 | 17.8 | | | 5.6 | 8.3 |
| 7 | | | 10.3 | 16.7 | 10.0 | 17.2 | 8.9 | 12.0 | 4.4 | 8.9 |
| 8 | | | 10.0 | 16.4 | 10.5 | 17.8 | 8.6 | 14.2 | 4.4 | 7.2 |
| 9 | | | 11.1 | 14.0 | 10.0 | 17.2 | 8.1 | 14.5 | 5.6 | 6.7 |
| 10 | | | 10.3 | 16.7 | 11.1 | 16.1 | 8.1 | 15.0 | 5.0 | 8.9 |
| 11 | | | 10.8 | 16.7 | 9.2 | 15.6 | 8.9 | 16.4 | 3.3 | 6.1 |
| 12 | | | 10.5 | 15.6 | 9.5 | 14.0 | 10.0 | 15.9 | 2.2 | 5.3 |
| 13 | | | 10.0 | 16.7 | 8.9 | 12.0 | 9.5 | 16.4 | 3.3 | 6.1 |
| 14 | | | 10.5 | 16.1 | 9.2 | 12.8 | 10.3 | 17.2 | 2.2 | 6.1 |
| 15 | | | 10.5 | 16.1 | 9.2 | 16.7 | 10.0 | 17.0 | 3.3 | 5.8 |
| 16 | | | 10.5 | 16.7 | 10.0 | 15.6 | 10.5 | 14.5 | 3.6 | 5.6 |
| 17 | | | 10.8 | 16.7 | 8.9 | 17.0 | 8.6 | 12.8 | 3.9 | 6.7 |
| 18 | | | 11.1 | 16.7 | 8.9 | 17.0 | 6.4 | 8.3 | 4.4 | 6.1 |
| 19 | | | 11.1 | 16.4 | 9.5 | 16.7 | 7.2 | 12.2 | 2.2 | 5.0 |
| 20 | 9.2 | 14.0 | 10.3 | 15.6 | 8.9 | 17.2 | 7.2 | 13.1 | 2.2 | |
| 21 | 9.2 | 14.5 | 10.5 | 16.4 | 10.0 | 16.7 | 6.7 | 12.8 | | |
| 22 | 9.2 | 14.7 | 10.5 | 16.1 | 9.5 | 17.0 | 8.3 | 13.3 | | |
| 23 | 9.2 | 14.7 | 10.5 | 13.6 | 10.0 | 17.0 | 9.2 | 14.5 | | |
| 24 | 8.9 | 14.5 | 10.3 | 16.7 | 10.0 | 17.2 | 8.3 | 14.0 | | |
| 25 | 9.9 | 14.2 | 10.0 | 16.4 | 11.7 | 19.5 | 7.8 | 14.0 | | |
| 26 | 9.5 | 15.6 | 10.3 | 13.3 | 12.2 | 15.6 | 9.2 | 12.2 | | |
| 27 | 9.2 | 15.6 | 10.0 | 16.7 | 10.8 | 13.3 | 7.2 | 10.5 | | |
| 28 | 8.9 | 16.1 | 10.3 | 16.1 | 10.0 | 12.8 | 6.4 | 10.5 | | |
| 29 | 9.5 | 16.1 | 10.3 | 15.6 | 9.5 | 11.7 | 7.2 | 11.4 | | |
| 30 | 9.5 | 16.1 | 10.5 | 15.0 | 10.0 | 16.7 | 6.1 | 11.7 | | |
| 31 | 9.5 | 15.6 | 10.0 | 15.9 | | | 6.1 | 10.3 | | |

Appendix Table 3. Daily minimum and maximum water temperatures (degrees F) for the Marias River 33.7 km below Tiber Dam (Dugout Coulee section) recorded during 1982.

