Evaluation of Management of Water Releases for Painted Rocks Reservoir, Bitterroot River, Montana

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Final Report

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EVALUATION OF MANAGEMENT OF WATER RELEASES FOR PAINTED ROCKS RESERVOIR, BITTERROOT RIVER, MONTANA

Final Report

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EXECUTIVE SUMMARY

This study was initiated in July, 1983 to develop a water management plan for the release of water purchased from Painted Rocks Reservoir. Releases were designed to provide optimum benefits to the Bitterroot River fishery. Fisheries, habitat, and stream flow information was gathered to evaluate the effectiveness of these supplemental releases in improving trout populations in the Bitterroot River. The study was part of the Northwest Power Planning Council's Fish and Wildlife Program and was funded by the Bonneville Power Administration. This report presents data collected from 1983 through 1986.

Approximately 15,000 AF of supplemental reservoir water was released annually into the Bitterroot River during summer periods from 1983 through 1986. Supplemental releases significantly enhanced summer flows upstream from Hamilton during all years, but were insufficient to maintain minimum flow recommendations in the dewatered section during years with low stream flow (1985 and 1986). Most water released failed to reach the dewatered section because of losses to irrigation withdrawals. Losses to irrigation systems were greatest when river flows were lowest and large, gravel dikes were constructed to divert water. Irrigators were willing to cooperate in maintaining flows in the river, but efforts to do so were limited by the complexity and inefficiency of the canal network.

The relatively low trout numbers observed in the dewatered section (Tucker), compared to the control section (Darby), indicates that poor stream flows adversely effect trout populations in the Bitterroot River. Dewatering appears to result in reduced survival of young-of-the-year trout, which may consequently limit the size of the adult population. The number of yearling brown trout in the Tucker section increased following years with adequate flows, and declined following the drought of 1985. In contrast, survival, growth rates, and condition factors of adult trout in the Tucker section were not adversely effected by dewatering. The deep pools, cooled by groundwater inflows, in the dewatered section appeared to provide adequate habitat for adult trout during relatively brief periods of critically low flow.

Supplemental releases from Painted Rocks Reservoir have enhanced the rainbow trout population in the control section (Darby). Rainbow trout numbers increased by over 200 percent during the period of releases. Although changes in fishing regulations took effect during this period, increases in numbers most likely were a result of enhanced flows since the majority of the population increase occurred in young age classes less effected by regulation changes that were designed to protect larger trout.

Stream flow levels in the lower Bitterroot River are replenished by irrigation returns and are typically maintained above minimum recommended levels. Consequently, the low trout population levels observed in this area (Poker Joe section) was unexpected. Comparisons of age structure and YOY densities among different study sections indicate that inadequate recruitment or rearing habitat may limit the trout population in the lower river. Since spawning trout migrate from the lower river to the dewatered section (and associated tributaries) in significant numbers, the dewatered section may be an important source of recruitment. Therefore, low stream flows in the Tucker section which reduce YOY survival may also negatively influence trout populations in the lower river. In addition, losses of YOY emigrants to tributary irrigation diversions was observed, but the extent of the problem was not determined.

Minimum instream flow recommendations obtained from wetted perimeter-discharge relationships averaged 8.63 m^3/sec (304 ft^3/sec) in the Darby area, 11.41 m^3/sec (402 ft^3/sec) for the dewatered section, and 8.50 m^3/sec (300 ft^3/sec) for the section rewatered by irrigation returns. The minimum recommended flow for the lower segment of the West Fork of the Bitterroot River was 5.11 m^3/sec (180 ft^3/sec). A flow of 4.25 m^3/sec (150 ft^3/sec) provided the minimum depth and width criteria needed to float drift boats or rafts over the shallow riffle areas in the Bitterroot River.

INTRODUCTION

The Bitterroot River, located in western Montana, is an important and heavily used resource, providing water for agriculture and many forms of recreation. Water shortages in the river, however, have been a persistent problem for both irrigators and recreational users. Five major diversions and numerous smaller canals remove substantial quantities of water from the river during the irrigation season. The river has historically suffered from reduced stream flows between the towns of Hamilton and Stevensville as a result of these withdrawals, and critical dewatering frequently occurs between Woodside crossing and Bell crossing (Figure 1).

Demands for irrigation water from the Bitterroot River have often conflicted with the instream flow needs for trout. Withdrawals of water can decrease availability of suitable depth, velocity, substrate and cover for trout (Stalnaker and Arnette 1976, Wesche 1976). Habitat losses associated with dewatering have been shown to diminish the carrying capacities for trout populations (Nelson 1980). Additionally, dewatering of the Bitterroot River has forced irrigators to dike or channelize the streambed to obtain needed flows. These alterations reduce aquatic habitat and degrade channel stability. Odell (pers. comm.) found a substantial reduction in the total biomass of aquatic insects within a section of the Bitterroot River that had been bulldozed for irrigation purposes.

In 1983, the Montana Department of Fish, Wildlife and Parks (MDFWP) submitted a proposal to the Northwest Power Planning Council for the purchase of 10,000 acre-feet (AF) of stored water in Painted Rocks Reservoir. The water would be managed by MDFWP in conjunction with the 5,000 AF presently contolled by MDFWP. The goal of the proposed purchase of water was to augment summer stream flows in the Bitterroot River to benefit the trout fishery.

The present study was undertaken to: 1) develop an implementable water management plan for supplemental releases from Painted Rocks Reservoir which would provide optimum benefits for the river; 2) gather fisheries, habitat, and stream flow information to evaluate effects of dewatering; 3) obtain baseline information to determine effectiveness of supplemental water releases in improving the river fishery. The study was initiated in July, 1983, and data collection was completed in November, 1986.

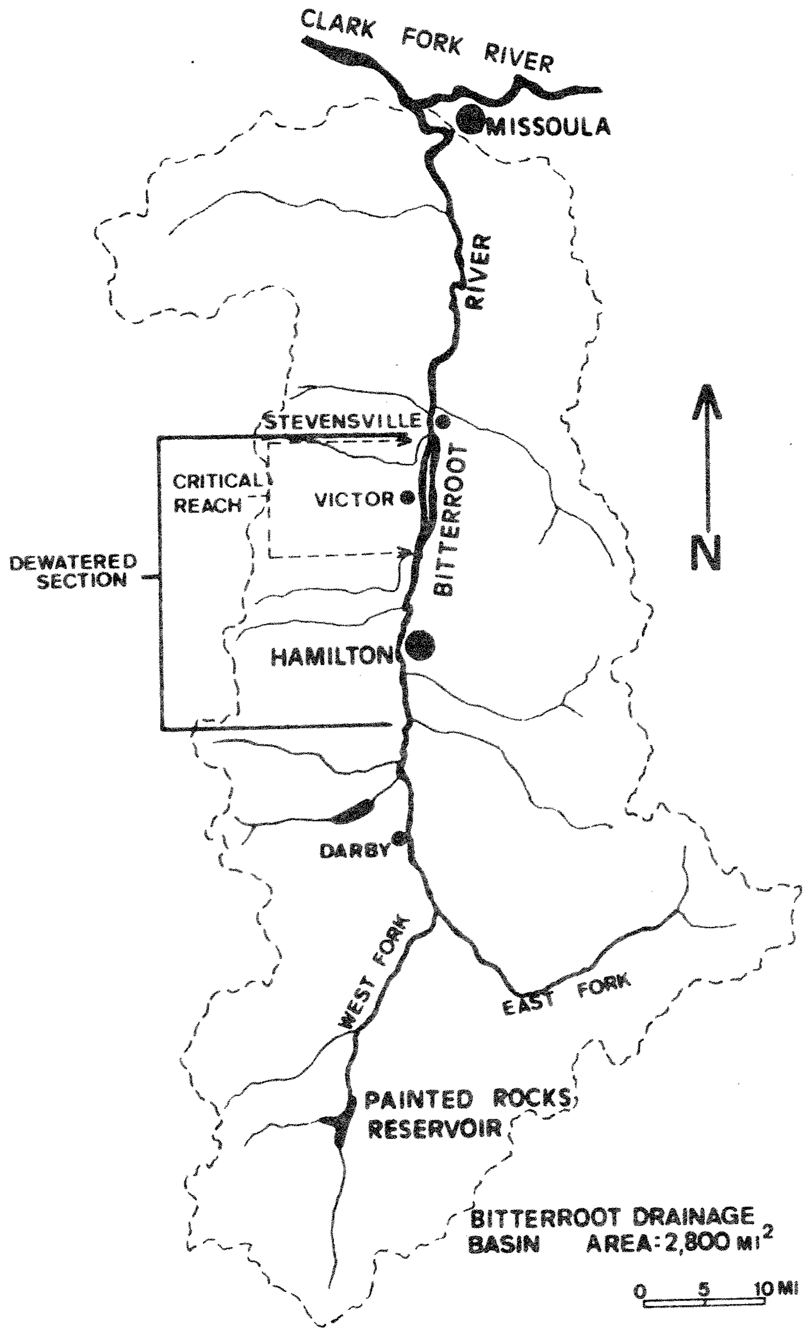


Figure 1. Map of the Bitterroot River showing dewatered areas.

DESCRIPTION OF THE STUDY AREA

The Bitterroot River is located in Ravalli and Missoula counties in west central Montana (Figure 2). It originates at the confluence of the East Fork and West Fork of the Bitterroot River near the town of Conner and flows northerly for approximately 135 km (84 mi) to its confluence with the Clark Fork River near Missoula. The elevation of the river ranges from 1,222 m (4,010 ft) near Conner to 942 m (3,090 ft) at Missoula. The gradient of the river averages about 3.22 percent near Darby and about 0.57 percent near Missoula. The basin drains approximately 725,212 hectares (2,800 mi^2).

From Conner to Sleeping Child Creek, the Bitterroot River flows through a relatively narrow mountain valley. Downstream from Sleeping Child Creek, the river bottom broadens into the farmlands of the Bitterroot Valley. A majority of the valley bottom consists of irrigated cropland or pastureland. Substantial acreage in the valley has been divided into parcels of less than 40 acres. These parcels have been classified as "rural and suburban tracts" by the U.S. Department of Agriculture (1977). In association with these "suburban" tracts, the development of subdivisions is common throughout the valley.

The streambed of the Bitterroot River is typified by large bars of deposited gravel and an extensive network of side channels. The wide riparian zone is dominated by a cottonwood (<u>Populas</u> <u>spp</u>.)/Ponderosa Pine (<u>Pinus</u> <u>ponderosa</u>) overstory. Numerous developed and undeveloped recreational sites provide good access to the river.

The river valley is bordered on the west by the Bitterroot Mountains and on the east by the Sapphire Mountains. The Bitterroot Mountains receive up to 254 cm (100 in) of annual precipitation and the Sapphire Mountains receive up to 127 cm (50 in) of precipitation (Senger 1973). The majority of mountain precipitation is snowfall. Numerous tributaries drain the bordering mountains and supply water for irrigation to the farmlands of the valley. The west-side streams exhibit greater seasonal fluctuations in flow than do the east-side streams (McMurtrey et al. 1972). Tributaries from the mountains add considerable flow to the Bitterroot River during spring runoff but many are diverted for irrigation and contribute little flow during the summer and early fall.

Painted Rocks Reservoir is located on the West Fork of the Bitterroot River approximately 36 km (22 mi) upstream from its confluence with the East Fork. The reservoir was completed in 1940 as a multi-purpose project and is operated by the Department of Natural Resources and Conservation (DNRC). The reservoir has a storage capacity of 32,362 acre-feet (AF) and a surface area at full pool of 265 hectares (Brown 1982). Elevation at the spillway

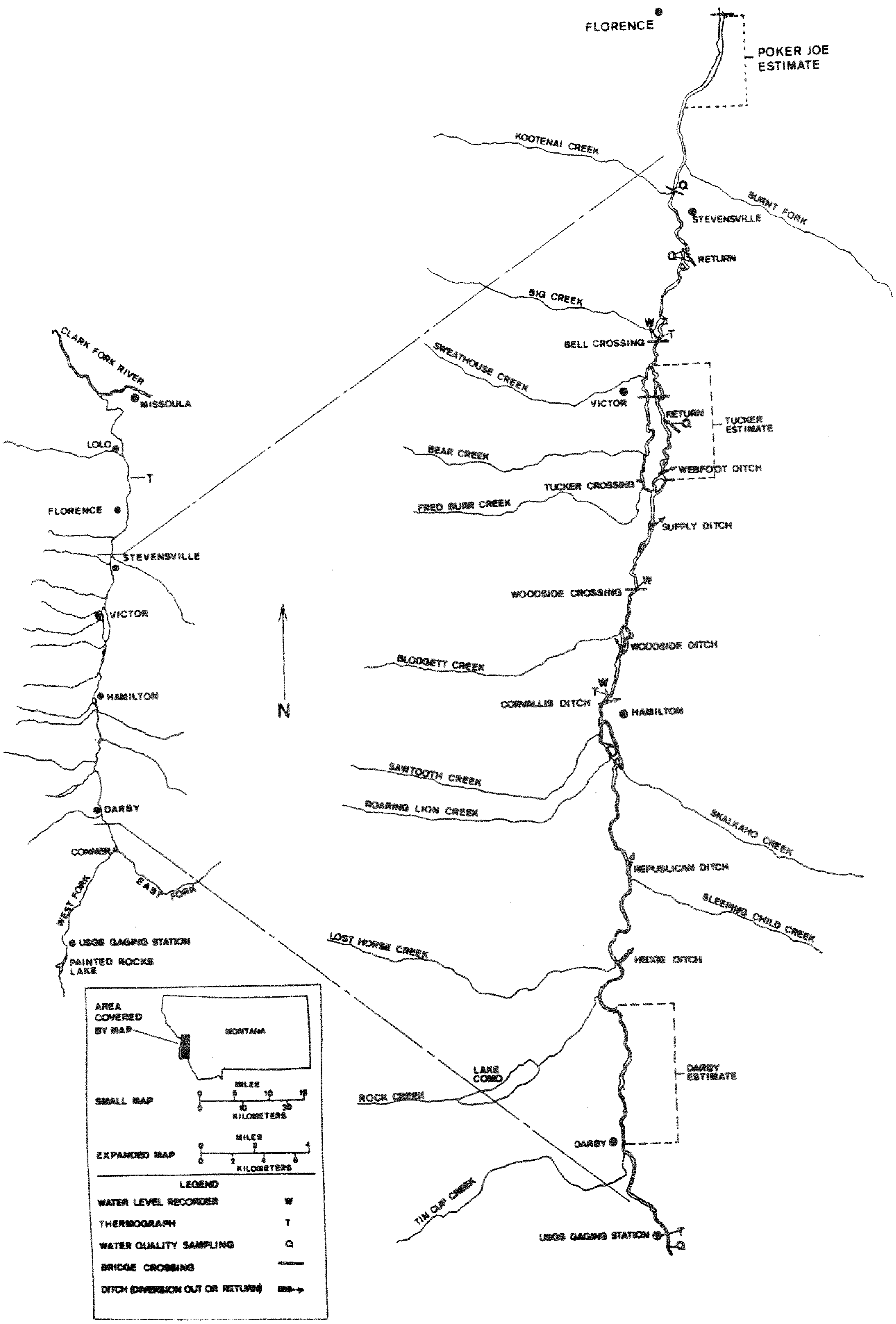


Figure 2. Map of Bitterroot River showing locations of study sections.

is 1,440 m (4,725 ft). As a matter of DNRC policy, flow released from the reservoir is maintained at 3.45 m^3/sec (125 ft^3/sec) during August through November and 2.83 m^3/sec (100 ft^3/sec) during December through July (DNRC 1980). These flow releases do not include spill from the reservoir during spring runoff.

Mean, minimum, and maximum discharges of the Bitterroot River measured near Darby over a 46-year period ending in 1983 were 26.4, 2.0, and 325.7 m^3/sec (931, 71, and 11,500 ft^3/sec), respectively (U.S.G.S. 1983). Annual flow of the river at Missoula averages approximately 64.8 m^3/sec (2,290 ft^3/sec). Characteristics of flow monitored at the U.S.G.S. stations established on the West Fork near Painted Rocks Reservoir, the East Fork near Conner and the main stem near Darby have been summarized by Brown (1982). Median values of average monthly flow recorded at these stations during July, August and September are given in Table 1. Flows in the Bitterroot River downstream from the gauging station near Darby vary greatly from reach to reach due to losses from irrigation withdrawals and to gains from tributary inflow and irrigation returns (Figure 2). Critical dewatering of the river commonly occurs in the reach located between Hamilton and Stevensville as a result of irrigation withdrawals.

Three study sections were established on the Bitterroot River for extensive investigation (Figure 2). The Darby section begins near the bridge at Darby and extend 9.36 km (5.82 mi) downstream to the Como bridge. This section remains well watered throughout the year and serves as a control.

The Tucker section begins at Tucker crossing and extends 8.92 km (5.54 mi) downstream to approximately 1.6 km (1 mi) upstream from Bell crossing. This section is characterized by two channels that become separated by as much as 1.6 km (1 mi). Because of differences in flow and habitat characteristics, each channel was treated as a distinct reach. The Tucker section was established within the reach of river that historically has become severely dewatered.

The Poker Joe section begins at the railroad trestle located upstream from the Poker Joe Fishing Access site and extends 8.41 km (5.23 mi) downstream to the Florence bridge. This section, located downstream of the dewatered reach, remains well watered throughout the year due to a major irrigation return located near Stevensville.

During the fall of 1986, an additional population estimate section (Conner section) was established in the lower reach of the West Fork of the Bitterroot River near Conner, Montana. The Conner section is 4.59 km (2.85 miles) long, extending from about 1.6 km (1.0 mi) below the mouth of the Trapper Creek to the Conner bridge (approximately 3.2 km (2 mi) above the confluence with the East Fork of the Bitterroot River).

Table 1. Historic median values of average monthly flows recorded at stations on the upper Bitterroot River for July, August and September.

	West Fork		East Fork		Darby	
Month	m^3/sec	ft^3/sec	m^3/sec	ft^3/sec	m^3/sec	ft^3/sec
July	7.0	247	8.3	293	28.0	990
August	3.8	135	3.1	108	10.4	367
September	3.8	133	2.6	91	8.9	313

METHODS

Parameters of Stream Flow

Bitterroot River Discharge

Stage of the Bitterroot River was monitored using Belfort continuous water level recorders (5-FW series). Recorders were installed near Hamilton, Woodside crossing, Bell crossing and Poker Joe Fishing Access. At Hamilton, the recorder was mounted in an abandoned DNRC gauge house above a functional stilling well. The recorder at Woodside crossing was mounted on a 3-in (in diameter) standpipe that was fastened to a bridge abutment. At Bell crossing, the recorder was mounted on an observation well installed approximately 2.7 m, (9.5 ft) from waters edge. This well was constructed by pounding a 3-in (in diameter) steel pipe about 4.5-6.0 m (15-20 ft) into the ground. Changes in ground-water levels at this site were known to be closely correlated with changes in river stage (Lere 1984). The recorder installed near the Poker Joe Fishing Access was mounted on a 3-in (in diameter) steel standpipe that had been pounded approximately 1.0 m (3.0 ft) into the streambed.

Eight-day time scale gears were used to drive the charts for each recorder. The stage ratio gearing used in recorders at Hamilton and Bell crossing was 12.7 cm (5 in) of chart to 30.5 cm (12 in) of water. For recorders at Woodside crossing and Poker Joe, the stage ratio was 2.5 cm (1 in) of chart to 30.5 cm (12 in) of water.

Discharge of the river was measured using a Price AA current meter according to standard techniques of the U.S.G.S. (Corbette et al. 1943). Stage-discharge rating curves were developed for each gauging station. Rating curves were used to predict discharge for hourly stage recordings. Averages of 24 hourly recordings were computed to obtain mean daily discharge.

Irrigation Withdrawals

Belfort continuous water level recorders (5-FW series) were used to monitor flow in the Hedge, Corvallis, Supply and Webfoot diversions in 1985 (Figure 2). During 1986, an additional diversion (Republican Ditch) was monitored using a water level recorder. A staff gauge was used to monitor flow in the Republican diversion during 1985. This gauge, mounted on a steel fence post, was located about 1 km downstream from the headgate. Stage readings were taken periodically and discharge was computed from a derived rating curve.

Recorders were mounted on 3-in (in diameter) steel standpipes that had been pounded approximately 1.0 m (3.0 ft) into the bed of the ditch. Thirty-two day time scale gears were used to drive the charts for each recorder. The stage ratio gearing used in the recorders was 2.5 cm (1 in) of chart to 30.5 cm (12 in) of water.

Flow in each ditch was measured using a Price AA current meter according to standard U.S.G.S. techniques. Stage-discharge rating curves developed for each diversion were used to predict discharge for stage recordings taken every six hours. Averages of four recordings were computed to obtain mean daily discharge.

Test Releases

The release of water from Painted Rocks Reservoir was monitored using the U.S.G.S. station located on the West Fork of the Bitterroot River. The volume of supplemental water passing downstream gauging stations was quantified by computing the difference between hourly recorded discharge and discharge projected to occur if water had not been released. Projected flows were determined graphically from the hydrographs derived for each station. Incremental discharge values were converted to acre-feet and then summed to obtain the total volume of spill reaching each station. A similar approach was used to compute flow changes in the monitored diversions as a result of the test spill.

Reservoir Elevations

The elevation of the water level in Painted Rocks Reservoir was monitored biweekly using standard survey techniques. Water level elevations were established from a U.S.G.S. benchmark located on the dam.

Average monthly inflow into the reservoir was determined using the formula (Brown 1982):

$I = (V_1 - V_2) + R$ where:

I = Total monthly inflow (AF),

V_1 = Month-end contents (AF),

V_2 = Previous month-end contents (AF), and

R = Total monthly outflow (AF).

Water Temperatures

Thirty-day continuous recording thermographs (Taylor models) were used to monitor water temperatures in the main stem of the Bitterroot River. Recorders were mounted in gauge houses at the

U.S.G.S. station near Darby and at the abandoned DNRC station at Hamilton (Figure 2). Two additional recorders were mounted in steel boxes at Bell crossing and at MaClay bridge. The thermocouple lead for each thermograph was extended through plastic sewer pipe as far as possible into the river and anchored with rock. A maximum/minimum thermometer installed near the base of Painted Rocks Reservoir was used to monitor temperatures in the West Fork. Thermometer readings at this site were made biweekly.

Water Quality

Analyses of pH, total ammonia and conductivity for water samples collected during 1983 were conducted by the Water Quality Bureau of the Montana State Health Department. Analyses of pH, bicarbonate, total nitrogen, nitrate nitrogen, total phosphorus and conductivity for water samples collected during 1984 were conducted by Dr. Juday at the University of Montana. Analyses of total ammonia for water samples collected during 1984 were conducted by the Water Quality Bureau. Analyses of samples by the Water Quality Bureau were conducted one to three weeks following collection. Analyses of samples by Dr. Juday were conducted within one week following collection.

Measurements of dissolved oxygen, pH, and total alkalinity were made *in situ* at the time water samples were collected. Concentrations of dissolved oxygen were determined using the azide modification of the Winkler method (APHA 1976). Analyses of pH were made colorimetrically using methods of the Hach Company. Concentrations of total alkalinity were determined by titration using methods of the Hach Company. Field methods used for analyses of pH and total alkalinity did not meet APHA (1976) standards.

Physical Characteristics of Study Sections

Physical characteristics of the Darby, Tucker East, and Tucker West study sections were measured during August, 1984. Ten equally spaced stations were established within each study section. At each station, four transects were established perpendicular to the stream channel at intervals of 61 m (200 ft) in a downstream direction. The number of channels containing water at each transect was counted. Stream width was measured to the nearest 0.3 m (1 ft) from water edge to water edge at each transect. Water depth was measured to the nearest 1.5 cm (0.6 in) at 10 equally spaced intervals along each cross section. The deepest measurement along each transect was considered to be the thalweg of the cross section.

The lengths of a single pool and single riffle within each station were measured by tape. A pool was defined as a portion of the river having reduced water velocities and substantial depths. Pool-riffle periodicity (average distance between the heads of successive riffles divided by the average stream width) and pool-riffle ratio (total length of pools divided by total length of riffles) were determined for each study section using 10 measurements of pool-riffle length. Gradient and section length were determined by measurements taken from U.S.G.S. topographic maps.

The total area of potential overhanging and instream cover was measured within 1.5 m (5 ft) on either side of each transect. Cover was classified as either brush, debris, undercut banks or rock shelves. Only features which were within the water or $\leq$ 0.6 m (2 ft) above the surface were considered cover. Depth of the water beneath these features had to be greater than 15 cm (6 in).

Fish Populations

Population Estimates

A mobile electrofishing system was used to sample trout populations in the Bitterroot River. A 4.0 m (13 ft) fiberglass boat with negative electrodes suspended from the gunwales was used to carry a portable 2,000-watt generator and a Coffelt (Model VVP-2E) rectifying unit. The positive electrode was hand held and attached with approximately 10 m (30 ft) of 14-gauge electrical cord.

Captured salmonids were classified by species, measured to the nearest 1.0 mm (total length) and weighed to the nearest 10 grams. Multiple marking and recapture runs were necessary to obtain adequate samples for population estimates. Fish were marked with a caudal fin punch. Samples of scales were taken for analyses of age and growth. All fish were released near their site of capture. Recapture runs were made approximately two weeks following marking runs.

Population estimates were made using Chapman's modification of Peterson's mark and recapture formula (Ricker 1975):

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

where:

N = Population estimate,

M = Number of fish marked,

C = Number of fish recaptured, and

R = Number of marked fish in recapture sample.

A computer program developed by MDFWP was used to calculate estimates of populations, condition factors for fish over 12.6 cm (5 in) in total length and corresponding 80 percent confidence intervals. Estimates of numbers and biomass were computed by length and age groups. Condition factors were calculated using the formula (Carlander 1969):

$$K = \frac{10^5 W}{L^3} \quad \text{where:}$$

K = condition factor,

W = total weight (gm) and

L = total length (mm).

Age and Growth

Scale samples were mounted on acetate slides and impressions were magnified 63x by a microfiche reader for aging. Scales were aged twice on different dates to verify precision. Repeatability of aging (precision) ranged from 78 to 93 percent. A majority of the error was associated with mis-aging older fish by one year.

The Monastyrsky method (Tesch 1971) was used to back-calculate lengths at age of fish:

Predicted length = K x (scale measurement)^n, where:

K = intercept on the ordinate and

n = slope of the relationship

Trout Rearing and Recruitment Studies

Electrofishing surveys along the river shoreline were used to determine habitat types used by YOY rainbow trout and brown trout during August and September, 1984. Main channel and side channel shorelines were categorized into four habitat types. These habitat types were identified as riffle areas with rock border, riffle areas with a root/brush border, pool areas with a rock border, and pool areas with a root/brush border. Numbers of YOY brown trout and rainbow trout collected per 10 meters of river border were determined for each habitat type in the Darby and Tucker sections.

During August and September, 1986, additional electrofishing surveys were conducted to determine relative densities of YOY brown and rainbow trout within, and to some extent between, the established population estimate sections (Conner, Darby, Tucker, and Poker Joe). A single habitat type, riffle area with rock border, was sampled to allow comparisons of YOY densities between sections. This habitat type was chosen because: 1) it provided the most consistent selection of sampling sites; 2) it was present in all sections; and 3) it was known to be desirable rearing habitat. Riffle areas with rock border, however, provide a better comparison of rainbow trout YOY densities than brown trout YOY. Brown trout YOY appear to prefer root/brush borders over rock borders.

Emigration of young-of-the-year brown and rainbow trout from tributaries into the dewatered reach of the Bitterroot River was monitored using drift nets. Emigration from six tributaries (Blodgett Creek, Mill Creek, South Fork Bear Creek, North Fork Bear Creek, Sweathouse Creek, and Big Creek) was monitored from May through mid July, 1986.

Traps were constructed of hardware cloth (6.35 mm mesh tapering to 3.18 mm; 0.25 in - 0.125 in). Trap diameter was 508 mm (20 in), tapering to 76.2 mm (3 in) at the cod end. Traps were secured to bridges or logs located near tributary mouths. The number of each species of trout captured was recorded at each trap visit (once or twice daily) and a subsample of total lengths were measured.

Trapping objectives were:

1) To determine relative importance of tributary vs. main stem sources of recruitment;

2) To determine the predominant age at which tributary fish migrate to Bitterroot River;

3) To determine seasonal pattern of emigration;

4) To assess potential effects of tributary dewatering on recruitment timing or success;

5) To determine feasibility of developing a sampling plan to evaluate tributary recruitment annually with minimal cost and effort.

Instream Flow Recommendations

The wetted perimeter/inflection point methodology was used to quantify instream flow recommendations. In general, this technique derives wetted perimeter-discharge relationships at selected channel cross sections using a hydraulic simulation model. A graphical plotting of these relationships typically delineates an inflection point on the derived curve. At this point, the rate of loss of wetted perimeter greatly increases as discharge decreases. Nelson (1980) found standing crops of adult trout substantially decreased in years when flows were less than derived inflection points. A detailed description of the rationale and methodology for this technique has been given by Nelson (1984).

Wetted perimeter data were obtained from three channel cross sections established at each riffle. A flow recommendation for a single riffle was computed by averaging the wetted perimeter data predicted for associated flows of interest obtained at the three cross sections. Inflection point values derived for all riffles within a section were typically averaged to obtain a final flow recommendation.

Eighteen riffles were surveyed to determine instream flow needs during this study (Table 2). Four riffles were not used because they had poor stage discharge relationships or lacked well-defined inflection points. Two of the riffles were located in the West Fork of the Bitterroot River near Conner, three were in the Darby (control) section, ten were in the dewatered section between Hamilton and Bell crossing, and three were in the rewatered section between Stevensville and Poker Joe (Table 2).

Table 2. Locations of riffles surveyed to determine wetted perimeter-discharge relationships in the Bitterroot River.

Wetted Perimeter Riffle	Location
West Fork Bitterroot River	
West Fork #1	T1N R21W Sec 3 NW, NE
West Fork #2	T1N R21W Sec 3 NW, SE
Darby (control) Section	
Darby #1	T3N R21W Sec 2 NW, SE
Darby #2	T3N R21W Sec 2 SE, NW
Darby #3	T3N R21W Sec 11 NE, NW
Dewatered Section	
Hamilton #1	T6N R21W Sec 13 SE, NW
Hamilton #2	T6N R20W Sec 7 NW, NW
Hamilton #3[a]	T6N R20W Sec 6 NW, SW
Tucker East #1[a]	T7N R20W Sec 8 NE, NW
Tucker East #2	T8N R20W Sec 32 NE, NW
Tucker West #1[a]	T7N R20W Sec 18 NE, NW
Tucker West #2	T8N R20W Sec 32 NW, NW
Bell crossing #1	T8N R20W Sec 20 SE, NW
Bell crossing #2[a]	T8N R20W Sec 17 NE, NW
Bell crossing #3	T8N R20W Sec 17 NE, NE
Rewatered Section	
Stevensville #1	T9N R20W Sec 22 NW, NW
Stevensville #2	T9N R20W Sec 15 NW, SE
Stevensville #3	T9N R20W Sec 10 NE, SW

[a] Riffle not used in analysis.

RESULTS AND DISCUSSION

Bitterroot River Discharge

Supplemental Releases

A supplemental 15,000 AF of Painted Rocks Reservoir water was available for release into the Bitterroot River by MDFWP from 1983 through 1986. The release of water was based on a schedule described in a water management plan developed as a part of this study (Lere 1984). The modified water management plan is presented in Appendix B.

The release schedule recommended by Lere (1984), was based on historical flow records, and was designed to maximize the amount of time a flow of 10.62 m^3/sec (375 ft^3/sec) would be met at Bell crossing. Supplemental releases of 1.42, 3.17, and 3.12 m^3/sec (50, 112, 110 ft^3/sec) during July 16-31, August 1-31, and September 1-30, respectively, were recommended. Releases began when discharge at Bell crossing fell below 10.62 m^3/sec (375 ft^3/sec). Water not released during a specific month because of adequate flows at Bell crossing was proportionately applied to the following month.

During 1983 and 1984, stream flows at Bell crossing were relatively high, and July releases were not necessary (Table 3). Due to adequate flows in 1983 and 1984, the quantity of released water reaching the target area (Bell crossing) was not a serious issue.

During 1985, supplemental releases began on July 12, and ended on September 22 (Table 3). Due to the severe drought conditions during July, ten irrigation companies purchased a total of 4,600 AF of water from Painted Rocks Reservoir to supplement releases into the river. Water for irrigation was released at a rate of 2.12 m^3/sec (75 ft^3/sec) for the periods of July 30 through August 7 and August 30 through September 20. The combined volume of supplemental water released from Painted Rocks Reservoir by the MDFWP and irrigation companies totaled 18,046 AF (Table 3). These releases were made in addition to the 3.54 m^3/sec (125 ft^3/sec) base flow maintained by DNRC.

Releases made by MDFWP during the low stream flows of 1985 were not reaching Bell crossing because of extensive diking on the river and the subsequent withdrawals by irrigation systems. In an attempt to protect supplemental releases from being appropriated during 1985, the MDFWP requested water users on the river to petition the district court for the appointment of a water commissioner. An agreement between MDFWP and the owners of decreed water rights on the river to file this petition was reached on July 29. As a result, a commissioner was appointed on

Table 3. Comparisons of release rates of supplemental water from Painted Rocks Reservoir, 1983-1986.

Year	Date	Release Rate (ft^3/sec)[a] MDFWP	Irrigators	Total
1983	8/9 -9/9	100	---	100
	9/9 -9/13	0	---	0
	9/13-10/28	100	---	100
		14,476 AF		14,476
1984	8/18-9/19	150	---	150
	9/20-10/7	75	---	75
		14,269 AF		14,269 AF
1985	7/12-7/29	50	0	50
	7/30-8/7	112	75	187
	8/8 -8/29	112	0	112
	8/30-9/20	112	75	187
	9/12-9/22	112	0	112
		13,446 AF	4,600 AF	18,046 AF
1986	7/22-7/25	0	100	100
	7/26-8/4	50	50	100
	8/5 -8/16	115	50	165
	8/17-8/31	165	0	165
	9/1 -9/15	110	0	110
		12,016 AF	3,070 AF	15,086 AF

a/ 1.0 $f^3/sec = 0.02832\ m^3/sec$

August 2 with the understanding that MDFWP would pay the entire cost and that a minimum of 75 percent of the MDFWP supplement released from Painted Rocks Reservoir would reach Bell crossing. This agreement remained relatively untested, however, because flows in the river substantially increased during early August as a result of above normal precipitation.

Prior to the summer of 1986, a tentative agreement was reached between MDFWP and the main stem irrigators in an effort to resolve the problems experienced in 1985. Under the agreement, MDFWP gave 3,000 AF of purchased water to the irrigators to use as needed. In return, irrigators were to lower headgates during the last half of September if flows fell below minimum recommendations. Under the original release schedule, approximately 3,000 AF of water was reserved for September 15-30. Thus, the agreement consisted of an exchange of water that provides higher releases during the early summer when irrigation needs are highest, combined with assurances that irrigators will help maintain minimum flows during late summer. Also, as part of the agreement, irrigators were not to oppose the appointment of a water commissioner to ensure that a substantial percentage of the purchased water released from the reservoir remained instream. These modifications of the original release schedule were in effect during the summer period of 1986.

During 1986, irrigators began releases on July 22 with the intention to increase flows and avoid the need for diking at diversions (Table 3). Discharge exceeded 10.62 m^3/sec (375 ft^3/sec) until July 26 when MDFWP assumed half of the 2.83 m^3/sec (100 ft^3/sec) release. Combined releases during most of August were 4.67 m^3/sec (165 ft^3/sec), which provided the highest rate of release during the period of lowest flows.

Supplemental water was available through September 15. Irrigator cutbacks during late September were not requested because of extensive rainfall which adequately restored flow levels throughout the river.

Discharge Comparisons (1983-1986)

Discharge patterns in the Bitterroot River were monitored at two permanent (U.S.G.S.) and as many as four temporary gauging stations from 1983 through 1986. The permanent stations were located on the West Fork near Painted Rocks Reservoir, and on the main stem near Darby. Temporary stations were located at Hamilton, Woodside crossing, Bell crossing, and Poker Joe Fishing Access (Figure 3). The Woodside station was not monitored in 1986 due to damages caused during spring runoff. Discharge at Poker Joe was only monitored during 1985 and 1986.

Of the four years that stream flow data was collected in the Bitterroot River drainage, two years (1983 and 1984) experienced relatively high stream flows through the summer period, and two

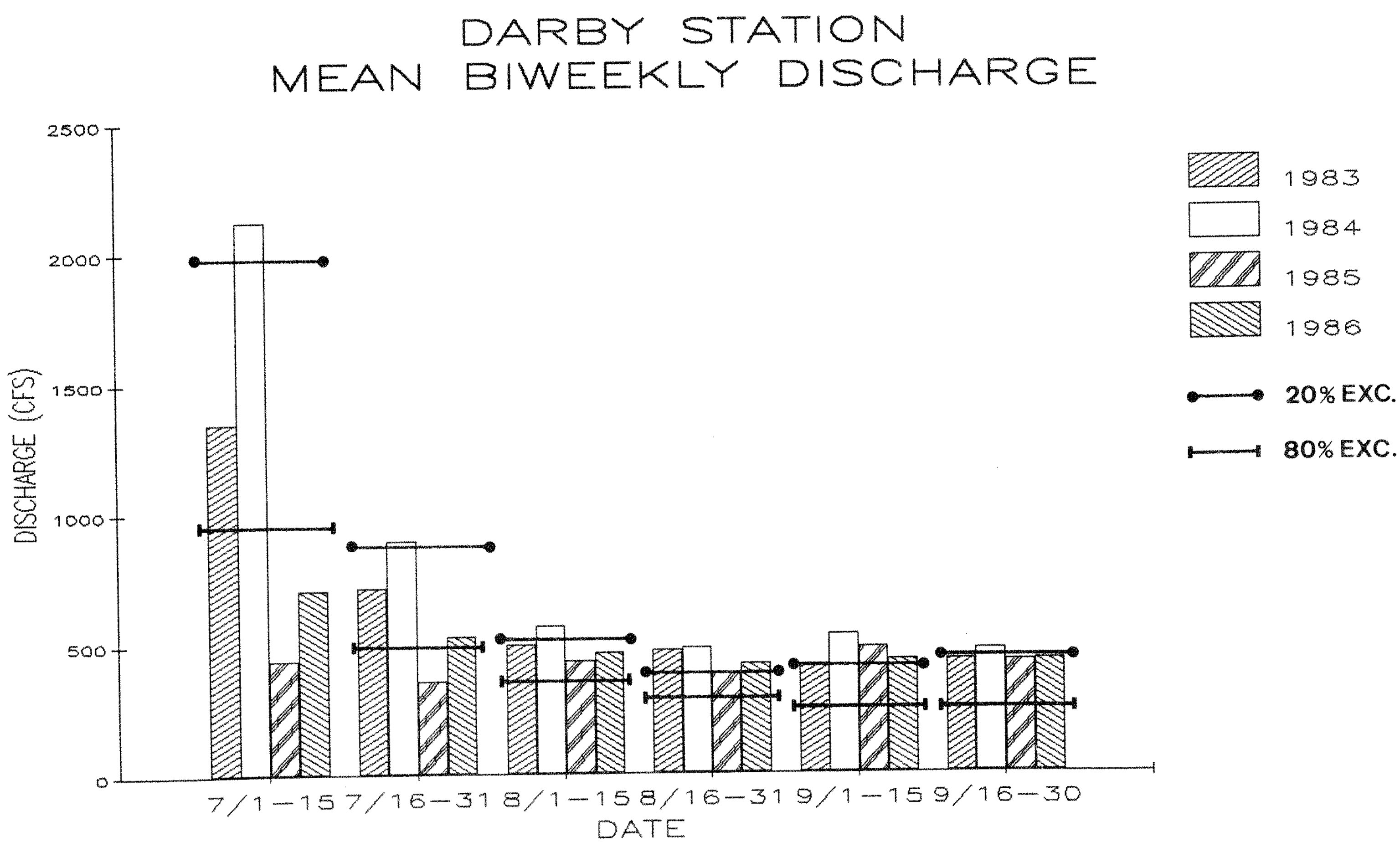


Figure 3. Comparisons between mean biweekly discharge in the Bitterroot River at Darby during supplemental releases (1983-1986) and historic 20% and 80% exceedence values.

years (1985 and 1986) were characterized by having low stream flows during early summer and above average flows in late summer. Bitterroot River discharge at Darby was higher than historic median values throughout the summer periods of 1983 and 1984 (Figure 3). During the particularly high flows of 1984, discharge at Darby was consistently above 20 percent exceedence values. In contrast, July flows were typically below or near 80 percent exceedence values in 1985 and 1986 at Darby.

The release of supplemental water from Painted Rocks Reservoir, and wetter than normal weather conditions contributed to the occurrence of relatively high stream flows throughout 1983 and 1984, and during the late summer periods of 1985 and 1986. Summer precipitation amounts in 1983 and 1984 were 9.2 cm (3.63 in) and 3.51 cm (1.38 in) above normal from June through September, respectively (Table 4).

Late spring snowpack levels, however, were below historic averages during 1983 and 1984 (Table 5). Apparently, above average stream flow can occur in the upper river (Darby) during years with below average snowpack levels because of supplemental releases and/or above average summer rainfall.

The below normal stream flows of 1985 were caused by unusual weather patterns. Extreme drought conditions during June and July contributed to the low level of flow in the river in 1985 (Table 4). Total precipitation for June and July at gauging stations in the valley was almost 5.1 cm (2 in) below normal (U.S. Department of Commerce 1985). In addition, snowpack in the basin as of May 1, 1985 (U.S. Department of Agriculture 1985) was only 78 percent of average (Table 5). During August and September, however, valley precipitation was 10.2 cm (4 in) greater than normal. This increased precipitation, which began on August 11, contributed to the greater than normal August and September flows during 1985.

In 1986, the weather pattern was similar to that of 1985. Rainfall during June and July was below normal, but was considerably above 1985 levels (Table 4). Bitterroot basin snowpack for May 1 was only 72 percent of normal in 1986. Supplemental releases maintained near normal stream flows at Darby during August despite dry conditions. Heavy rainfall beginning on August 28 resulted in high September stream flows which were near 20 percent exceedence values at Darby (Figure 3).

Based on comparisons of Darby stream flow from 1983 through 1986, it appears that July flows can vary considerably depending primarily on weather conditions (precipitation, snowpack, and snowmelt timing). During the base flow period of August and September, Darby flows varied relatively little between years despite the variability observed in weather patterns. In general, supplemental releases from the reservoir enhance stream flows at Darby enough to offset the effects of dry weather patterns.

Table 4. Monthly summer precipitation (inches) averaged for 3 stations[a] located in the Bitterroot Valley from 1983 to 1986.