| | March | | April | | May | | June | | July | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| 1 | | | 40 | 42 | 46 | 53 | 50 | 52.5 | | |
| 2 | | | 37 | 40 | | | 50.5 | 52 | | |
| 3 | | | 35 | 37 | | | 50 | 52 | | |
| 4 | | | 34.5 | 35 | | | 51 | 52.5 | | |
| 5 | | | 34.5 | 39.5 | | | 51 | 53 | | |
| 6 | | | 38 | 39 | | | 51.5 | 54 | | |
| 7 | | | 35 | 38 | | | 51.5 | 53 | | |
| 8 | | | 34.5 | 37 | | | 51 | 52 | 56 | 60.5 |
| 9 | | | 37 | 42.5 | | | 51 | 54 | 53.5 | 60 |
| 10 | | | 40 | 44 | | | 52 | 54 | 53 | 58.5 |
| 11 | | | 41.5 | 45 | | | 52 | 56 | 53 | 58.5 |
| 12 | | | 43.5 | 48 | | | 52 | 55.5 | 53 | 58.5 |
| 13 | | | 44 | 49.5 | | | 52 | 55.5 | 53 | 60 |
| 14 | | | 46 | 49 | 51 | 55 | 52.5 | 54 | 54.5 | 60 |
| 15 | | | 43 | 46 | 52.5 | 55.5 | 53 | 56 | 54.5 | 59.5 |
| 16 | | | 40 | 45 | 53 | 55.5 | 54 | 57.5 | 55 | 58 |
| 17 | | | 42 | 46.5 | 53 | 56 | 55.5 | 57.5 | 52.5 | 58 |
| 18 | | | 43 | 45.5 | 54 | 57 | 56 | 57 | 55.5 | 58 |
| 19 | | | 40 | 44 | 52 | 56 | | | 56 | 61 |
| 20 | | | 40.5 | 46.5 | 50 | 53 | | | 57 | 61 |
| 21 | | | 43 | 51 | 50.5 | 55.5 | | | 58 | 62 |
| 22 | | | 46.5 | 54 | 51 | 54 | | | 60 | 63 |
| 23 | | | 48.5 | 55 | 50.5 | 54.5 | | | 60 | 63 |
| 24 | | | 49.5 | 53.5 | 50 | 52.5 | | | 59 | 62 |
| 25 | | | 47 | 51 | 51 | 54 | | | 60 | 63 |
| 26 | | | 46 | 52 | 50 | 55 | | | 60 | 63 |
| 27 | | | 48 | 55 | 49 | 50 | | | 61 | 64 |
| 28 | | | 49 | 54 | 49 | 49.5 | | | 61 | 65.5 |
| 29 | | | 44 | 49.5 | 48 | 49 | | | 62.5 | 67 |
| 30 | 41 | 44 | 44.5 | 49.5 | 48 | 48.5 | | | 63 | 67 |
| 31 | 40 | 43.5 | | | 48 | 51.5 | | | 63.5 | 66.5 |

Appendix Table 3 continued.