Year	June		July		August		September		TOTAL June-September	
	Mean	Departure[b]	Mean	Departure[b]	Mean	Departure[b]	Mean	Departure[b]	Mean	Departure[b]
1983	1.37	-0.36	2.23	+1.45	2.51	+1.62	1.98	+0.92	8.09	+3.63
1984	1.84	+0.11	0.60	-0.18	1.89	+1.00	1.51	+0.45	5.84	+1.38
1985	0.38	-1.35	0.16	-0.62	2.70	+1.81	3.25	+2.19	6.49	+2.03
1986	1.49	-0.24	0.77	-0.01	1.56	+0.67	1.89	+0.83	5.71	+1.25

a/ The three stations are located at Darby, Hamilton and Stevensville (U.S. Department of Commerce 1983, 1984, 1985, 1986).

b/ Departure from normal

Table 5. Mean snowpack as of May 1 for ten stations in the Bitterroot basin from 1983 to 1986.

Year	Mean Snowpack[a]	Percent of historic mean
1983	19.05	76
1984	22.52	90
1985	19.63	78
1986	18.04	72

[a] Mean water content in inches from 10 survey stations (U.S. Department of Agriculture 1983, 1984, 1985, 1986).

In contrast with the upper Bitterroot River, low stream flows resulting from dry weather conditions in the dewatered reach are not as easily offset by supplemental releases. Mean August discharge during years of supplemental releases was below the historic median at Hamilton (Table 6). Supplemental water flows reach Hamilton, but not in large enough quantities to offset the effects of extremely dry weather conditions and subsequent increases in irrigation withdrawal.

From 1983 to 1986, mean biweekly discharge varied substantially between stations due to extensive irrigation withdrawals and to inflow from tributaries and irrigation returns (Table 7). Stream flow at the West Fork and Darby stations were maintained above minimum recommended flows (refer to section on Instream Flow Recommendations) throughout the summer periods from 1983 through 1986 (Figures 4 and 5).

At the Hamilton station, located at the beginning of the dewatered section, mean biweekly discharge was more variable between years (Figure 6). Discharge data during 1983 and 1984 was incomplete, but flows generally exceeded the recommended values throughout the summer months. During 1985, the low flow period of July resulted in flows less than the minimum recommendation (11.38 m^3/sec; 402 ft^3/sec), but rainfall beginning in early August increased flows to levels above the recommendation.

Discharge was below 11.38 m^3/sec (402 ft^3/sec) throughout August of 1986. A higher rate of supplemental release (4.67 m^3/sec; 165 ft^3/sec) during August, however, maintained flows near the recommended values at Hamilton despite dry conditions and significant irrigation withdrawals. Flows at Hamilton should meet or exceed minimum recommended levels during most years with supplemental releases.

The numerous irrigation diversions downstream from Hamilton significantly influence summer stream flows at Bell crossing, particularly during years with low flows. Above average precipitation during the summer months of 1983 and 1984 reduced irrigation demand and increased tributary inflow which resulted in stream flows at or near the minimum recommended flow levels (11.38 m^3/sec; 402 ft^3/sec) at Bell crossing. The relatively high flow levels, accompanied by decreased irrigation demand, also contributed in helping supplemental releases reach Bell crossing.

Supplemental water released during 1985, however, was not sufficient to maintain the target flow at Bell crossing during July and the first half of August (Figure 7). Daily discharge at Bell crossing was less than 2.83 m^3/sec (100 ft^3/sec) for a 20-day period beginning July 14, and was less than 1.42 m^3/sec (50 ft^3/sec) for a 13-day period beginning July 20 (Table 8). In comparison, flows at Bell crossing were never less than 8.50

Table 6. Comparisons of historic median values of average monthly discharge with mean monthly discharge during supplemental releases (1983-1986).

		Mean Monthly Discharge	
Station	Month	Historic Median	During Supplemental Releases (1983-1986)
West Fork	July	247	268
	August	135	247
	September	133	228
Darby	July	990	882
	August	367	465
	September	313	456
Hamilton	July 16-31	1139	440[a/]
	August	445	421[b/]
	September	451	698[b/]

a/ Includes 1985 and 1986 data.

b/ Includes 1984, 1985, and 1986 data.

Table 7. Mean biweekly flows (ft^3/sec)[a] recorded at the Darby, Hamilton, Woodside, Bell, and Poker Joe stations on the Bitterroot River from July 1983 to September 1986.

	Year	West Fork[b]	Darby[b]	Hamilton	Woodside Crossing	Bell Crossing	Poker Joe
July 1-15	1983	282	1349	---	---	---	---
	1984	565	2126	---	---	2805	---
	1985	144	441	432	460	301	601
	1986	209	711	975	---	995	2429
July 16-31	1983	203	718	---	---	945	---
	1984	268	898	---	---	919	---
	1985	218	357	273	258	37	361
	1986	259	529	607	---	443	938
August 1-15	1983	179	497	---	---	554	---
	1984	227	569	---	591	495	---
	1985	265	436	461	433	331	703
	1986	310	465	363	---	160	563
August 16-31	1983	218	477	---	---	497	---
	1984	259	483	449	459	373	---
	1985	242	384	420	436	376	697
	1986	274	420	354	---	220	607
Sept. 1-15	1983	194	418	---	482	421	---
	1984	269	533	714	711	683	---
	1985	288	483	625	601	664	1314
	1986	235	436	512	---	671	1004
Sept. 16-30	1983	230	433	---	583	551	---
	1984	219	476	877	877	878	---
	1985	185	432	784	842	908	1514
	1986	206	437	679	---	806	1205

a/ $1.0\ ft^3/sec = 0.02832\ m^3/sec$

b/ U.S.G.S. Discharge data

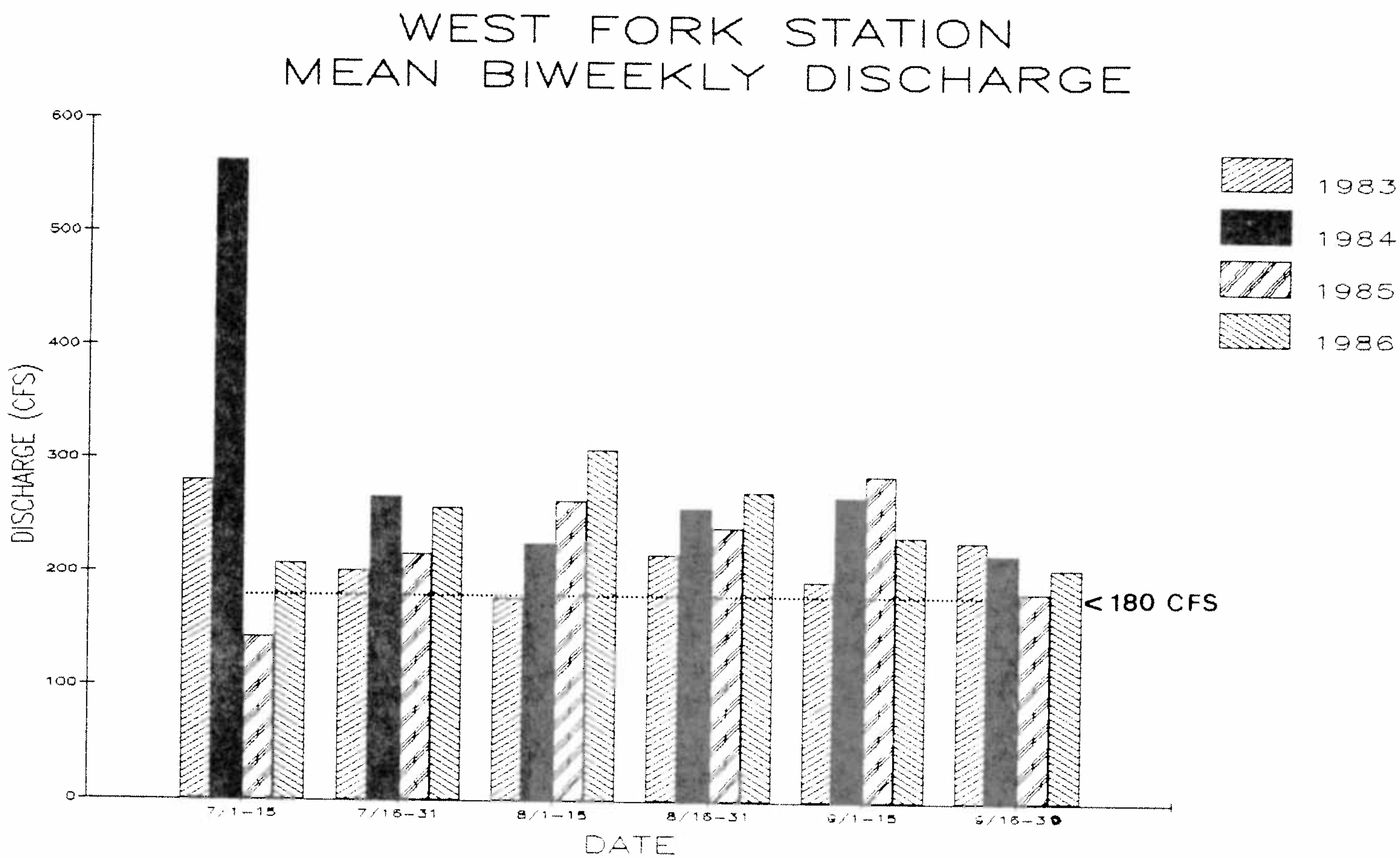


Figure 4. Comparisons between mean biweekly discharge in the West Fork of the Bitterroot River during supplemental releases (1983-1986) and the minimum recommended flow level.

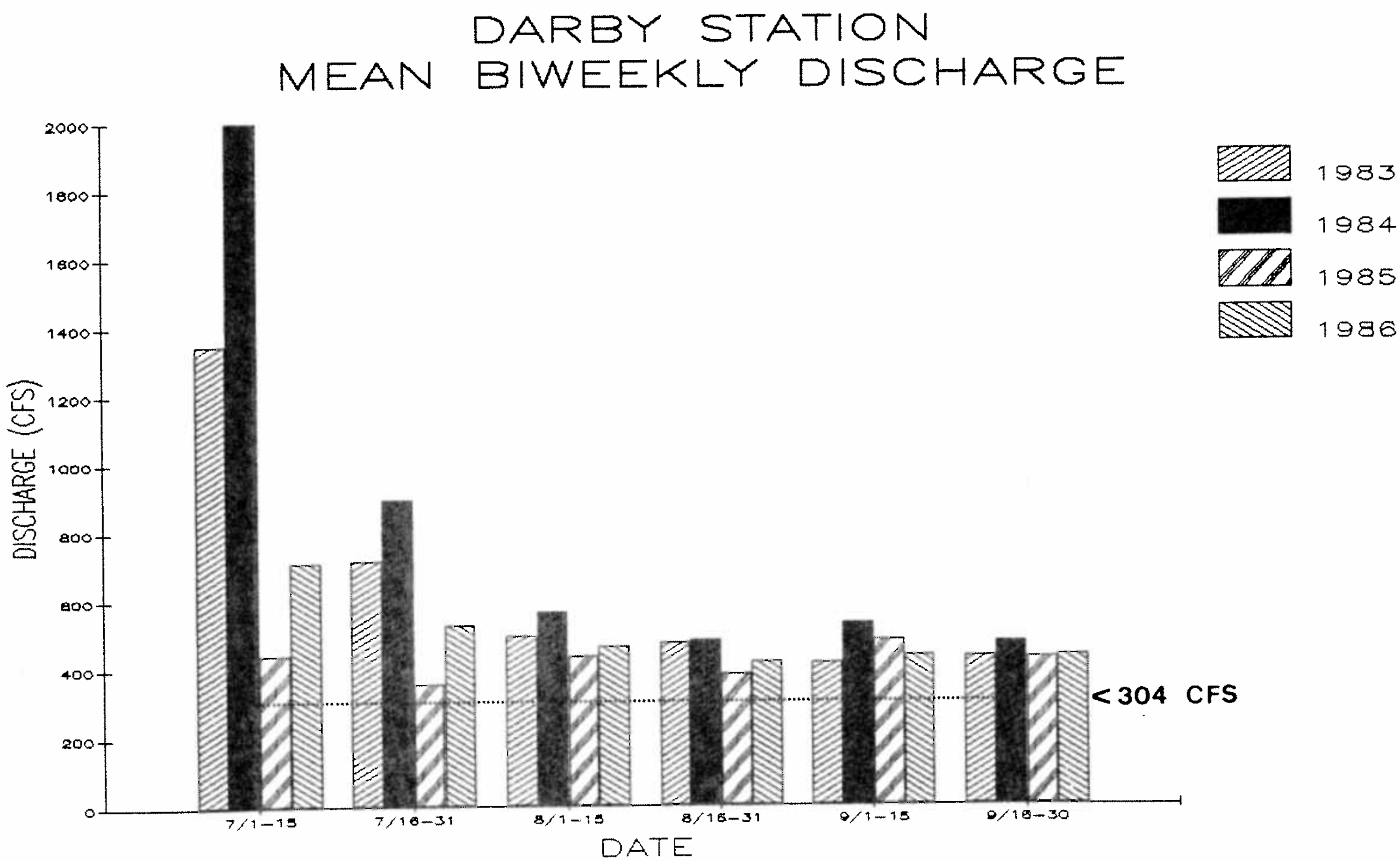


Figure 5. Comparisons between mean biweekly discharge in the Bitterroot River at Darby during supplemental releases (1983-1986) and the minimum recommended flow level.

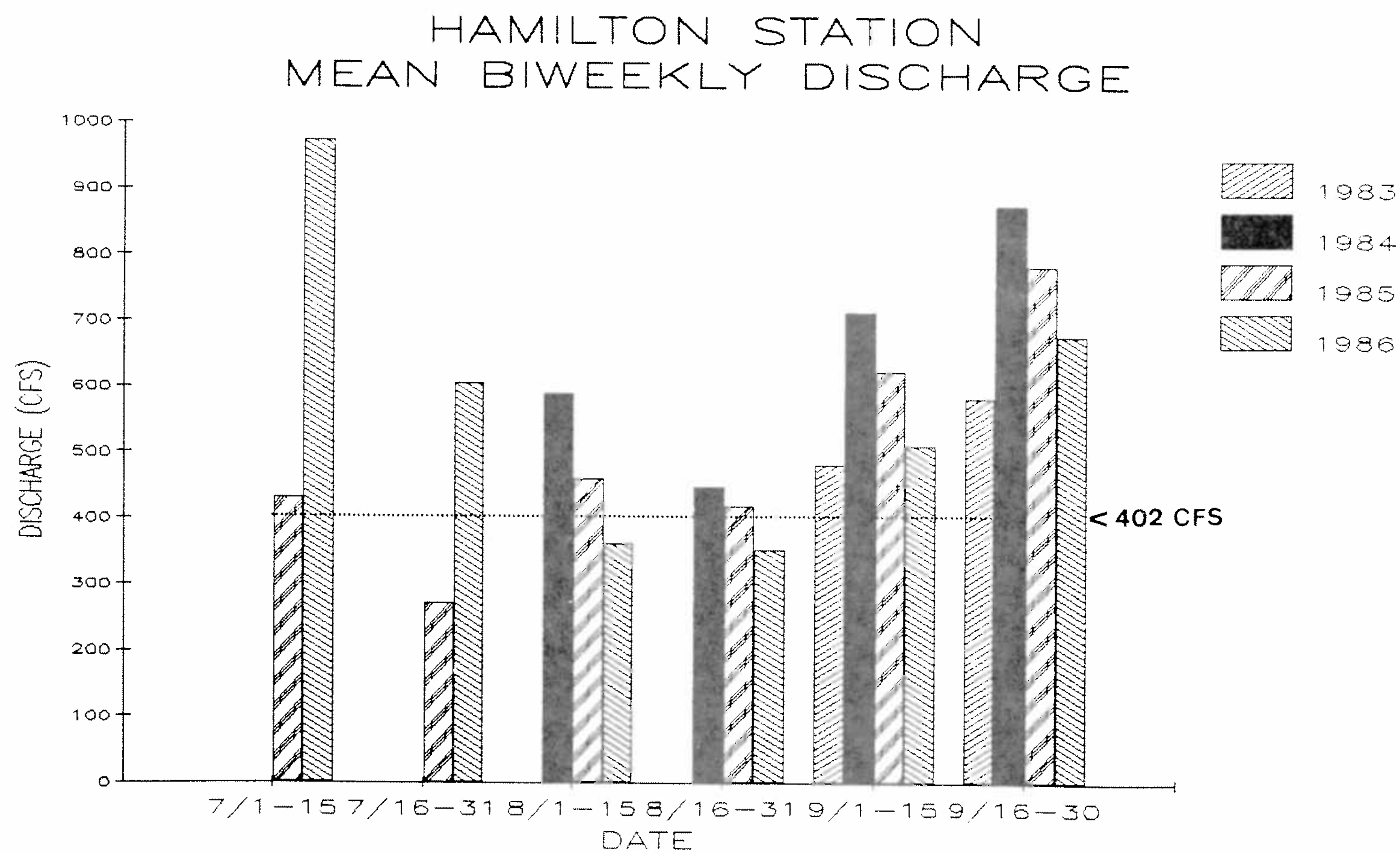


Figure 6. Comparisons between mean biweekly discharge in the Bitterroot River at Hamilton during supplemental releases (1983-1986) and the mimimum recommended flow level.

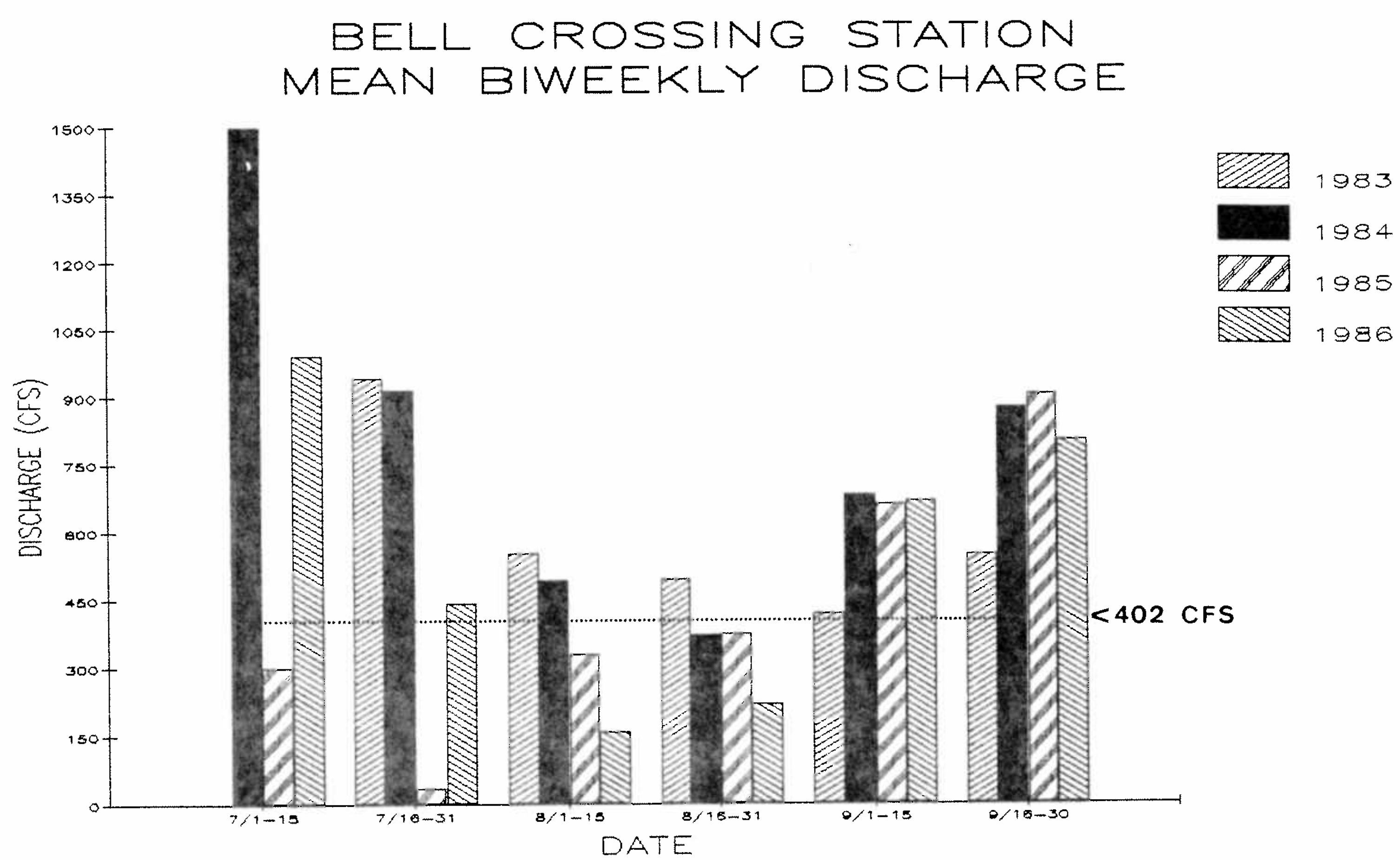


Figure 7. Comparisons between mean biweekly discharge in the Bitterroot River at Bell crossing during supplemental releases (1983-1986) and the mimimum recommended flow level.

Table 8. Number of days discharge at Bell crossing was less than or equal to 402, 375, 300, 200 and 100 ft^3/sec for the period from July 1 through September 30 during 1983, 1984, 1985, and 1986 (percentage in parentheses).

Number of days flow (ft^3/sec) was:	1983	1984	1985	1986
≤ 402	9(10)	16(17)	53(58)	37(40)
≤ 375	1(1)	11(12)	52(57)	37(40)
≤ 300	0(0)	0 (0)	41(45)	36(39)
≤ 200	0(0)	0 (0)	21(23)	26(28)
≤ 100	0(0)	0 (0)	20(22)	0 (0)

m^3/sec (200 ft^3/sec) during 1983 and 1984, and fell below the target level for only nine days in 1983 and for 16 days in 1984. The minimum flow observed at Bell crossing was 0.68 m^3/sec (24 ft^3/sec) during 1985.

In 1986, stream flows exceeded the target level during most of July and September, but were less than 11.38 m^3/sec (402 ft^3/sec) throughout August (Figure 7). The lowest daily flow observed during 1986 (3.96 m^3/sec; 140 ft^3/sec) occurred on August 17. Although flows did not reach the critically low levels of 1985, stream flow was less than 5.66 m^3/sec (200 ft^3/sec) for a longer period in 1986 (Table 8).

Daily discharge near Poker Joe Fishing Access was only monitored during 1985 and 1986. Mean biweekly discharge at this site always exceeded the minimum recommended value (8.50 m^3/sec; 300 ft^3/sec) during the summer periods of 1985 and 1986 (Figure 8). Irrigation return flows, which re-enter the Bitterroot River near Stevensville, adequately maintain favorable stream flows in this area even during relatively poor water years. The lowest flows observed during 1985 and 1986 were 8.95 m^3/sec (316 ft^3/sec) and 14.50 m^3/sec (512 ft^3/sec), respectively. The relatively low instream flow requirement of this reach of the river (compared to the dewatered reach) is discussed in the minimum flow recommendation section of this report.

Irrigation Withdrawals

Flows in Hedge, Republican, Corvallis, Supply, and Webfoot diversions were monitored during 1985 and 1986 to assess the effects of irrigation withdrawal on discharge in the Bitterroot River. Withdrawal comparisons were based on mean daily discharge (data averaged on a six-hour basis) from March through September. Maps of selected diversion locations throughout the Bitterroot River drainage are presented in Appendix C. For a listing of water users on the main stem of the Bitterroot compiled by Vernon Woolsey, the Water Commissioner of 1985, refer to Appendix D.

Diversion of water for irrigation typically began in late April, and closures of the systems at the end of the irrigation seasons occurred during mid to late September in 1985 and 1986 (Figure 9). The five monitored diversions exhibited extreme fluctuations in flow rates during the irrigation season. These fluctuations were primarily due to headgate adjustments and channel alterations rather than changes in water availability (river flow). For example, the marked increase in ditch withdrawal on July 22, 1986, resulted from diking the west channel of the Tucker section to provide water to irrigation diversions on the east channel. This diking was also done during 1985.

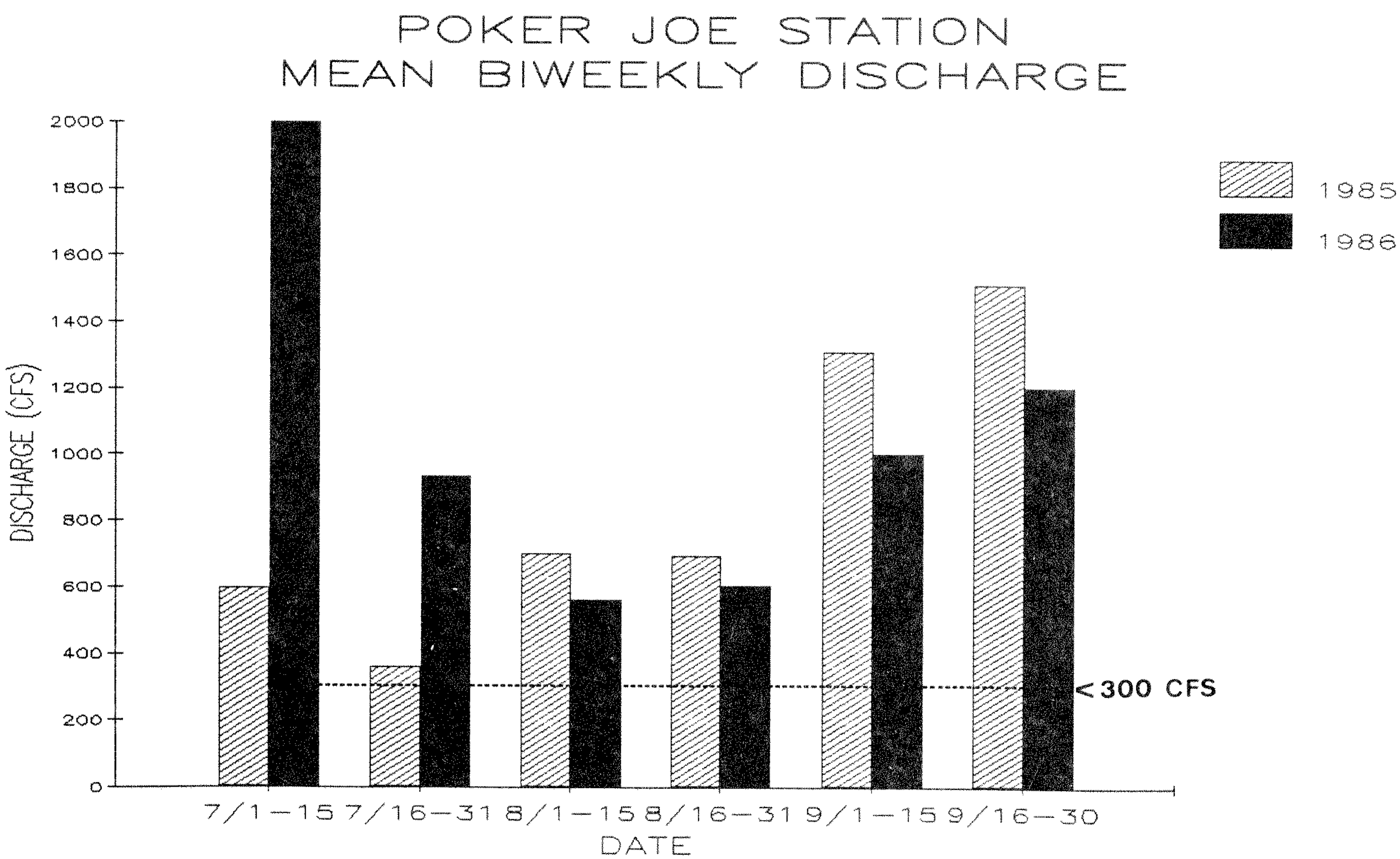


Figure 8. Comparisons between mean biweekly discharge in the Bitterroot River at Poker Joe during supplemental releases (1983-1986) and the minimum recommended flow level.

Withdrawals by ditch companies varied between years based on water demand by agricultural crops. The agricultural experiment station near Corvallis, Montana, monitored daily precipitation and Penman Evapotranspiration (a climatic index that considers temperature, solar radiation, humidity, and wind movement), which were used to recommend optimal water application rates. The higher irrigation withdrawals during early summer, 1985, coincided with the higher Penman Evapotranspiration index, and the lower precipitation of that period (Figures 9 and 10). The relatively high withdrawals during August, 1986, also appeared to be related to high water demand by crops.

During 1985 and 1986, the five major ditches diverted 171,177 and 165,582 AF of water, respectively, from April 1 through September 30. Average monthly discharge of ditches was higher in 1985 during every month except August (Table 9). Total ditch withdrawal of the five major ditches remained below the combined decreed water right of 20.0 m^3/sec (706 ft^3/sec) throughout 1985 and 1986 (Table 9). Two ditches, however, periodically exceeded their respective decrees during 1985 and 1986.

Irrigation withdrawals during July and August were frequently greater than the mean monthly river flows recorded at the U.S.G.S. station near Darby (Figure 9). Differences between stream flow and withdrawal were even greater when all diversions on the river were used for comparison. There were at least an additional 15 unmonitored ditches diverting water. Withdrawals by these ditches during the peak of irrigation were estimated to average 0.42 m^3/sec (15 ft^3/sec) each. As a result, combined withdrawals by all diversion systems on the Bitterroot River during peak irrigation were roughly estimated to total 24.1 m^3/sec (850 ft^3/sec). Without substantial returns by groundwater seepage, ditch losses, and unconsumed water from flood irrigation, flows in the Bitterroot River would not be able to sustain the heavy irrigation demands during July and August.

Water distribution, rather than availability, appears to be the major problem for water users in the Bitterroot River. Users recognize that water is a valuable resource, yet diversion and distribution of irrigation water remains inefficient because adequate investments in the canal system are lacking. On the main stem of the Bitterroot River, there are no adequate water measuring devices. The two measuring devices that exist on the entire river are submerged and not functional according to Vernon Woolsey (Water Commissioner of 1985).

In addition, there are a large number of diversions (particularly between Hamilton and Bell crossing) which irrigate relatively small parcels of cropland. The lack of coordination between canal systems contributes to the large amounts of waste-water that flow parallel to the river largely unused for irrigation and unavailable to the river fishery. Coordination of water use between irrigation systems, along with ditch consolidation

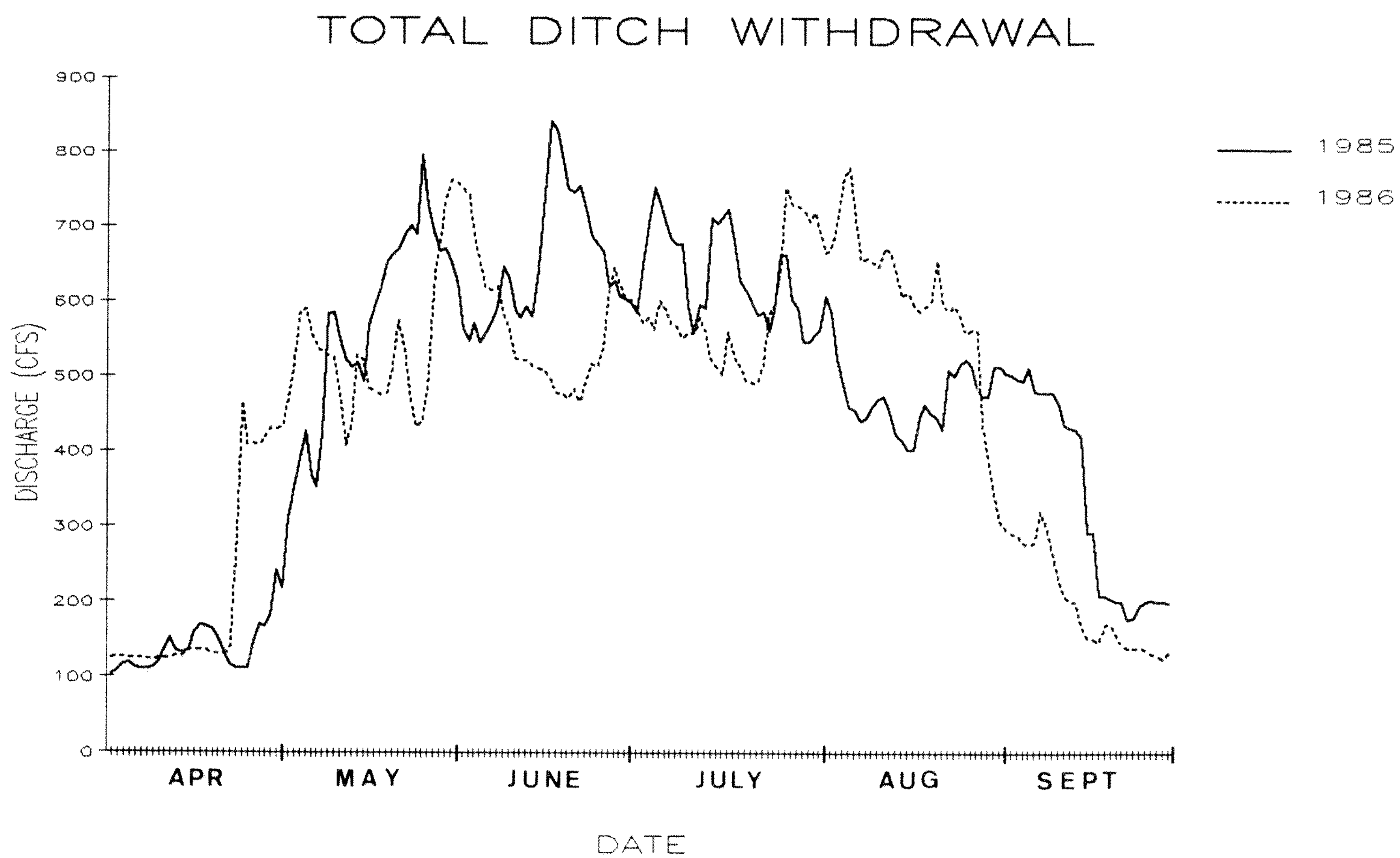
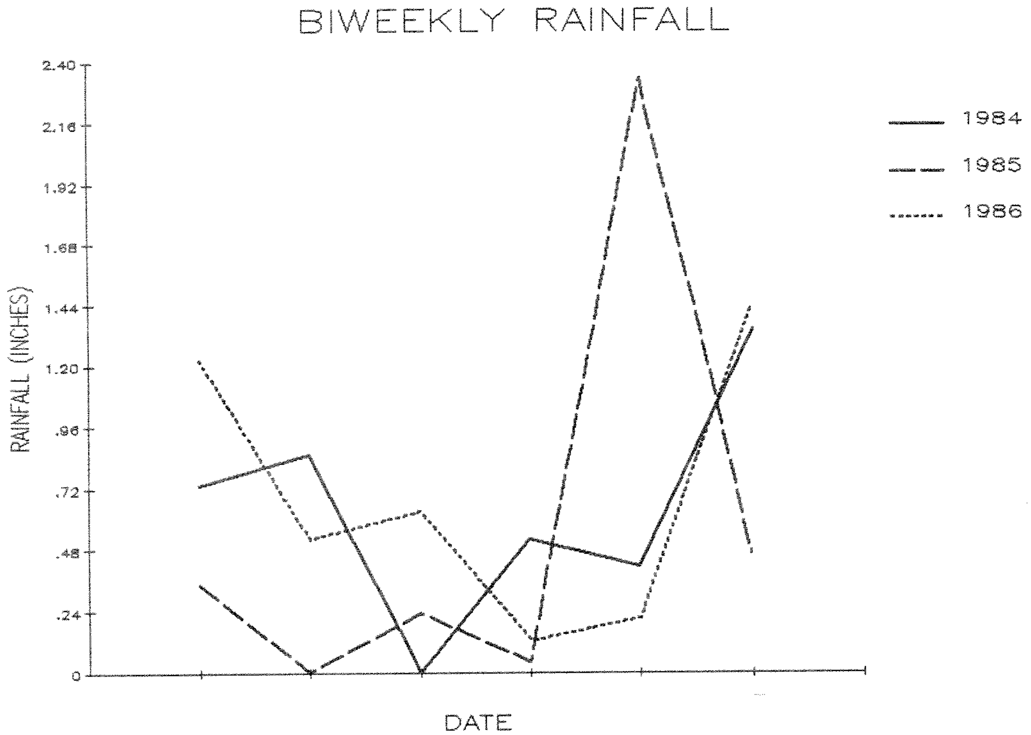


Figure 9. Daily withdrawals by five irrigation diversions (Hedge, Republican, Corvallis, Supply, and Webfoot ditches) during 1985 and 1986.



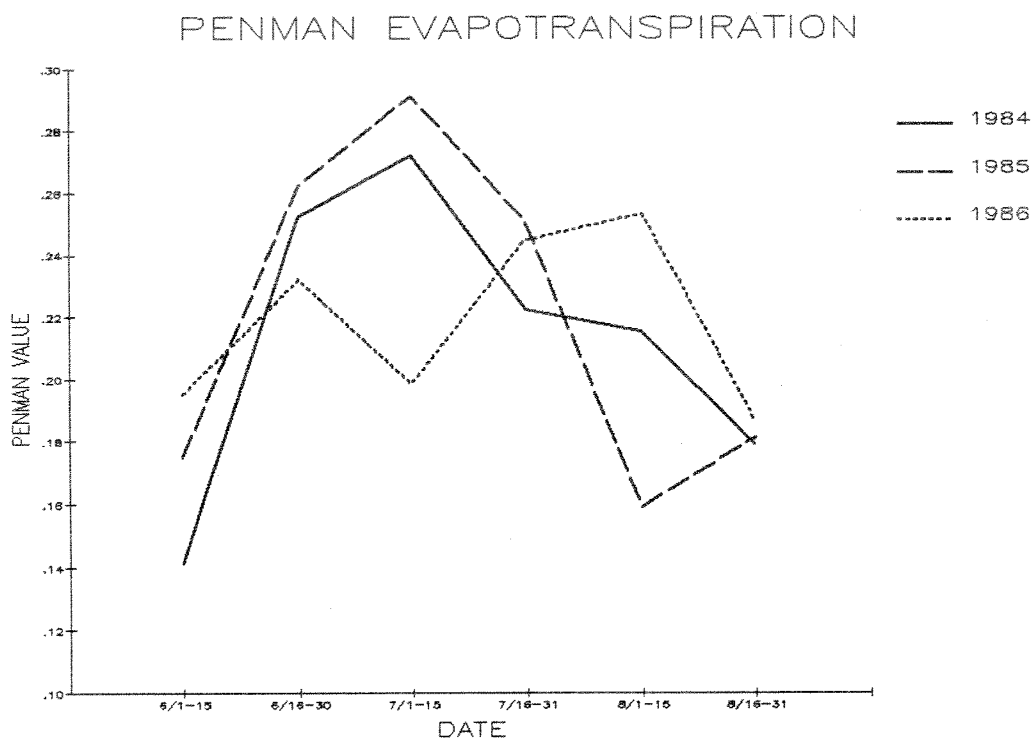


Figure 10. Climatic data (rainfall and evapotranspiration) used to estimate water demand by crops in the Corvallis area, 1984-1986 (data provided by Bonneville Irrigation Scheduling Services Program).

Table 9. Mean monthly flow and decreed water rights for Hedge, Republican, Corvallis, Supply, and Webfoot diversions on the Bitterroot River during 1985 and 1986.

		Mean Monthly Flow (ft^3/sec)					DECREE[a/]
DITCH	YEAR	MAY	JUNE	JULY	AUGUST	SEPT.	(ft^3/sec)
Hedge	1985	84	84	126	128	65	140
	1986	74	89	113	117	50	
Republican	1985	159	165	140	125	74	150
	1986	---	126	117	160	25	
Corvallis	1985	128	73	59	29	34	125
	1986	106	79	87	47	21	
Supply[b/]	1985	123	166	174	78	51	175
	1986	193	156	124	155	46	
Webfoot[c/]	1985	172	170	126	118	57	116
	1986	147	109	146	136	62	
TOTAL	1985	---	658	625	478	281	706
	1986	---	559	587	615	204	

a/ Case no. 1287 (State Engineer's Office 1958)

b/ Decreed rights for Supply and Wood-Parkhurst (common headgate)

c/ Decreed rights for Webfoot, Union, Etna (common headgate) (where feasible) would enhance instream flows, reduce streambed disturbance due to diking, and lower the potential for fish loss to irrigation ditches.

Incentives to improve efficiency of water use do not exist because irrigation costs are not based on amounts of water used. In addition, adequate quantities of irrigation water is delivered to users during most years. Water shortages primarily effect the amount of water left instream, not the amount of water delivered to irrigators except during extreme drought conditions.

Drafting of Reservoir

The elevation of water level in Painted Rocks Reservoir was monitored from 1984 through 1986 to evaluate the effects of accelerated drafting due to the release of purchased water. The water level, following spring runoff, remained at or above full pool through mid August in 1984. The 1984 reservoir volume was less than historic median values throughout the summer, but was greater than 90 percent exceedence values despite supplemental releases totaling about 15,000 AF (Table 10).

Due to early season runoff, below average snowpack levels, and below normal precipitation during both 1985 and 1986, reservoir volumes were below 90 percent exceedence values from the end of July through October (Table 10). The reservoir remained at full pool until early July, and was rapidly drawn down through October. By December 1, the reservoir level was drained to the elevation level of the outlet in both 1985 and 1986.

Although supplemental releases contributed to accelerated drafting of the reservoir in 1985 and 1986, summer inflows were considerably below mean monthly values which resulted in the rapid decrease of reservoir levels (Table 10). Inflows were 14,650 and 10,782 AF lower than historic averages during July and August (combined) of 1985 and 1986. In contrast, July and August inflows during 1984 were 8,130 AF above the historic average.

The effects of reservoir drawdown on boat launching was monitored at three public sites during 1984. At the campground on Little Boulder Creek, the boat ramp became unusable due to drawdown by mid September when reservoir volume was approximately 20,000 AF. On October 29, the distance from the top of the ramp to waters edge was approximately 84 m (276 ft). Launching of boats from the Slate Creek campground became difficult during mid September (at approximately 20,000 AF volume), due to the exposure of a mud flat. Boats are launched from a gravel beach at this campground. On October 29, the distance from the gravel beach to waters edge was about 350 m (1,148 ft). The boat ramp at the state recreation area became unusable by early September when

Table 10. Comparisons of monthly inflows to Painted Rocks Reservoir and month-end reservoir contents from 1984 to 1986.

	Month-end Contents (AF)				
Month	Median[a]	90% Exceedence	1984[b]	1985[b]	1986[b]
June	32,070	31,765	---	31,707	31,708
July	31,960	29,840	---	26,922	25,778
August	30,625	21,711	25,000	16,652	12,926
September	27,215	12,850	18,800	5,439	4,726
October	21,275	6,000	15,200	3,848	603
	Monthly Inflows (AF)[c]				
Month	Mean (1961-1985)		1984	1985	1986
July	16,700		23,930	4,910	8,720
August	7,900		8,800	5,040	5,098
September	6,500		6,220	5,470	4,888

a/ From Brown (1982).

b/ Values obtained within seven days of the end of the month.

c/ 1.0 ft^3/sec for 24 hours = 1.98347 AF.

Reservoir Elevations & Painted Rocks releases are available for 84, 85 & 86 should also be able to determine elevations for 1988 also.

reservoir volume was about 25,000 AF. An extensive mud flat was exposed at this site due to drafting of the reservoir. The distance from the bottom of the boat ramp to waters edge on October 29 was approximately 692 m (2,271 ft).