| Day | August Min | August Max | September Min | September Max | October Min | October Max | November Min | November Max |
|---|---|---|---|---|---|---|---|---|
| 1 | 62.5 | 66.5 | 57 | 60 | 50 | 51 | 41.5 | 42 |
| 2 | 61 | 66 | 48 | 61 | 49.5 | 52 | 41 | 42 |
| 3 | 61 | 64 | 59 | 63 | 51 | 52.5 | 39.5 | 41 |
| 4 | 58.5 | 63 | 60 | 63 | 50 | 51 | 39 | 40 |
| 5 | 60.5 | 64.5 | 57.5 | 61 | 50 | 51 | 39 | 41 |
| 6 | 62 | 65 | 57 | 61 | 49 | 52 | 40 | 41 |
| 7 | 62 | 65 | 57.5 | 61 | 48.5 | 50 | 38.5 | 40 |
| 8 | 61.5 | 64 | 58 | 62 | 47 | 49 | 37 | 38.5 |
| 9 | 60 | 63.5 | 58.5 | 62 | 46 | 48.5 | 37 | 37 |
| 10 | 58.5 | 64 | No data | | 46 | 49 | 37 | 38.5 |
| 11 | 62.5 | 66 | 55 | 57 | 47 | 50.5 | | |
| 12 | 61 | 64 | 52 | 56 | 49.5 | 52 | | |
| 13 | 59 | 63.5 | 49 | 52 | 50 | 53 | | |
| 14 | 61 | 64 | 49 | 50 | 51.5 | 54.5 | | |
| 15 | 59.5 | 63 | 49 | 54 | 52 | 54.5 | | |
| 16 | 61 | 64 | 53.5 | 56 | 53 | 54 | | |
| 17 | 62 | 65 | 52.5 | 56 | 49 | 53 | | |
| 18 | 62.5 | 65.5 | 53 | 57 | 43 | 49 | | |
| 19 | 62 | 65 | 54 | 57 | 42 | 43 | | |
| 20 | 62 | 65 | 53 | 56 | 41.5 | 44 | | |
| 21 | 61 | 64.5 | 54 | 57 | 43 | 45 | | |
| 22 | 61 | 64 | 54 | 57 | 44 | 47.5 | | |
| 23 | 59.5 | 62 | 55.5 | 58 | 47 | 50 | | |
| 24 | 56 | 61 | 55 | 57.5 | 47.5 | 49.5 | | |
| 25 | 59 | 62 | 56 | 59.5 | 47.5 | 49 | | |
| 26 | 57.5 | 62 | 57 | 59 | 48 | 49 | | |
| 27 | 55 | 60 | 53 | 57 | 46.5 | 49 | | |
| 28 | 58.5 | 61 | 50.5 | 53 | 44 | 46.5 | | |
| 29 | 58 | 61 | 49 | 50.5 | 43 | 44 | | |
| 30 | 57.5 | 60 | 48.5 | 51 | 42 | 43.5 | | |
| 31 | 56 | 59 | | | 41.5 | 42.5 | | |

Appendix Table 3 continued. Daily minimum and maximum water temperatures (degrees C) for the Marias River 33.7 km below Tiber Dam (Dugout Coulee Section) recorded during 1982.

| | March | | April | | May | | June | | July | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| 1 | | | 4.4 | 5.6 | | | 10.0 | 11.4 | | |
| 2 | | | 2.8 | 4.4 | | | 10.3 | 11.1 | | |
| 3 | | | 1.7 | 2.8 | | | 10.0 | 11.1 | | |
| 4 | | | 1.4 | 1.7 | | | 10.5 | 11.4 | | |
| 5 | | | 1.4 | 4.2 | | | 10.5 | 11.7 | | |
| 6 | | | 3.3 | 3.9 | | | 10.8 | 12.2 | | |
| 7 | | | 1.7 | 3.3 | | | 10.8 | 11.7 | | |
| 8 | | | 1.4 | 2.8 | | | 10.5 | 11.1 | 13.3 | 15.9 |
| 9 | | | 2.8 | 5.8 | | | 10.5 | 12.2 | 12.0 | 15.6 |
| 10 | | | 4.4 | 6.7 | | | 11.1 | 12.2 | 11.7 | 14.7 |
| 11 | | | 5.3 | 7.2 | | | 11.1 | 13.3 | 11.7 | 14.7 |
| 12 | | | 6.4 | 8.9 | | | 11.1 | 13.1 | 11.7 | 14.7 |
| 13 | | | 6.7 | 9.7 | | | 11.1 | 13.1 | 11.7 | 15.6 |
| 14 | | | 7.8 | 9.5 | 10.5 | 12.8 | 11.4 | 12.2 | 12.5 | 15.6 |
| 15 | | | 6.1 | 7.8 | 11.4 | 13.1 | 11.7 | 13.3 | 12.5 | 15.3 |
| 16 | | | 4.4 | 7.2 | 11.7 | 13.1 | 12.2 | 14.2 | 12.8 | 14.5 |
| 17 | | | 5.6 | 8.1 | 11.7 | 13.3 | 13.1 | 14.2 | 11.4 | 14.5 |
| 18 | | | 6.1 | 7.5 | 12.2 | 14.0 | 13.3 | 14.0 | 13.1 | 14.5 |
| 19 | | | 4.4 | 6.7 | 11.1 | 13.3 | | | 13.3 | 16.1 |
| 20 | | | 4.7 | 8.1 | 10.0 | 11.7 | | | 14.0 | 16.1 |
| 21 | | | 6.1 | 10.5 | 10.3 | 13.1 | | | 14.5 | 16.7 |
| 22 | | | 8.1 | 12.2 | 10.5 | 12.2 | | | 15.6 | 17.2 |
| 23 | | | 9.2 | 12.8 | 10.3 | 12.5 | | | 15.6 | 17.2 |
| 24 | | | 9.7 | 12.0 | 10.0 | 11.4 | | | 15.0 | 16.7 |
| 25 | | | 8.3 | 10.5 | 10.5 | 12.2 | | | 15.6 | 17.2 |
| 26 | | | 7.8 | 11.1 | 10.0 | 12.8 | | | 15.6 | 17.2 |
| 27 | | | 8.9 | 12.8 | 9.5 | 10.0 | | | 16.1 | 17.8 |
| 28 | | | 9.5 | 12.2 | 9.5 | 9.7 | | | 16.1 | 18.6 |
| 29 | | | 6.7 | 9.7 | 8.9 | 9.5 | | | 17.0 | 19.5 |
| 30 | 5.0 | 6.7 | 7.0 | 9.7 | 8.9 | 9.2 | | | 17.2 | 19.5 |
| 31 | 4.4 | 6.4 | | | 8.9 | 10.8 | | | 17.5 | 19.2 |