Recreational use of Painted Rocks Reservoir appeared to decline during September. This decline was probably due to the loss of boat launching facilities and to cooler weather conditions. An extension of the boat ramp at the campground on Little Boulder Creek could delay the loss of launching facilities due to accelerated drawdown of the reservoir.

In general, boating opportunities appear to be significantly reduced when reservoir volume is less than 20,000 AF. Based on median values of reservoir storage and expected rates of supplemental releases, boat launching should not be adversely effected in July and the majority of August during typical years. Boat launching will be difficult in September during average water years. During periods when instream flow requirements are met at Bell crossing, releases should be ceased to prolong boat access at Painted Rocks Reservoir.

Test Releases from Painted Rocks Reservoir

Supplemental water released into the Bitterroot River may be depleted by natural losses (infiltration and evaporation), or by losses to main stem irrigation withdrawals. Four test releases of reservoir water were conducted to determine the relative importance of these sources of depletion.

The amount of supplemental water reaching downstream stations was significantly diminished during each of the four test spills. The amount of water reaching the target area (Bell crossing) was negatively correlated with existing stream flow levels; i.e., when flows were lowest and additional water was needed most at the target area, supplemental water was least likely to arrive there. This was due to high irrigation demands during periods of dry weather and low stream flow when extensive diking at diversion points controlled stream flows. When large dikes were present, additional stream flow increased ditch discharge while river discharge downstream from dikes remained relatively steady.

During the two tests of 1984, stream flows were relatively high and there was minimal diking at diversion points. Results of these two test spills were similar with 82 and 88 percent of the releases reaching Darby in April and August, respectively (Figure 11). Little water was lost between Darby and Hamilton (Hamilton data not available in April), and equal percentages (37 percent) reached Bell crossing. The majority of depletion occurred between Hamilton and Bell crossing where numerous irrigation diversions are located. Discharge in diversions, however, were not monitored in 1984.

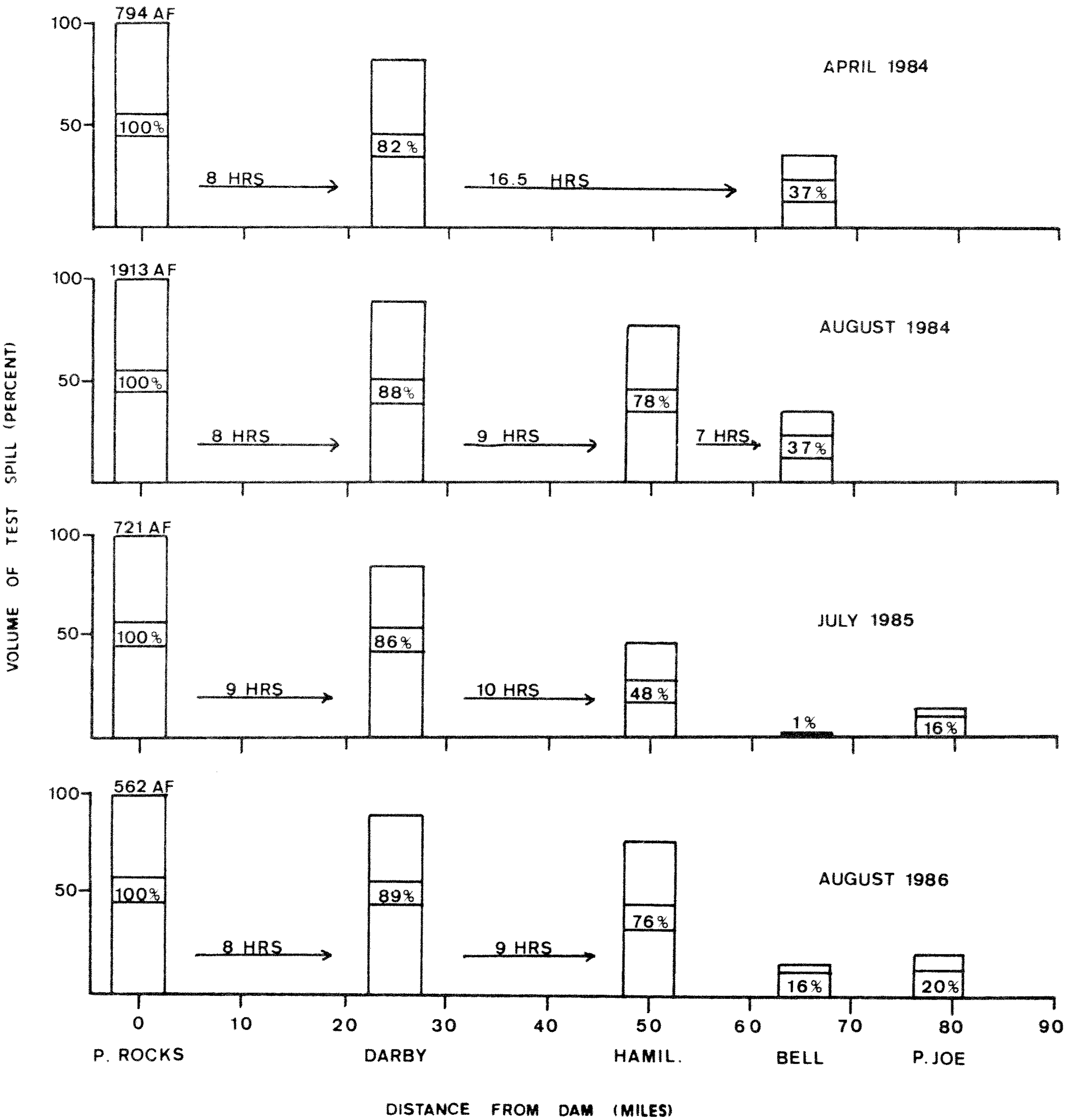


Figure 11. Percentages of test spill water reaching downstream stations during four releases from Painted Rocks Reservoir.

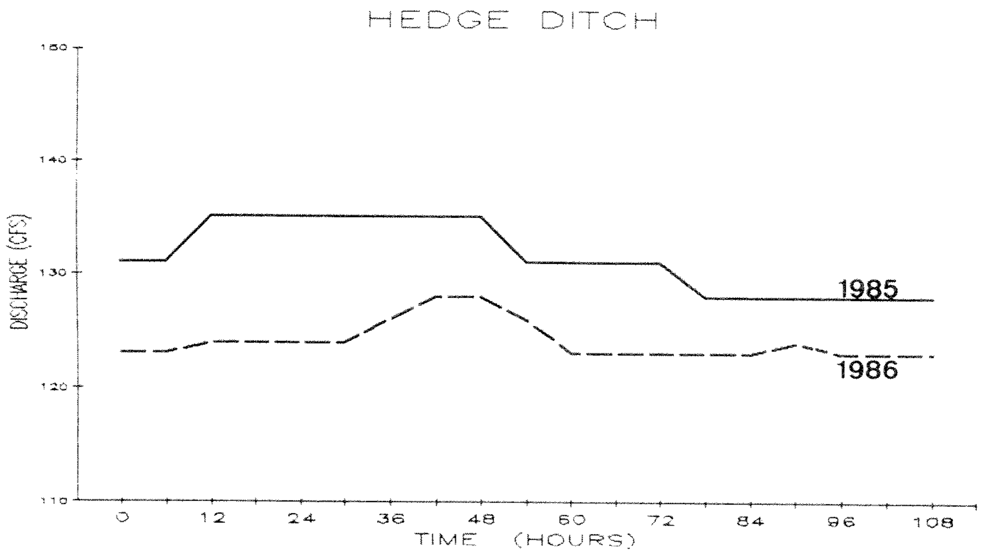
During July 1985, a test release was conducted during a period of critically low flows at Bell crossing (discharge was less than 1.42 m^3/sec; 50 ft^3/sec). Supplemental flows were diminished to a greater extent during the 1985 test release compared to test releases of 1984. Approximately 14 percent of the original release was lost before reaching the Darby station and about 52 percent of the original release was lost before passing the Hamilton station (Figure 11). Nearly all of the remaining supplemental water was diverted or lost from the river before reaching Bell crossing. Gravel dikes constructed upstream from Bell crossing were effectively blocking all flow in the river. Since a greater percentage of the original release reached the Poker Joe station than the Bell station, flows apparently were being diverted around the reach of river at Bell crossing and were being returned to the river via irrigation drains upstream from Poker Joe.

Approximately 35 percent (255 AF) of the original 1985 release was diverted from the river by four monitored ditches. An unknown additional amount was diverted by unmonitored ditches and Republican ditch which was monitored upstream from Skalkaho Creek where a portion of excess water is spilled into the creek and returns to the river above Hamilton. Republican ditch diverted 158.7 AF, but an unknown amount was returned via Skalkaho Creek.

Hedge, Corvallis, Supply, and Webfoot ditches gained 13.9, 36.7, 77.4 and 127.4 AF, respectively, as the test spill passed through the system (Figures 12 and 13). The amount of water diverted by ditches was positively correlated with the size of the dam at the point of diversion.

The results of the 1985 test clearly indicated that supplemental releases would not reach the target area during critically low flow conditions, when water is most needed, without the cooperation of irrigators. During 1986, the test release was repeated during another period of low flow conditions at Bell crossing (discharge prior to the test was 4.33 m^3/sec; 153 ft^3/sec) and extensive diking by irrigators. Prior to the test spill, the five major ditch companies were notified and asked to adjust headgates in an attempt to successfully transport water downstream.

A degree of cooperation from irrigators during 1986 resulted in 76 percent (427 AF) of the test spill reaching Hamilton; a larger amount than the 1985 test and a similar percentage observed in 1984. The majority of the difference at Hamilton between 1985 and 1986 was gained at Corvallis ditch which decreased withdrawals during the test spill, effectively adding 66 AF of water during the 48-hour release. In 1985, Corvallis ditch diverted 36.7 AF of water during the test (Figures 12 and 13). Hedge ditch diverted a similar amount (9.9 AF; 1.8 percent) of the test spill that was diverted in 1985 (13.9 AF; 1.9 percent). No diking occurs at this diversion, and supplemental releases pass the canal with only minor losses.



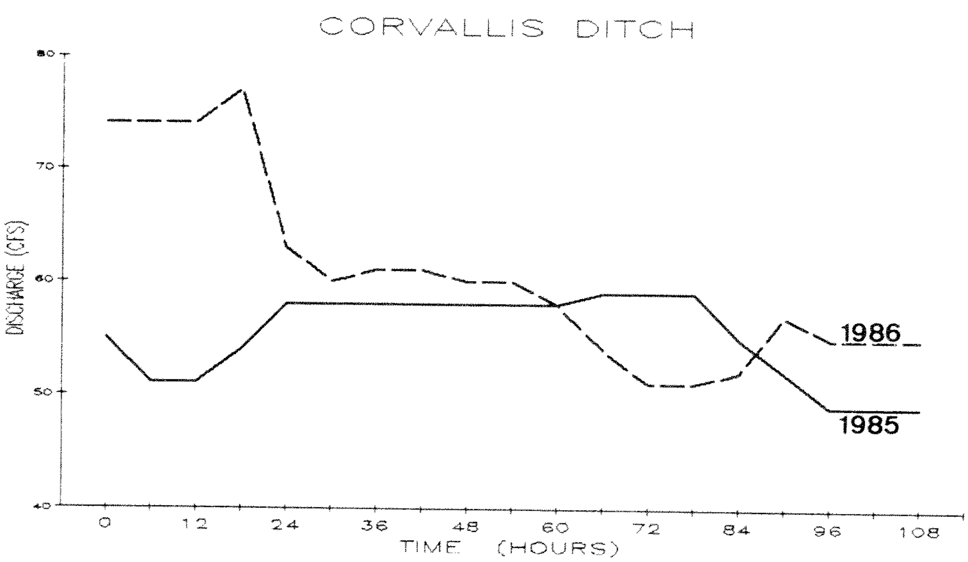


Figure 12. Hydrographs for Hedge and Corvallis diversions during test releases from Painted Rocks Reservoir in 1985 and 1986.

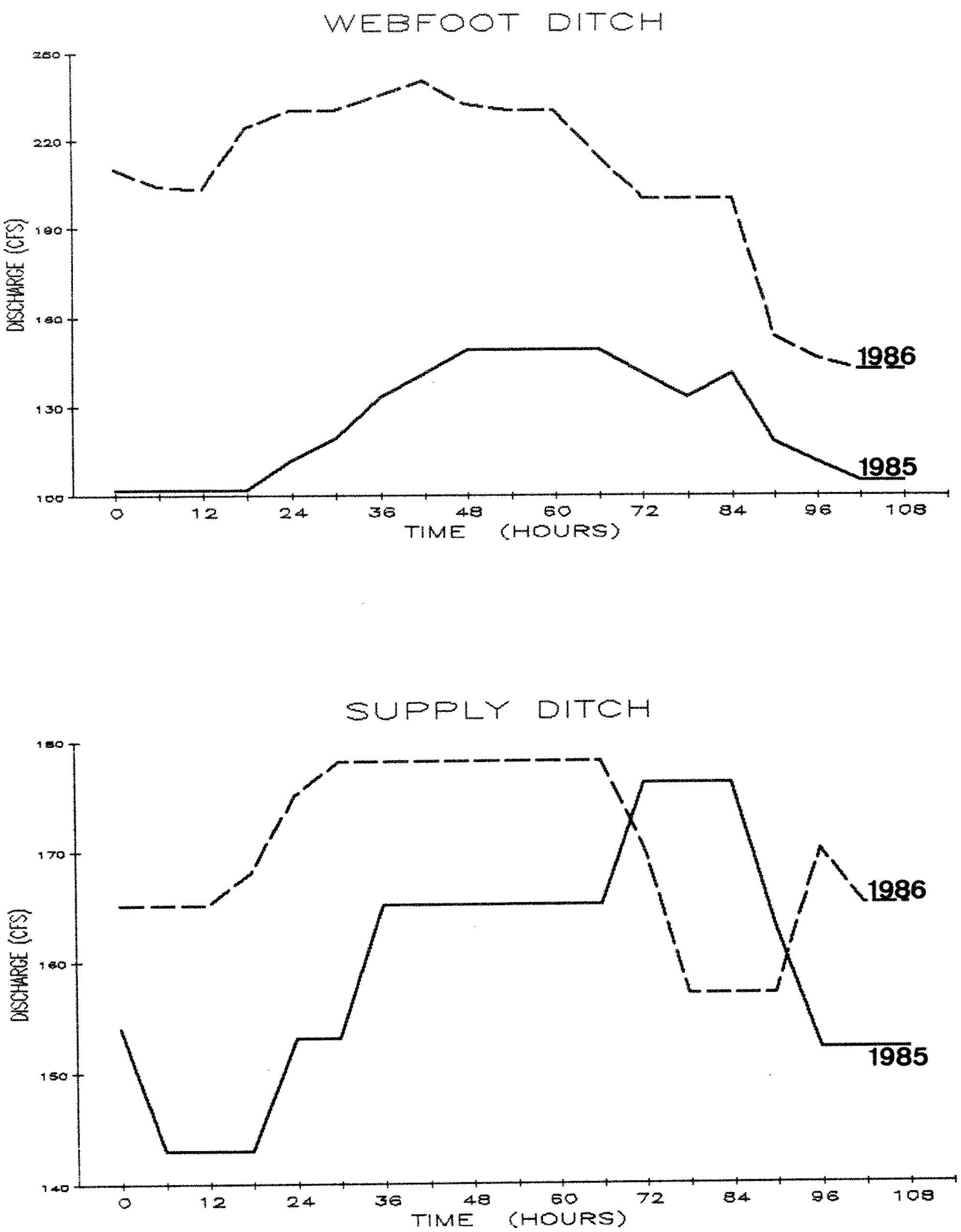


Figure 13. Hydrographs for Supply and Webfoot diversions during test releases from Painted Rocks Reservoir in 1985 and 1986.

The two monitored ditches between Hamilton and Bell crossing (Supply and Webfoot) made headgate adjustments in response to the test as evidenced by the lower level of ditch flow after the test water passed. The additional head created by test spill water, however, still resulted in test spill water entering the ditches. Based on water amounts reaching Hamilton, a smaller percentage of test spill water was diverted at Supply and Webfoot ditches in 1986, compared to 1985. At Supply ditch, 77.4 AF (22.4 percent) and 54.0 AF (12.6 percent) of the test spill volumes were diverted in 1985 and 1986, respectively (Figures 12 and 13). Webfoot ditch withdrew 127.4 AF (36.8 percent) and 117.9 AF (27.6 percent) of the test release water in 1985 and 1986, respectively.

Despite the efforts of the major ditches to avoid diverting test water, only 16 percent of the test spill reached Bell crossing. It was apparent that the relatively small ditches, which also constructed dikes, were diverting a large portion of the water gained from cutbacks by major ditches. In addition, some of the smaller ditches have no headgate, and no means of regulating ditch flow short of breaching the dike (one irrigator did this). Supplemental water will not enhance flows during critically low water years if these diversions are not modified to allow regulation of withdrawals.

The Poker Joe station passed similar percentages of test releases in 1985 (16 percent) and 1986 (20 percent) (Figure 11). This station is approximately 128 km (80 miles) downstream from Painted Rocks Reservoir.

Water Temperature

West Fork of Bitterroot River

Monthly maximum/minimum water temperatures in the West Fork of the Bitterroot River near the base of Painted Rocks Reservoir were monitored from 1983 to 1986. Temperature data for a complete summer period, however, are only available for 1984 and 1985.

In 1984, water temperature ranged from 2.2 to 15.0 C (36 to 59 F) from April 1 to November 30 (Table 11). The maximum temperature occurred during the first half of July when water was flowing over the spillway. August temperatures were slightly cooler because of the hypolimnetic draw of Painted Rocks Dam. Releases of supplemental water did not significantly effect water temperatures in the West Fork of the Bitterroot River.

In 1985, maximum water temperature was slightly higher than 1984 during June, August, and September. Water spilled over the crest of the dam ceased during early July, which resulted in a cooling trend in water temperature (Table 11). Water temperature ranged from 0.3 to 17.8 C (32.5 to 64 F), with the maximum

Table 11. Monthly maximum and minimum water temperatures (°F)[a] in the West Fork of the Bitterroot River at the base of Painted Rocks Reservoir during 1984 and 1985.

	1984		1985	
Month	Maximum Temperature	Minimum Temperature	Maximum Temperature	Minimum Temperature
April	44	36	44	33
May	--	--	54	40
June	55	45	58	44
July	59	52	56	46
August	57	48	60	48
September	58	49	64	48
October	54	39	48	42
November	45	38	--	--
December	--	--	43	32.5

a/ $^{o}C = (^{o}F-32)5/9$

temperature occurring during the last half of September. As in 1984, supplemental releases did not significantly change water temperature in the West Fork.

Main Stem of the Bitterroot River

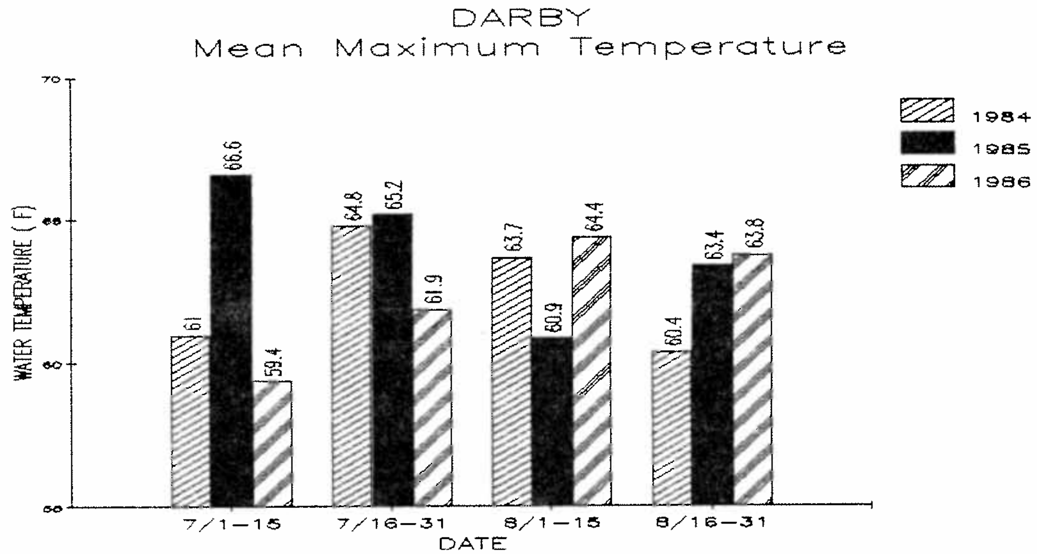
Water temperature in the Bitterroot River was monitored during March through late November from 1984 through 1986. Monitoring stations were established near Darby, Hamilton, Bell crossing, and MaClay bridge to evaluate the relationship between stream flow and water temperature in various reaches of the Bitterroot River. Maximum summer water temperatures in the dewatered reach of the river were of particular interest.

Water temperatures greater than 17-20 C (63-68 F) have been shown to exceed the physiological optimum for salmonid growth (Brett et al. 1969, Brockson and Bugge 1974). Since water temperatures frequently exceed these optimal values during the summer months in some reaches of the river, mean maximum temperatures were compared between sections and years to determine whether summer temperatures posed significant problems for the fishery. Comparisons were also made to evaluate the effects of supplemental releases on maximum water temperatures in the Bitterroot River. The highest water temperatures occurred during July or August, and data during these months were used for comparisons.

Mean maximum temperature at the Darby and Hamilton stations depended on the two related factors of stream flow and weather conditions. The low stream flows and associated hot weather of July 1985 resulted in higher water temperatures at Darby and Hamilton, compared to other years (Figure 14). During the four years of data collection, August stream flows at Hamilton were lowest in 1986. Consequently, the highest August water temperatures were observed in 1986. August water temperatures at Darby appeared to be more influenced by hot weather than stream flow since the highest temperatures occurred in 1986 despite the slightly lower flows observed in 1985.

In general, maximum water temperatures at Hamilton were higher than those at Bell crossing (Figures 14 and 15). This was not expected because of the extremely low flows observed at Bell crossing, which were assumed to cause high temperatures. Apparently, groundwater inflows in the dewatered section effectively moderate temperatures.

The extremely low flows of July 1985 did create the highest temperatures observed at Bell crossing, but during the last half of July and the first half of August, 1984, temperatures were greater than those of 1985, despite the occurrence of higher stream flows.



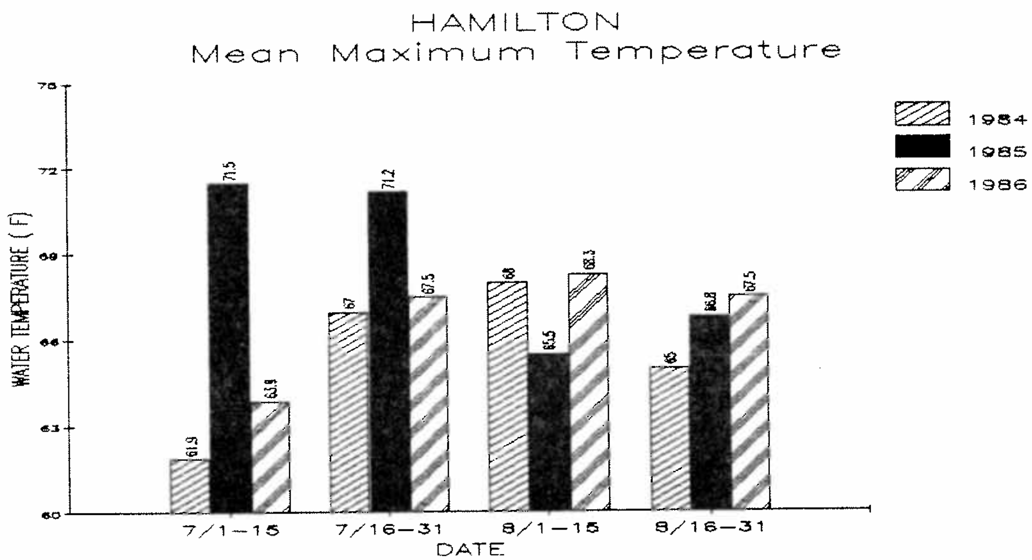
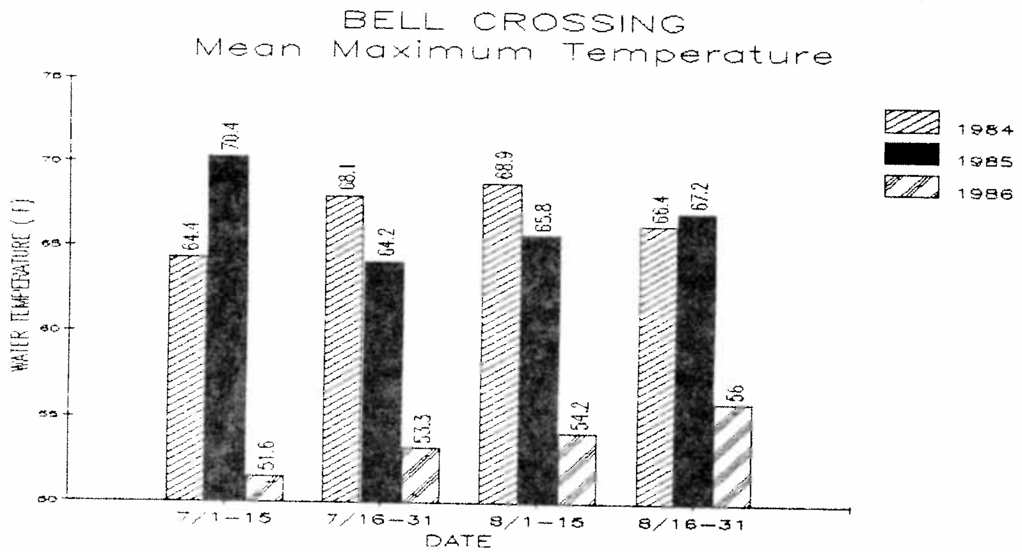


Figure 14. Comparisons of mean maximum water temperature in the Bitterroot River at Darby and Hamilton stations, 1984-1986.



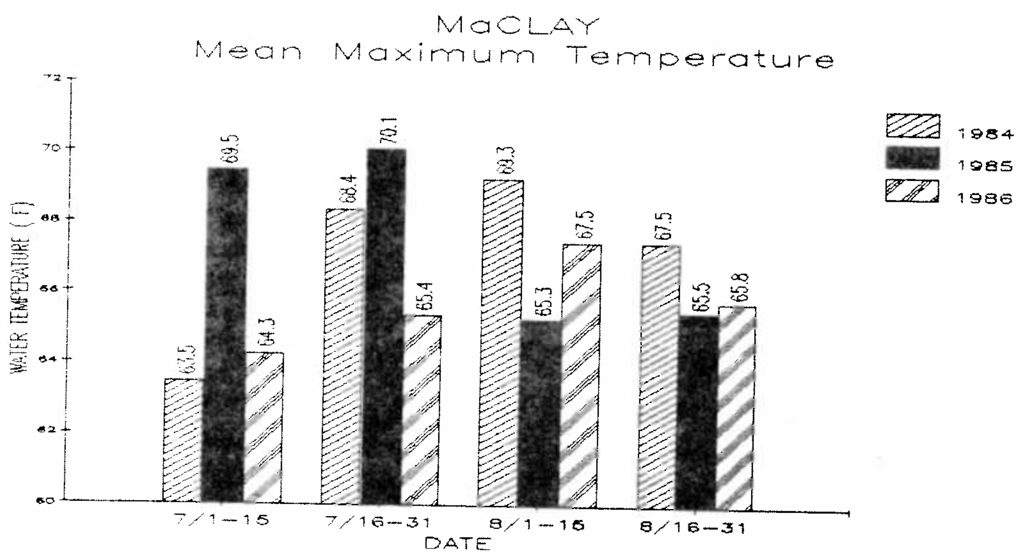


Figure 15. Comparisons of mean maximum water temperature in the Bitterroot River at Bell crossing and MaClay stations, 1984-1986.

Bell crossing water temperature data during 1986 were not comparable to previous years because the thermograph lead was buried by approximately 10 cm (4 in) of gravel during spring runoff. As a result, this thermograph was monitoring the temperature of groundwater inflow just below the substrate level. The significantly lower temperatures just below the level of the substrate indicate that groundwater inflow rates are relatively high. In addition, there are numerous pools within the dewatered section exceeding three meters (10 ft) in depth. Based on casual observation, water temperatures at the depths of these pools were cooler than surface temperatures.

Groundwater seepage may also influence water temperatures at MaClay bridge. July water temperatures were highest during the year with the lowest stream flow (1985), and August temperatures were highest during 1984 (Figure 15).

Water temperature at the Darby station rarely exceeded the thermal optimum range 19 C (67 F) for salmonids (Figure 16). At all stations except MaClay bridge, temperatures exceeded the optimum range for the largest number of days during the year with the lowest stream flow (1985).

Based on water temperature and stream flow data, it appears that the number of days critical temperatures are exceeded in the Bitterroot River is not strictly a function of flow level. Groundwater inflows, and air temperatures also influence maximum water temperatures. At Hamilton, summer flows were positively correlated with the number of days temperature exceeded 19 C (67 F), and during low water years, temperatures at Hamilton were higher than those at Bell crossing and MaClay bridge. When stream flows were at or near minimum recommended values, critical temperatures were exceeded more often in the lower river (MaClay station).

Supplemental releases that enhance flows throughout the river could be expected to moderate temperatures in the upper river (Darby and Hamilton), but will have little influence on temperatures in the dewatered reach of the river. Extremely hot and dry weather influence water temperatures regardless of stream flow levels.

Physical Characteristics of Study Sections

Physical characteristics of the Darby, Tucker East, and Tucker West sections were measured during 1984 in an attempt to quantify differences in available habitat between sections. Available habitat varied considerably between the Darby section and the Tucker section.

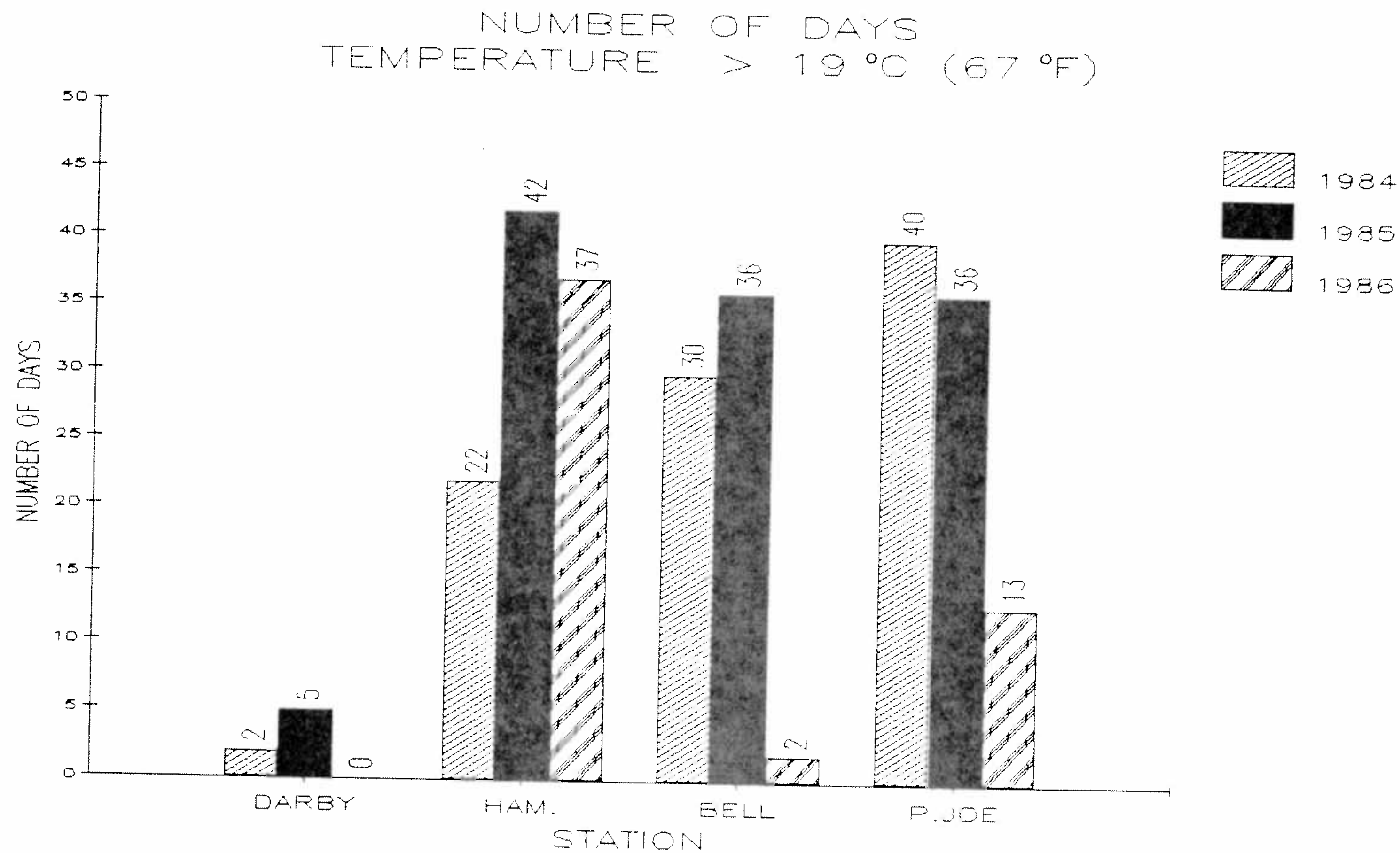


Figure 16. Comparisons of number of days water temperature exceeded 19 C (67 F) in the Bitterroot River at four stations, 1984-1986.

Differences in widths and depths among the study sections were partially due to the presence of side channels and to the characteristic channel split of the Tucker section (Table 12). The mean number of channels containing water was significantly greater in the Darby and Tucker East sections than the Tucker West section. Few side channels were present in the Tucker West section. Mean total widths (side channels included) were significantly different among the three study sections. Total width was greatest in the Darby section, intermediate in the Tucker East section, and least in the Tucker West section. Width of the dominant channel was significantly greater in the Darby section than in the two Tucker sections. Mean depths and thalweg depths in the Darby and Tucker West sections were not significantly different, but were significantly greater than in the Tucker East section. These data indicate the dominant channel of the Darby section was relatively wide and deep in comparison to the narrow, shallow channel of the Tucker East section and the narrow, deep channel of the Tucker West section.

Pool numbers as measured by pool-riffle periodicity were not significantly different among study sections (Table 12). In contrast, the pool-riffle ratio was less in the Darby section than in the Tucker East and Tucker West sections. Average pool length was similar among study sections. Mean riffle length, however, was significantly greater in the Darby section than the two Tucker sections. These data indicate the Darby section contained a greater quantity of riffle habitat than the Tucker East and Tucker West sections.

The total amount of potential cover present was less in the Darby and Tucker East sections that the Tucker West section (Table 13). The Tucker West section contained approximately 200 percent more cover than did the other two sections. Shoreline debris was the dominant cover type in the Darby section, comprising 36.7 percent of the total amount of cover present. Instream debris was the dominant cover type in the Tucker East and Tucker West sections, comprising 44.1 and 49.1 percent of the available cover, respectively. A majority of the debris in all three sections was composed of snags from fallen cottonwood and conifer trees.

Several studies have demonstrated the importance of pool area and cover to trout populations (Boussu 1954, Lewis 1969, Enk 1977). Based on pool and cover characteristics measured in the Bitterroot River, the amount of potential habitat for trout appears to be greater in the Darby and Tucker West sections than in the Tucker East section. Pool and cover features, however, represent only a general measure of habitat quality.

Differences in physical characteristics between the Darby section and the Tucker Sections are large enough to create differences in trout populations, regardless of flow conditions in the two areas. During years of high stream flow, the Tucker sections contain more available fish habitat than the Darby

Table 12. Selected physical characteristics of study sections in the Bitterroot River measured during August, 1984. Standard deviations in parentheses.

Parameter	Section: Darby	Section: Tucker East	Section: Tucker West
Mean number of channels	1.55 (0.68)	1.68 (0.66)	1.05 (0.22)
Mean total width (m)[a]	45.4 (10.3)	37.9 (13.1)	27.7 (8.2)
Mean dominant channel width (m)	42.2 (9.4)	25.9 (8.1)	27.2 (8.1)
Mean depth (cm)	54.0 (37.0)	44.0 (33.0)	52.0 (36.0)
Mean thalweg depth (cm)	96.0 (34.0)	75.0 (31.0)	93.0 (34.0)
Pool-riffle periodicity	8.11 (3.62)	7.29 (2.56)	10.98 (4.78)
Mean pool length (m)	187.9 (91.7)	143.6 (70.5)	228.9 (111.2)
Mean riffle length (m)	155.5 (135.6)	45.1 (19.0)	69.5 (42.2)
Pool riffle ratio	1.21	3.19	3.29
Gradient %	3.21	2.44	2.44
Discharge (m^3/sec)[b]	12.0-16.3	6.0-6.3	5.2-6.0
Section length (km)	9.36	8.88	8.95
Surface area (km^2)	0.425	0.337	0.248

a/ Sum of main channel and side channel widths.

b/ Discharge when characteristics were measured.

Table 13. Area (m^2/400 m) of potential cover in the study sections of the Bitterroot River measured during August, 1984.

Cover Type	Section Darby	Tucker East	Tucker West
Shoreline overhang			
Brush[a/]	14.94	3.81	51.82
(% of total cover)	(18.5)	(4.8)	(19.8)
Debris[b/]	29.57	15.24	19.21
(% of total cover)	(36.7)	(19.3)	(7.3)
Undercut[c/]	7.32	8.23	24.38
(% of total cover)	(9.1)	(10.5)	(9.3)
Rock shelf[d/]	22.10	16.76	38.10
(% of total cover	(27.4)	(21.3)	(14.5)
Instream			
Debris[b/]	6.71	34.75	128.93
(% of total cover)	(8.3)	(44.1)	(39.1)
Total Cover	80.62	78.79	262.43

a/ Overhanging rooted woody vegetation

b/ Snags, driftwood, and logs

c/ Undercut streambanks

d/ Shelves of rock within or overhanging the water section, but during years with poor stream flow, available habitat in the Tucker sections is greatly reduced compared to the Darby section. Physical characteristics measured in 1984 represent available habitat during a period of relatively high stream flows.

Water Quality Parameters

Water quality was monitored during 1983 and 1984 at three stations established on the Bitterroot River, and at two stations on irrigation returns to determine the effects of irrigation on water quality in various reaches of the Bitterroot River. The three river stations were located at the Darby U.S.G.S. gauge (station 1), immediately upstream from the Stevensville irrigation return (station 2), and below the irrigation return at the Stevensville bridge (station 3). Irrigation returns were located 1.5 km (0.9 mi) above Victor bridge (station 4), and 4.8 km (3.0 mi) above Stevensville bridge (station 5).

Mean values of pH, bicarbonate, total phosphorus, conductivity, and total alkalinity increased in a downstream direction at successive stations on the Bitterroot River (Table 14). These increases were probably due to inputs of chemical constituents from tributary inflow and from irrigation returns. Mean values of all measured parameters, except pH and total ammonia, were greater in the irrigation returns than in the Bitterroot River. A comparison of ionic concentrations among the five stations, as measured by specific conductance, is shown in Figure 17.

Based on the chemical parameters that were monitored, water quality in the Bitterroot River was considered favorable. Total nitrogen and phosphorus levels measured in the river were less than problem criteria for running waters given by the Environmental Protection Agency (Mills et al. 1982). The Environmental Protection Agency (EPA) criteria are presented in Table 15. Although less than the problem criteria given by EPA, nutrient levels in the irrigation returns were substantially greater than levels in the river. The source of these nutrients was apparently from the application of fertilizers on surrounding farmlands and from livestock wastes. The presence of dense growths of aquatic vegetation within the irrigation returns was probably a result of these higher nutrient levels. The un-ionized form of ammonia is toxic to freshwater aquatic life. The presence of this un-ionized form is dependent upon total ammonia concentration, pH, temperature and ionic strength. Total ammonia concentrations monitored in the river and irrigation returns were well below concentrations needed to reach toxic levels of the un-ionized form within the ranges of pH and temperature measured at the five stations. The EPA criterion for ammonia in un-ionized form is 0.02 mg/l (Environmental Protection Agency 1976). Ammonia concentrations monitored at the five stations were relatively low despite the common use of anhydrous ammonia as fertilizer on surrounding farmlands.

Table 14. Mean and range (in parentheses) of values for chemical parameters measured at stations on the Bitterroot River and irrigation returns during 1983 and 1984.