Appendix Table 3 continued. Daily minimum and maximum water temperatures (degrees C) for the Marias River 33.7 km below Tiber Dam (Dugout Coulee Section) recorded during 1982.

| | August | | September | | October | | November | |
|---|---|---|---|---|---|---|---|---|
| Day | Min | Max | Min | Max | Min | Max | Min | Max |
| 1 | 17.0 | 19.2 | 13.9 | 15.6 | 10.0 | 10.6 | 5.3 | 5.6 |
| 2 | 16.1 | 18.9 | 14.5 | 16.1 | 9.8 | 11.1 | 5.0 | 5.6 |
| 3 | 16.1 | 17.8 | 15.0 | 17.2 | 10.6 | 11.4 | 4.2 | 5.0 |
| 4 | 14.7 | 17.2 | 15.6 | 17.2 | 10.0 | 10.6 | 3.9 | 4.4 |
| 5 | 15.9 | 18.1 | 14.2 | 16.1 | 10.0 | 10.6 | 3.9 | 5.0 |
| 6 | 16.7 | 18.3 | 13.9 | 16.1 | 9.5 | 11.1 | 4.4 | 5.0 |
| 7 | 16.7 | 18.3 | 14.2 | 16.1 | 9.2 | 10.0 | 3.6 | 4.4 |
| 8 | 16.4 | 17.8 | 14.5 | 16.7 | 8.3 | 9.5 | 2.7 | 3.6 |
| 9 | 15.6 | 17.5 | 14.7 | 16.7 | 7.8 | 9.2 | 2.7 | 2.7 |
| 10 | 14.7 | 17.8 | | | 7.8 | 9.5 | 2.7 | 3.6 |
| 11 | 17.0 | 18.9 | 12.8 | 13.3 | 8.3 | 10.3 | | |
| 12 | 16.1 | 17.8 | 11.1 | 13.3 | 9.8 | 11.1 | | |
| 13 | 15.0 | 17.5 | 9.5 | 11.1 | 10.0 | 11.7 | | |
| 14 | 16.1 | 17.8 | 9.5 | 10.0 | 10.6 | 12.5 | | |
| 15 | 15.3 | 17.2 | 9.5 | 12.2 | 11.1 | 12.2 | | |
| 16 | 16.1 | 17.8 | 12.0 | 13.3 | 11.7 | 12.2 | | |
| 17 | 16.7 | 18.3 | 11.4 | 13.3 | 9.5 | 11.7 | | |
| 18 | 17.0 | 18.6 | 11.7 | 13.9 | 6.1 | 9.5 | | |
| 19 | 16.7 | 18.3 | 12.2 | 13.9 | 5.6 | 6.1 | | |
| 20 | 16.7 | 18.3 | 11.7 | 13.3 | 5.3 | 6.7 | | |
| 21 | 16.1 | 18.1 | 12.2 | 13.9 | 6.1 | 7.2 | | |
| 22 | 16.1 | 17.8 | 12.2 | 13.9 | 6.7 | 8.6 | | |
| 23 | 15.3 | 16.7 | 13.1 | 14.5 | 8.3 | 10.0 | | |
| 24 | 13.3 | 16.1 | 12.8 | 14.2 | 8.6 | 9.8 | | |
| 25 | 15.0 | 16.7 | 13.3 | 15.3 | 8.6 | 9.5 | | |
| 26 | 14.2 | 16.7 | 13.9 | 15.0 | 8.9 | 9.5 | | |
| 27 | 12.8 | 15.6 | 11.7 | 13.9 | 8.1 | 9.5 | | |
| 28 | 14.7 | 16.1 | 10.3 | 11.7 | 6.7 | 8.1 | | |
| 29 | 14.5 | 16.1 | 9.5 | 10.3 | 6.1 | 6.7 | | |
| 30 | 14.2 | 15.6 | 9.2 | 10.6 | 5.6 | 6.4 | | |
| 31 | 13.3 | 15.0 | | | 5.0 | 5.8 | | |