Parameter	Bitterroot River[a]						Irrigation Returns[a]			
	Station 1		Station 2		Station 3		Station 4		Station 5	
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984
<u>Lab Determination</u>										
pH	7.82 (7.7-8.0)	7.55 (7.5-7.6)	7.95 (7.9-8.0)	7.79 (7.7-7.9)	8.10 (8.1)	7.96 (7.8-8.2)	- -	8.48 (8.0-9.3)	8.35 (8.3-8.4)	8.10 (7.9-8.4)
HCO_3^-(mg/l)	- -	40.7 (26.9-50.8)	- -	56.1 (26.9-71.0)	- -	72.9 (37.8-93.6)	- -	118.2 (78.5-147.4)	- -	160.5 (148.6-174.8)
Total nitrogen (mg/l)	- -	0.49 (0.37-0.68)	- -	0.25 (0.12-0.37)	- -	0.26 (0.16-0.42)	- -	0.60 (0.14-1.83)	- -	0.75 (0.38-1.55)
NO_3-N(mg/l)	- -	0.012 (0.003-0.026)	- -	0.012 (0.003-0.020)	- -	0.029 (0.012-0.051)	- -	0.060 (<0.001-0.173)	- -	0.25 (0.114-0.475)
Total ammonia (mg/l)	<0.015 (<0.01-0.02)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01-0.01)	<0.015 (<0.01-0.02)	<0.020 (<0.01-0.05)	- - -	<0.01 (<0.01-0.02)	0.015 (<0.01-0.02)	0.06 (<0.01-0.16)
Total phosphorus (mg/l)	- -	0.015 (0.010-0.024)	- -	0.017 (0.009-0.033)	- -	0.023 (0.014-0.044)	- -	0.041 (0.011-0.112)	- -	0.049 (0.030-0.095)
Conductivity (umhos/cm)	76.5 (75-78)	74.1 (67-93)	95.5 (91-100)	98.1 (37-124)	114.0 (110-118)	123.9 (54-158)	- -	199.9 (133-282)	271 (264-278)	270.8 (242-295)
<u>Field Determinations</u>										
pH	7.62 (7.4-7.8)	6.56 (6.4-6.9)	8.05 (8.0-8.1)	6.70 (6.5-7.8)	8.42 (8.3-8.6)	6.74 (6.6-7.0)	- -	7.12 (6.8-8.4)	8.40 (8.2-8.8)	6.81 (6.6-7.8)
Dissolved oxygen (mg/l)	10.15 (9.30-11.35)	9.62 (8.25-11.20)	11.15 (10.80-11.50)	9.19 (7.55-11.60)	11.07 (10.50-11.50)	9.78 (8.60-11.70)	- - -	12.58 (9.90-14.20)	12.38 (11.95-12.80)	11.49 (10.10-12.60)
Total alkalinity (mg/l as $CaCO_3$)	48 (44-50)	35 (20-50)	53 (50-55)	44 (24-53)	65 (57-77)	54 (30-75)	- -	94 (67-140)	128 (117-138)	106 (50-137)

a/ Station 1 - Bitterroot River near Darby
Station 2 - Bitterroot River 4.8 km above bridge at Stevensville
Station 3 - Bitterroot River at bridge at Stevensville
Station 4 - Irrigation return 1.5 km above Victor crossing
Station 5 - Irrigation return 4.8 km above bridge at Stevensville

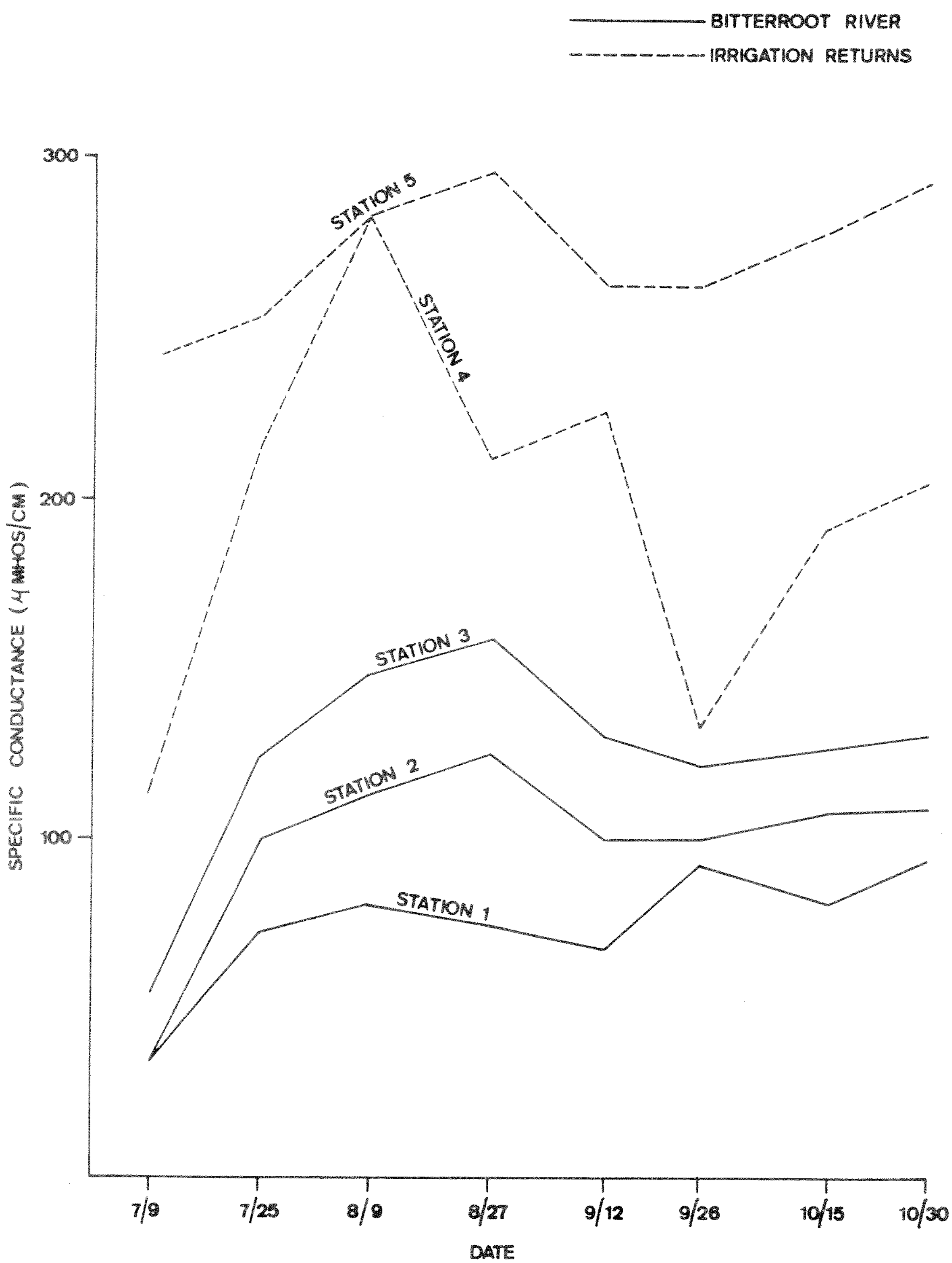


Figure 17. Comparisons of conductivity (μ mhos/cm) in the Bitterroot River and irrigation returns during 1984.

Table 15. EPA criteria for total phosphorus and nitrogen in running waters.

Total Phosphorus (mg/l)	Total Nitrogen (mg/l)	Significance
0.013	0.092	Problem threshold
0.13	0.92	Problem likely
1.3	9.2	Severe problem

The values for pH, bicarbonate, nitrate, and alkalinity measured at the five stations were within the range of values expected to occur in relation to the geologic characteristics of the valley. The values for dissolved oxygen monitored at the five stations were commonly above saturation levels. These data indicate favorable water quality in the Bitterroot River.

Fish Populations

Species Composition

Eighteen species representing seven families of fish are present in the Bitterroot River (Table 16). Of these, 15 species have been captured since the inception of the study. Predominant game fish, in order of abundance, were mountain whitefish, rainbow trout and brown trout. Predominant non game species included largescale and longnose suckers, longnose dace, redside shiner, northern squawfish and slimy sculpin.

Population Estimates

Population estimates were conducted during the spring (March, April, and May) and fall (September, October, and November) through the study to determine the relationship between summer stream flow levels and trout populations. Estimates of trout numbers were obtained from the upper river (Conner and Darby sections) where summer stream flows are adequate, the middle river (Tucker section which consists of two distinct channels) where stream flows are typically lowest due to irrigation depletions, and the lower river (Poker Joe section) where stream flows are replenished from irrigation returns.

Fall population estimates provided more reliable trend information than spring estimates because electrofishing efficiencies were higher, allowing the capture of all age classes except age 0. Rainbow trout and yearling brown trout estimates were most reliable during the fall, although adult brown trout estimates were biased in the fall because of extensive spawning movements. Comparisons of adult brown trout (fish greater than 356 mm; 14 in) numbers were based on spring estimates.

In general, spring population estimates were of limited value despite the large effort required to obtain them; approximately five marking and five recapture runs per section were needed to estimate numbers. Rainbow trout estimates were biased by spring spawning movements, and should be used only as an index of change. In addition, spring brown trout estimates were influenced by flow conditions which resulted in widely variable capture efficiencies on fish smaller than about 256 mm (14 in). For example, the early spring runoff of 1985 and 1986 increased flows during the estimates which reduced capture efficiencies, especially for

Table 16. Fish species present in the Bitterroot River (Relative abundance in parentheses).[a]

Family / Scientific name	Common name
SALMONIDAE	
Salmo gairdneri	*Rainbow trout (A)
Salmo trutta	*Brown trout (A)
Salmo clarki	*Cutthroat trout (C)[b]
Salvelinus fontinalis	*Brook trout (C)[b]
Salvelinus confluentus	*Bull trout (R)
Prosopium williamsoni	*Mountain whitefish (A)
ESOCIDAE	
Esox Lucius	*Northern pike (R)
CYPRINIDAE	
Rhinichthys cataractae	*Longnose dace (A)
Mylocheilus caurinus	Peamouth (R)
Richardsonius balteatus	*Redside shiner (A)
Ptychocheilus oregonensis	*Northern squawfish (A)
CATOSTOMIDAE	
Catostomus catostomus	*longnose sucker (A)
Catostomus macrocheilus	*Largescale sucker (A)
CENTRARCHIDAE	
Micropterus salmoides	*Largemouth bass (R)
Lepomis gibbosus	*Pumpkinseed (R)
PERCIDAE	
Perca flavescens	Yellow perch (R)
COTTIDAE	
Cottus cognatus	*Slimy sculpin (A)
Cottus confusus	Shorthead sculpin (U)

a/ Relative abundance -- A = abundant, C = common, R = rare, U = status unknown.

b/ Abundant in tributaries.

* Species captured since inception of study.

smaller size groups. Consequently, spring estimates for brown and rainbow trout were higher in 1984, compared to 1985 or 1986, in all sections (Appendix Figures E1 through E6).

Caution should also be used in interpreting age class estimates (Appendix Tables E1 through E5). Relatively poor electrofishing efficiencies and small sample sizes in sections with low population numbers resulted in lower than optimal numbers of recaptures per age group. This was particularly true during spring estimates, and age class estimates were discarded during selected years. Fall age class estimates, although more reliable, should not be used for detailed analyses such as estimation of annual mortality rates. Use should be confined to general comparisons of age structures between years or between river sections.

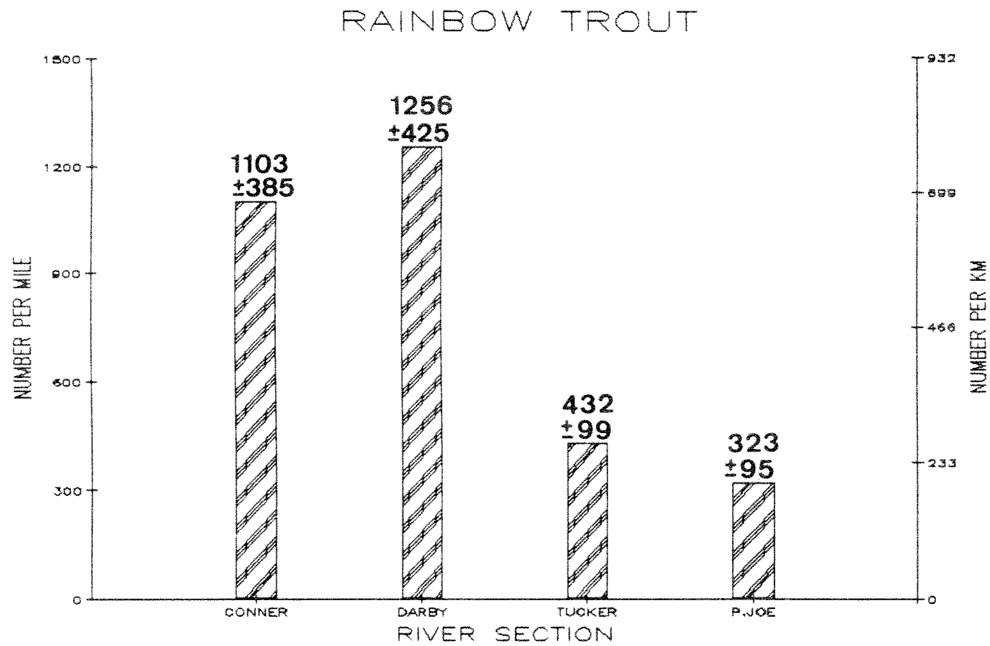
During future population assessments, it is recommended that fall estimates be used. However, it should be recognized that estimates of adult brown trout will be inflated during fall periods. Adult brown trout (fish larger than 356 mm; 14 in) numbers were typically higher during fall periods (compared to spring) at the Darby and Tucker sections (Appendix Figures E1 through E6).

Comparisons Between Sections

The upper reaches of the Bitterroot River, represented by the Conner (West Fork) and Darby sections, are predominantly rainbow trout fisheries (Figure 18). Rainbow trout numbers sharply decline between the Darby and Tucker sections. Brown trout are the most abundant trout species in the two channels of the Tucker section, but are relatively scarce in the lower river (Poker Joe section) and the West Fork of the Bitterroot River (Conner section). Brown trout numbers were not significantly different (80 percent confidence intervals overlap) in the Tucker and Darby sections (Figure 19).

Estimated numbers of rainbow trout were higher in the Darby section than in the Tucker section (Figure 19) or the Poker Joe section (Figure 18). These differences were statistically significant ($p<0.20$).

The relatively low trout numbers observed at the Tucker section indicate that poor stream flows in this section have adverse effects on trout populations. The dewatered reach of the river, if not severely depleted by irrigation withdrawals, would have greater summer flows than the Darby section. In addition, when flows were adequate during 1984, available trout habitat in the Tucker section (both channels combined) was more abundant than in the Darby section. Low summer stream flow, which reduces available trout habitat, is probably the limiting factor for trout populations in the Tucker section.



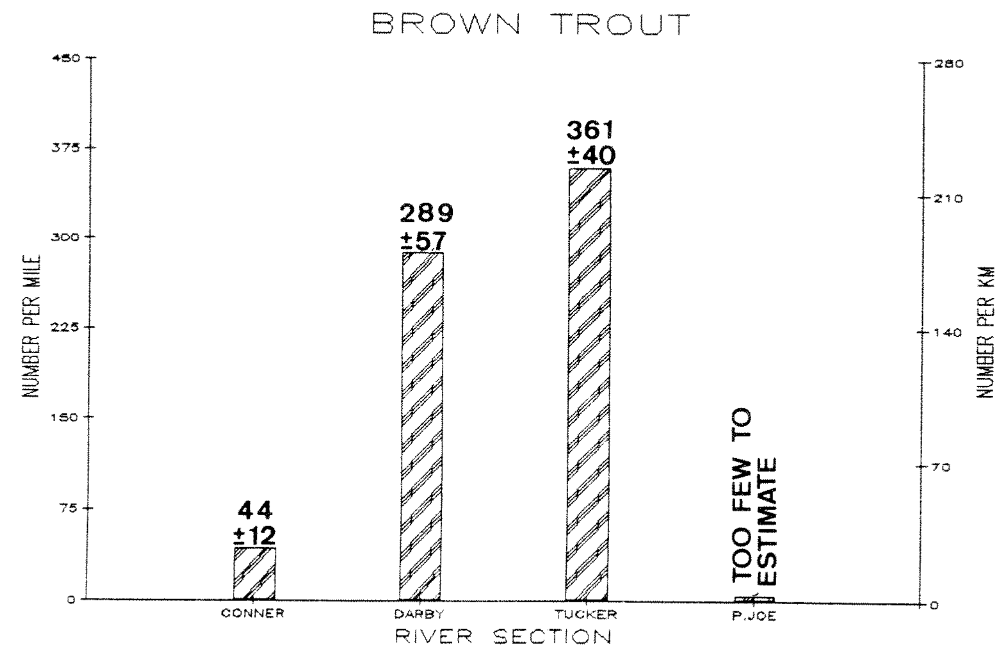
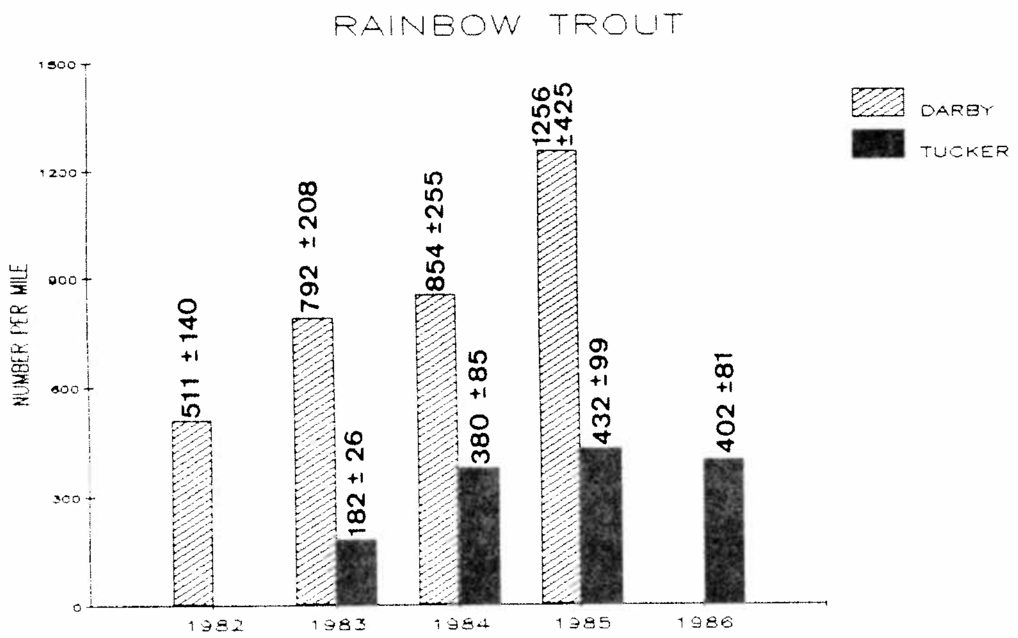


Figure 18. Estimated numbers of rainbow trout and brown trout in four study sections of the Bitterroot River during fall, 1985 (Conner data from fall, 1986). Plus or minus 80% confidence intervals.



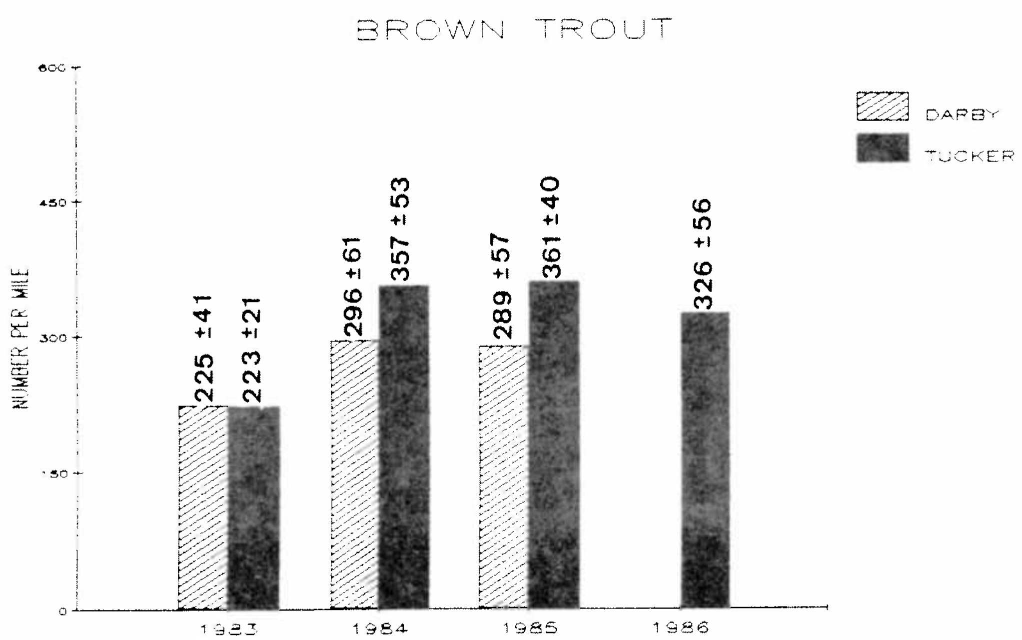


Figure 19. Comparisons of brown and rainbow trout numbers in the Darby and Tucker sections, Bitterroot River. Plus or minus 80% confidence intervals.

The low trout population levels observed in the Poker Joe section were unexpected since this reach of the river did not have problems with low stream flow, poor habitat characteristics (unmeasured), or poor water quality. Inadequate recruitment of juveniles into the population is one possible explanation for the relatively low densities of brown and rainbow trout observed in the Poker Joe section. Comparisons of trout age structure, and young-of-the-year (YOY) densities between river sections support this explanation, and are discussed in subsequent sections of this report.

Age Structure of Trout Populations

Age structures of trout populations in the Bitterroot River vary depending on recruitment and/or successful rearing of juvenile trout. Yearling trout numbers were highest in the upper river (Conner and Darby sections) where favorable flow conditions exist. In addition, yearling abundance increased following years with higher stream flows, indicating that supplemental releases enhance trout recruitment and/or rearing conditions.

Densities of YOY (age 0) were assumed to be the primary factor determining yearling numbers of the following year. Comparisons of YOY densities were not feasible because this age class was not effectively sampled during estimates. General trends in YOY abundance was also determined from surveys presented later in this report.

In the upper river (Darby and Conner sections), yearlings (age I fish) comprised over 50 percent of the rainbow trout population (Figure 20). Age II fish comprised the largest percentage of the population at the Tucker and Poker Joe sections, and only about 30 percent of these populations were comprised of yearlings (Figure 20).

Estimates of yearling rainbow trout were not obtained every year in the Tucker section due to low population levels; therefore, trends in abundance were not clear. In the Darby section, the number of yearlings increased from 121/km (194/mi) in 1982, to 461/km (742/mi) in 1985 (Appendix Table E1). This significant increase in yearling abundance was probably a result of supplemental releases from the reservoir and the relatively good water years of 1983 and 1984, which resulted in increased summer stream flows in the Darby section. Apparently, the enhanced stream flows have improved survival of juveniles and/or increased recruitment of juveniles into the section.