Appendix Table 4. Numbers of aquatic macroinvertebrates collected (per sample period) below Tiber Dam November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Mayfly | | | | |
| *Baetis* | 13 | 197 | 145 | 56 |
| *Heptagenia* | | | | |
| *Rhithrogena* | | 1 | | |
| *Stenonema* | | | | |
| *Ephemerella* | 153 | 209 | 310 | 147 |
| *Tricorythodes* | 2 | | | |
| *Choroterpes* | | | | |
| *Leptophlebia* | | | | |
| *Ephemera* | | | | |
| Total | 168 | 407 | 455 | 203 |
| Stonefly | | | | |
| *Pteronarcys* | | | | |
| Capniidae | | | | |
| *Claassenia* | | | | |
| *Isogenoides* | | | | |
| *Isoperla* | 3 | 56 | 33 | |
| Chloroperlidae | | | | |
| Total | 3 | 56 | 33 | 0 |
| Caddisfly | | | | |
| *Cheumatopsyche* | 1 | | | |
| *Hydropsyche* | 1 | 20 | 7 | |
| *Glossosoma* | | 60 | 43 | |
| *Agraylea* | 4 | | | 1 |
| *Brachycentrus* | | | | |
| *Lepidostoma* | | | | |
| *Helicopsyche* | | | | |
| *Leptocerus* | | | | |
| *Oecetis* | 3 | | | 1 |
| Total | 9 | 80 | 50 | 2 |

Appendix Table 4 continued. Numbers of aquatic macroinvertebrates collected (per sample period) below Tiber Dam November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Diptera | | | | |
| *Tipula* | 2 | | | |
| *Simulium* | | | | 2 |
| Chironomidae | 9 | 12 | 4 | 131 |
| *Chrysops* | 4 | | | |
| Total | 15 | 12 | 4 | 133 |
| Others | | | | |
| *Ophiogomphus* | | | | |
| Corixidae | | | | |
| Elmidae | | | | |
| *Hyallella* | 2 | | | |
| Oligochaeta | | 2 | 2 | 9 |
| *Physa* | 3 | | | 1 |
| *Gyraulus* | | 1 | | |
| *Ferrissia* | | | | |
| Pelecypoda | | | | |
| Total | 5 | 3 | 2 | 10 |

Appendix Table 5. Numbers of aquatic macroinvertebrates collected (per sample period) near Pugsley Bridge November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Mayfly | | | | |
| *Baetis* | 39 | 716 | 107 | 45 |
| *Heptagenia* | 3 | | | |
| *Rhithrogena* | 19 | 18 | 1 | 2 |
| *Stenonema* | 6 | | | |
| *Ephemerella* | 24 | 177 | 98 | 278 |
| *Tricorythodes* | 4 | 3 | | |
| *Choroterpes* | 3 | | | |
| *Leptophlebia* | 1 | | | |
| *Ephemera* | | | | |
| Total | 99 | 914 | 206 | 325 |
| Stonefly | | | | |
| *Pteronarcys* | | | | |
| Capniidae | | | | |
| *Claassenia* | | | | |
| *Isogenoides* | 3 | | | |
| *Isoperla* | 53 | 315 | 14 | 32 |
| Chloroperlidae | 20 | | | |
| Total | 76 | 315 | 14 | 32 |
| Caddisfly | | | | |
| *Cheumatopsyche* | 67 | 52 | | 2 |
| *Hydropsyche* | 269 | 120 | 3 | 16 |
| *Glossosoma* | | 13 | | 7 |
| *Agraylea* | 4 | | 3 | 3 |
| *Brachycentrus* | 1 | 1 | | |
| *Lepidostoma* | | | | |
| *Helicopsyche* | | | | |
| *Leptocerus* | | | | |
| *Oecetis* | 18 | 8 | | 17 |
| Total | 359 | 194 | 6 | 45 |

Appendix Table 5 continued. Numbers of aquatic macroinvertebrates collected (per sample period) near Pugsly Bridge November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Diptera | | | | |
| *Tipula* | 1 | | | |
| *Simulium* | | | | |
| Chironomidae | 14 | 28 | 9 | 23 |
| *Chrysops* | | | | |
| Total | 15 | 28 | 9 | 23 |
| Others | | | | |
| *Ophiogomphus* | | | | |
| Corixidae | | | | |
| Elmidae | 2 | | | |
| *Hyallella* | 2 | | | |
| Oligochaeta | 2 | 3 | | 3 |
| *Physa* | 3 | 1 | 1 | |
| *Gyraulus* | | | | |
| *Ferrissia* | | | | |
| Pelecypoda | | | | |
| Total | 9 | 4 | 1 | 3 |

Appendix Table 6. Numbers of aquatic macroinvertebrates collected (per sample period) near Moffat Bridge, November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Mayfly | | | | |
| *Baetis* | 6 | 138 | 147 | 203 |
| *Heptagenia* | 2 | | 1 | |
| *Rhithrogena* | 249 | 184 | 47 | 19 |
| *Stenonema* | | | 1 | |
| *Ephemerella* | 1 | 17 | 173 | 156 |
| *Tricorythodes* | 1 | 1 | | 1 |
| *Choroterpes* | | | | |
| *Leptophlebia* | | | | |
| *Ephemera* | | | 3 | |
| *Ameletus* | | | | 1 |
| Total | 259 | 340 | 372 | 380 |
| Stonefly | | | | |
| *Pteronarcys* | | 1 | | |
| Capniidae | | | | |
| *Claassenia* | 4 | 7 | | |
| *Isogenoides* | 32 | 23 | 2 | 78 |
| *Isoperla* | | 36 | 136 | |
| Chloroperlidae | 7 | | | |
| Total | 43 | 67 | 138 | 78 |
| Caddisfly | | | | |
| *Cheumatopsyche* | 64 | 131 | 8 | |
| *Hydropsyche* | 256 | 391 | 21 | 57 |
| *Glossosoma* | 2 | 7 | | |
| *Agraylea* | | | | |
| *Brachycentrus* | 2 | | | 3 |
| *Lepidostoma* | | | | |
| *Helicopsyche* | 1 | 1 | | |
| *Leptocerus* | | | | |
| *Oecetis* | 1 | 2 | 1 | 10 |
| Total | 326 | 532 | 30 | 70 |

Appendix Table 6 continued. Numbers of aquatic macroinvertebrates collected (per sample period) near Moffat Bridge, November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Diptera | | | | |
| *Tipula* | | 2 | 12 | |
| *Simulium* | | | | 11 |
| Chironomidae | 4 | 16 | | 28 |
| *Chrysops* | | | | |
| Total | 4 | 18 | 12 | 39 |
| Others | | | | |
| *Ophiogomphus* | | | | 2 |
| Corixidae | 1 | | | |
| Elmidae | 4 | | 1 | |
| *Hyalella* | | | 1 | |
| Oligocharta | 7 | | 21 | |
| *Physa* | | | 3 | |
| *Gyraulus* | 4 | | | |
| *Ferrissia* | | | | |
| Pelecypoda | | | | |
| Total | 16 | 0 | 27 | 2 |

Appendix Table 7. Numbers of aquatic macroinvertebrates collected (per sample period) near Circle Bridge November 10, 1981 through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Mayfly | | | | |
| *Baetis* | 20 | 37 | 3 | 108 |
| *Heptagenia* | 16 | | | |
| *Rhithrogena* | 9 | 44 | 6 | 13 |
| *Stenonema* | 139 | 67 | 7 | 6 |
| *Ephemerella* | 4 | 2 | 15 | 31 |
| *Tricorythodes* | 2 | | | 10 |
| *Choroterpes* | 2 | | | |
| *Leptophlebia* | 1 | | | |
| *Ephemera* | 4 | | | |
| Total | 197 | 150 | 31 | 168 |
| Stonefly | | | | |
| *Pteronarcys* | | | | |
| Capniidae | | 1 | | |
| *Claassenia* | | | 1 | 11 |
| *Isogenoides* | 7 | 14 | | 3 |
| *Isoperla* | 13 | 71 | 1 | |
| Chloroperlidae | | 1 | | |
| Total | 20 | 87 | 2 | 14 |
| Caddisfly | | | | |
| *Cheumatopsyche* | 46 | 31 | | 2 |
| *Hydropsyche* | 176 | 122 | 4 | 16 |
| *Glossosoma* | 1 | | | 1 |
| *Agraylea* | | | | [illegible] |
| *Brachycentrus* | 11 | 5 | 1 | 76 |
| *Lepidostoma* | 2 | | | |
| *Helicopsyche* | 4 | 2 | 2 | |
| *Leptocerus* | 2 | 1 | 2 | 1 |
| *Oecetis* | 12 | 4 | 1 | 1 |
| Total | 254 | 165 | 10 | 134 |

Appendix Table 7 continued. Numbers of aquatic macroinvertebrates collected (per sample period) near Circle Bridge November 10, 1981, through July 20, 1982.

| Organism | Fall | Winter | Spring | Summer |
|---|---|---|---|---|
| Diptera | | | | |
| *Tipula* | | | | |
| *Simulium* | 7 | | | 12 |
| Chironomidae | 43 | 263 | 3 | 105 |
| *Chrysops* | | | | |
| Total | 50 | 263 | 3 | 117 |
| Others | | | | |
| *Ophiogomphus* | | 2 | | 2 |
| Corixidae | | | | |
| Elmidae | 4 | 2 | | |
| *Hyalella* | 4 | 2 | | |
| Oligochaeta | 21 | 4 | 11 | 2 |
| *Physa* | 6 | 1 | 4 | 1 |
| *Gyraulus* | 5 | 13 | | 1 |
| *Ferrissia* | 2 | 6 | | |
| Pelecypoda | 5 | 5 | | |
| Total | 47 | 35 | 15 | 6 |