Brown trout age structure in the Darby and Tucker sections demonstrated a similar pattern. Yearlings comprised the largest proportion of the population in the Darby section, and the

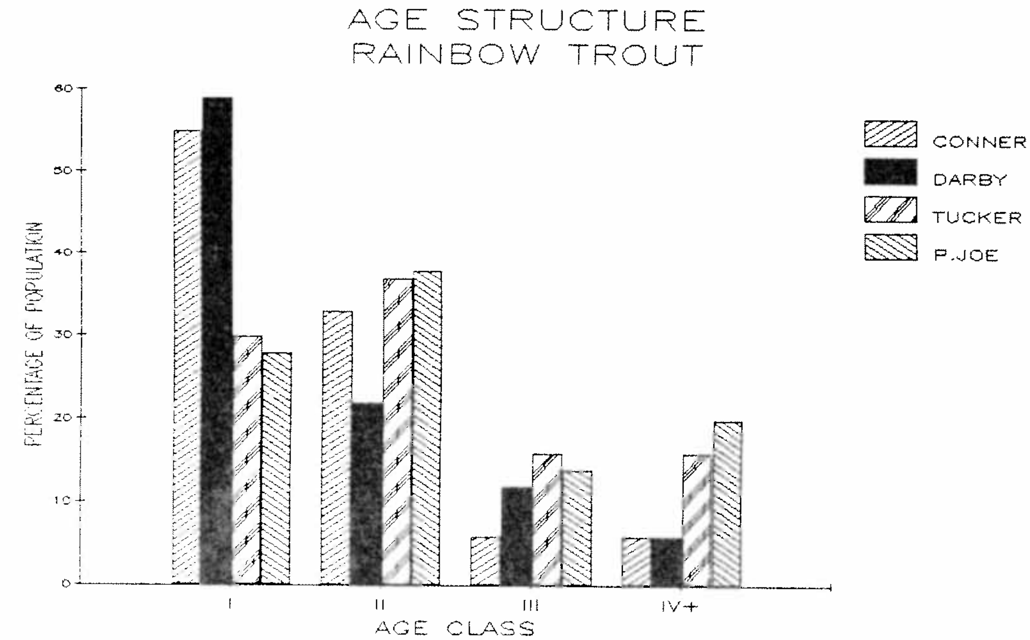


Figure 20. Age structure comparisons for brown and rainbow trout in study sections of the Bitterroot River.

percentage of fish in an age class declined steadily in subsequent age groups (Figure 20). In the Tucker section, each age class contained a similar percentage of the population.

As with rainbow trout, yearling brown trout numbers changed in response to summer stream flows of the previous year. The summer flows of the Bitterroot River were relatively low in 1982. The number of yearlings in the two channels of the Tucker section and the Darby section were relatively low in 1983. Yearling numbers increased and leveled off between 1983 and 1985 in response to the relatively high stream flows of 1983 and 1984 (Figure 21). The decrease in numbers observed during fall, 1986, in the Tucker channels was probably a result of the low flows of early summer, 1985.

Low stream flows along with large gravel dikes constructed on the west channel to supply water to irrigation diversions on the east channel resulted in severe dewatering of both Tucker channels in 1985 and 1986. Despite dewatering of both channels, fish populations appeared to respond differently in the two channels. Based on yearling numbers observed in 1986 (Figure 21), juvenile brown trout abundance was significantly reduced in the east channel, but only slightly reduced in the west channel as a result of the low stream flows.

The reason(s) for the different results in the two channels is not known, but two possible explanations exist. There are five irrigation diversions on the east channel, but only one in the lower end of the west channel. It is possible that significant numbers of YOY and/or yearling brown trout are lost to diversions when stream flows are critically reduced. The larger number of diversions on the east channel would result in higher losses if, in fact, these losses are occurring.

Another difference between the two channels is that four tributaries enter the west channel, but none enter the east channel. The tributaries are typically dewatered during dry summer periods and do not enhance west channel stream flows. Based on results of fish trapping presented in a later section, however, the tributaries do provide recruitment to the west channel. The majority of trout observed emigrating from tributaries were rainbow trout YOY which entered the river during late June and early July. These fish would be exposed to west channel dewatering during the summer. Since traps were ineffective during spring runoff, it is not known whether brown trout YOY and/or yearlings enter the west channel in significant numbers. It is possible that yearling brown trout (or rainbow trout) are better able to cope with dewatering than YOY because of differing habitat requirements. If significant numbers of trout migrate from tributaries as yearlings, poor survival of YOY in the west channel would be offset.

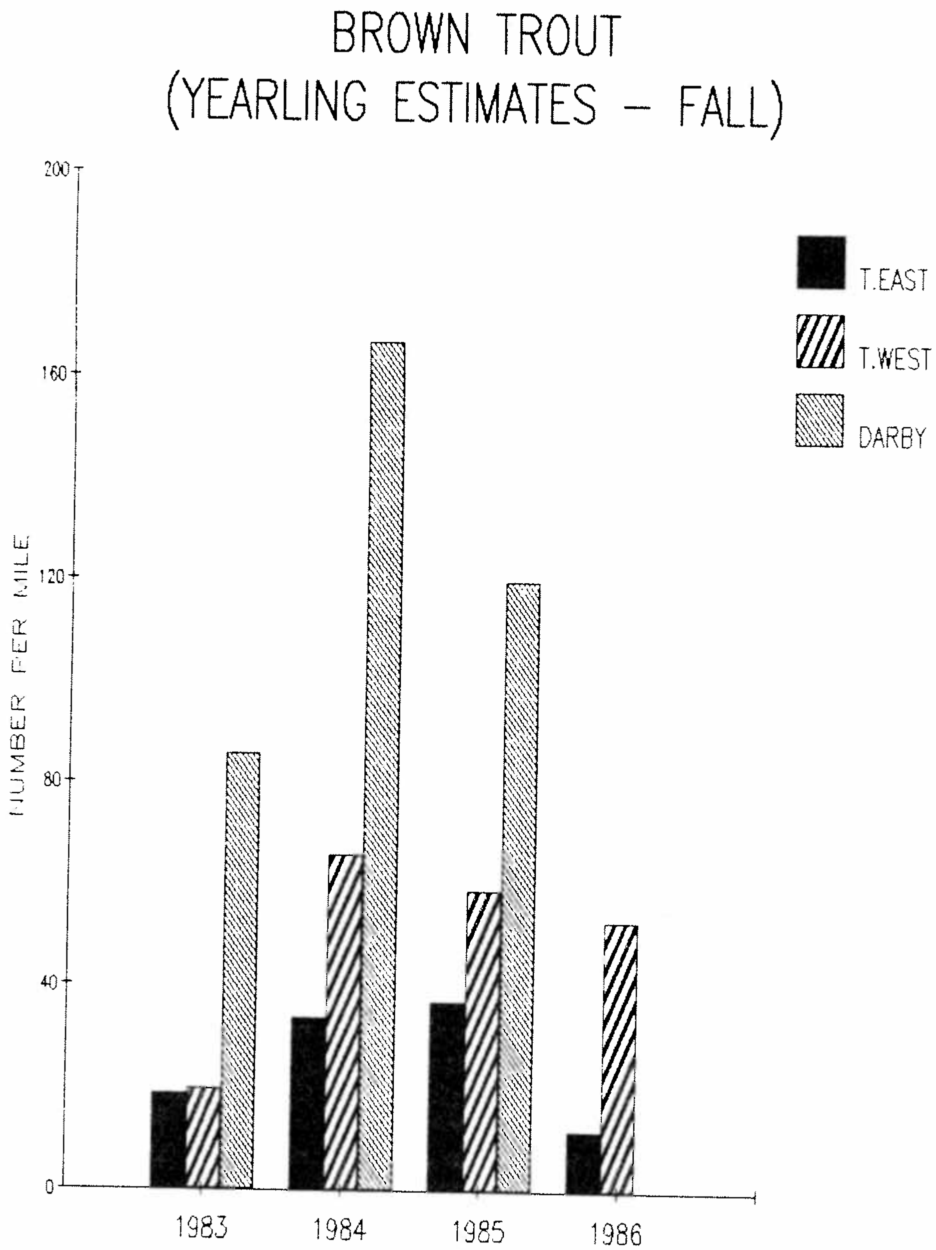


Figure 21. Comparisons of yearling brown trout numbers in three study sections of the Bitterroot River, 1983-1986.

Changes in Adult Trout Populations

Supplemental releases of water from Painted Rocks Reservoir accompanied by good water years in 1983 and 1984 appeared to result in larger numbers of juvenile trout. In addition, poor stream flows in 1985 reduced juvenile trout numbers in the Tucker sections. Adult populations, however, were less influenced by stream flows in the Darby and Tucker sections.

The numbers of rainbow trout in the Darby section have increased approximately 246 percent since population estimates were first obtained in 1982 (Figure 18). This increase may have been due to a change to restrictive fishing regulations begun in 1982 and/or to the release of supplemental water (15,000 AF) from Painted Rocks Reservoir begun in 1983. Although the data were inconclusive, the increase in rainbow trout numbers in the Darby section appeared to be attributable more to supplemental water releases than to regulation changes, since the most significant increases occurred in the younger age classes.

The changes in fishing regulations were designed to increase the number of larger fish. Possession limits in the Darby section were changed from a limit of 10 fish or 4.5 kg (10 lbs) plus one fish to five fish under 356 mm (14 in) or four fish under 356 mm (14 in) and one fish over 457 mm (18 in). Regulations also were restricted to the use of artificial lures. Estimated numbers of these larger brown and rainbow trout, however, have not substantially changed since 1982 (Appendix Figures E1 and E2).

A similar pattern was observed in the Tucker section. Based on fall estimates, rainbow trout numbers increased by 237 percent between 1983 and 1985 (Appendix Table E4), but this increase primarily represents changes in juvenile fish numbers. The number of rainbow trout larger than 356 mm (14 in) did not significantly change during fall estimates (Appendix Figures E3 and E4). Spring estimates of adult brown trout were also similar between years in the Tucker section (Appendix Figures E5 and E6).

Surprisingly, the severe dewatering in the Tucker section during 1985 and 1986 did not result in reduced numbers of adult trout. Unlike juvenile trout, it appeared that reduced flows which concentrated fish in the pools of the Tucker section had little effect on survival of adults. Since supplemental releases did not reach the dewatered reach in significant quantities, they were not believed to be responsible for changes, or lack of changes, in adult trout numbers.

Possession limits in the Tucker section were changed in 1982 from a limit of ten fish or 4.5 km (10 lb) plus one fish to five fish with only one of which could exceed 356 mm (14 in) in length. As in the Darby section, the number of larger trout did not significantly change as a result of regulation changes.

Mountain Whitefish Populations

Mountain whitefish are the most abundant game fish species in the Bitterroot River. They provide an important and popular sport fishery for local fishermen throughout the year, but especially during the winter.

Whitefish numbers were estimated in the Darby and Tucker sections during spring, 1984. Whitefish were considerably more abundant than brown or rainbow trout in both sections. Although differences were not statistically significant because of wide confidence intervals, whitefish numbers in the Darby section (7,676/km; 12,352/mi) were greater than those in the Tucker section (4,253/km; 6,849/mi) (Appendix Table E6).

It was not feasible to periodically monitor whitefish populations during this study. On the basis of a single population estimate, it was not possible to evaluate potential effects of supplemental releases on mountain whitefish populations.

Condition Factors

Mean condition factors (k) for rainbow trout and brown trout larger than 127 mm (5 in) were calculated for all sections throughout the study (Table 17). Mean condition factors for this wide range of fish length were influenced by changes in population structure and should only be used for general comparisons. Comparisons of condition factors using fish from 305 to 381 mm (12.0 to 14.9 in) in total length were considered more reliable. Fall, rather than spring condition factors were used because they more accurately reflect the relationship between summer stream flow and fish condition.

Although there were no statistical differences ($p>0.05$) between years or sections, trends in fall condition factors were apparent (Figure 22). Contrary to what would be expected, the highest condition factors for both brown trout and rainbow trout occurred during the poor water year of 1985. Brown trout condition factors were highest in the Darby section during all years, but rainbow trout condition factors were similar between sections each year (Figure 22).

Since condition factors were highest during years with the lowest summer stream flows (1985 and 1986), release of water from the reservoir is not likely to significantly improve fitness of adult trout in the Bitterroot River. Similarities between the condition of adult trout in the Tucker section and the Darby section indicates that growing conditions are not adversely affected by poor stream flows in the Tucker section. Apparently, the large, deep pools within the Tucker section which are cooled by extensive groundwater seepage, provide suitable habitat for larger trout.

Table 17. Mean condition factors (K) for rainbow trout and brown trout greater than 127 mm (5 in) in total length from study sections of the Bitterroot River from 1982 through 1986 (Standard deviations in parentheses).

		Condition Factors (K)							
SECTION	SPECIES	Fall 1982	Fall 1983	Spring 1984	Fall 1984	Spring 1985	Fall 1985	Spring 1986	Fall 1986
Darby	Rainbow trout	1.00	1.06	1.01	1.06	1.03	1.10	---	---
		(0.11)	(0.14)	(0.09)	(0.16)	(0.10)	(0.15)	---	---
	Brown trout	---	1.09	0.99	1.06	1.01	1.10	---	---
		---	(0.14)	(0.10)	(0.16)	(0.09)	(0.14)	---	---
Tucker East	Rainbow trout	---	1.04	1.04	1.07	1.07	1.16	1.11	1.12
		---	(0.09)	(0.11)	(0.13)	(0.10)	(0.16)	(0.15)	(0.13)
	Brown trout	---	1.02	1.00	1.04	1.01	1.11	1.05	1.07
		---	(0.09)	(0.09)	(0.12)	(0.11)	(0.13)	(0.18)	(0.12)
Tucker West	Rainbow trout	---	1.04	1.02	1.06	1.02	1.13	1.07	1.11
		---	(0.12)	(0.10)	(0.14)	(0.12)	(0.16)	(0.12)	(0.15)
	Brown trout	---	1.01	0.98	1.01	0.98	1.08	0.99	1.07
		---	(0.10)	(0.09)	(0.11)	(0.09)	(0.12)	(0.19)	(0.12)
Poker Joe	Rainbow trout	---	---	---	---	---	1.05	1.04	---
		---	---	---	---	---	(0.12)	(0.17)	---

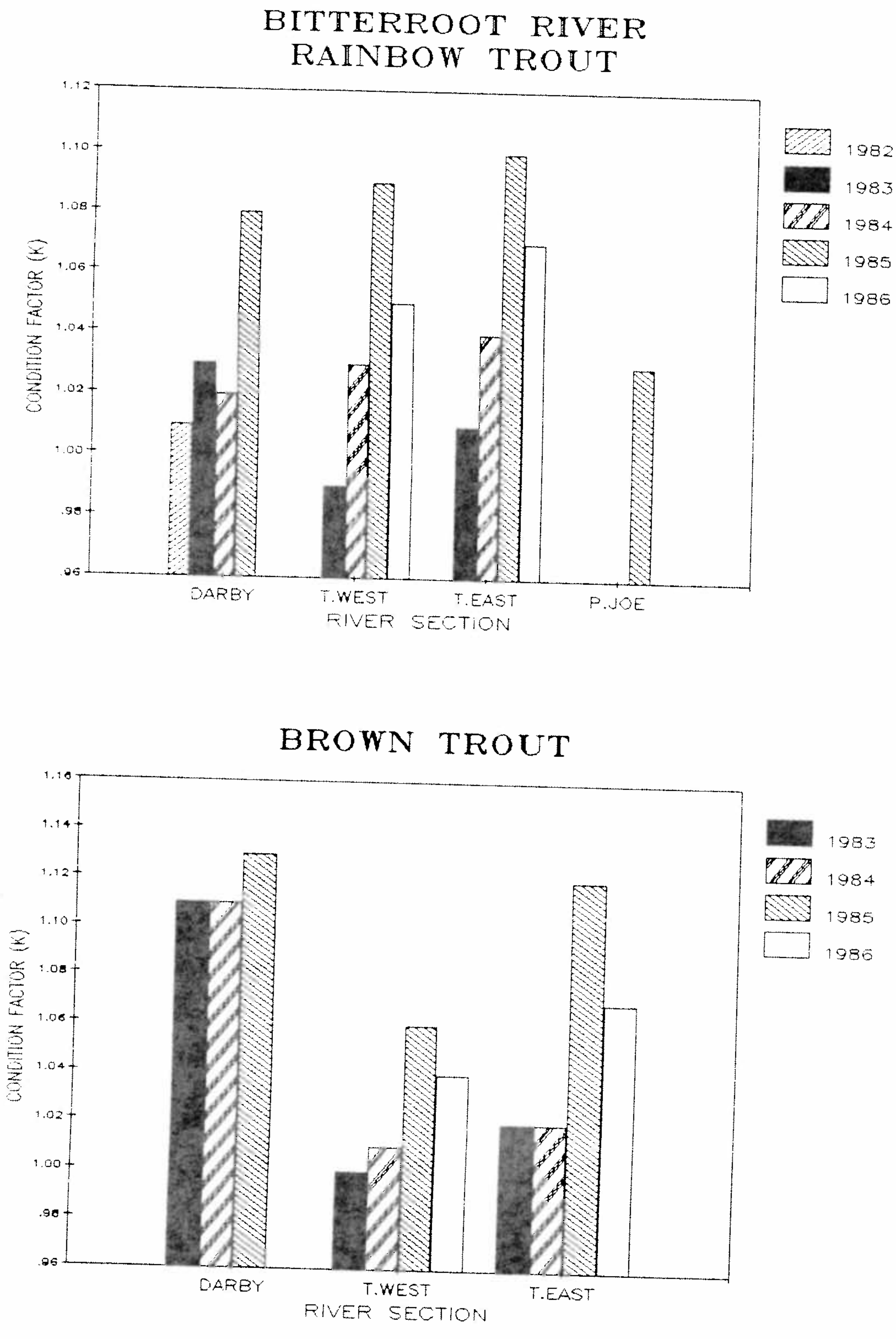


Figure 22. Mean condition factors for brown and rainbow trout between 305 and 381 mm (12.0 - 14.9 in) in total length from study sections of the Bitterroot River, 1982-1986.

Growth Rates

Growth rates of brown and rainbow trout were determined for the Darby and Tucker sections during 1983 and 1984, and for the Poker Joe section (rainbow trout only) during 1985 (Appendix Tables F1 through F3). Increments of trout growth were similar between sections, although growth rates appeared to be slightly higher in the east and west channels of the Tucker section (Figure 23).

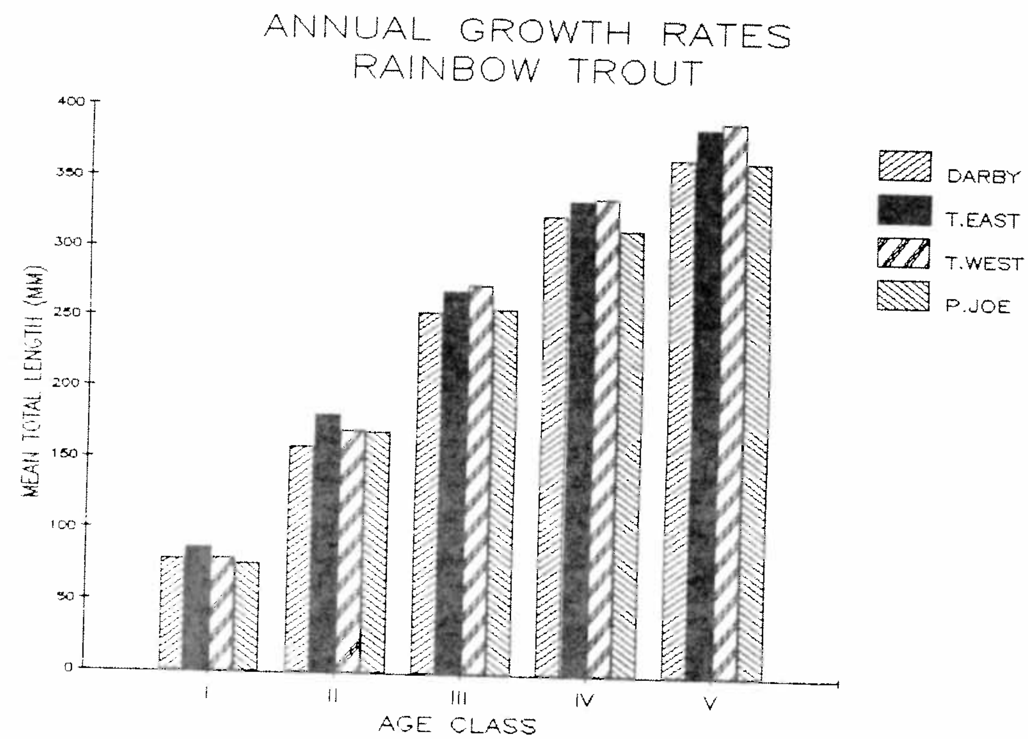
The growth increments of back-calculated length for rainbow trout averaged 81.2 mm (3.20 in) in the Darby section, and 84.8 mm (3.34 in) in the Tucker section. For brown trout, the increments of back-calculated length averaged 91.6 mm (3.61 in) in the Darby section, and 96.3 mm (3.79 in) in the Tucker section. Rainbow trout growth increments at Poker Joe averaged 79.0 mm (3.11 in).

Tag Distributions and Estimates of Harvest

Selected samples of trout captured while electrofishing were marked with individually numbered floy tags to evaluate movements and to obtain an index of angler harvest. A total of 3,129 floy tags were distributed in trout in the Bitterroot River since the inception of the study. The species tagged included 1,598 rainbow trout, 1,399 brown trout, 94 cutthroat trout, 3 brook trout, and 35 bull trout (Table 18). A majority of these tags were distributed in the Darby, Tucker, and Poker Joe electrofishing sections.

Due to poor compliance by anglers in returning tag information, harvest rates based on tag returns undoubtedly greatly underestimated actual harvest rates for trout in the Bitterroot River. Returns indicated only 2.9 percent of all tagged rainbow trout and 3.6 percent of all tagged brown trout were harvested by anglers (Table 19). Harvest rates for rainbow trout were greatest in the reach of river located between Bell crossing and Stevensville (100 percent of the rainbow trout tagged below Florence were harvested, but only three tags were distributed). For brown trout, harvest rates were greatest between Como bridge and Hamilton. Information returned by anglers indicated 22 percent of the tagged rainbow trout and 13.5 percent of the tagged brown trout captured while fishing were released back into the river.

Evaluation of trout movement was based on electrofishing and angler (when judged reliable) relocations of 493 rainbow trout and 789 brown trout tagged in various sections of the Bitterroot River. The number of relocations within a river section was largely a function of electrofishing effort in that section. For example, the largest number of relocations for brown and rainbow trout were obtained from the two channels of the Tucker section which were electrofished regularly from 1983 to 1986 (Table 20).



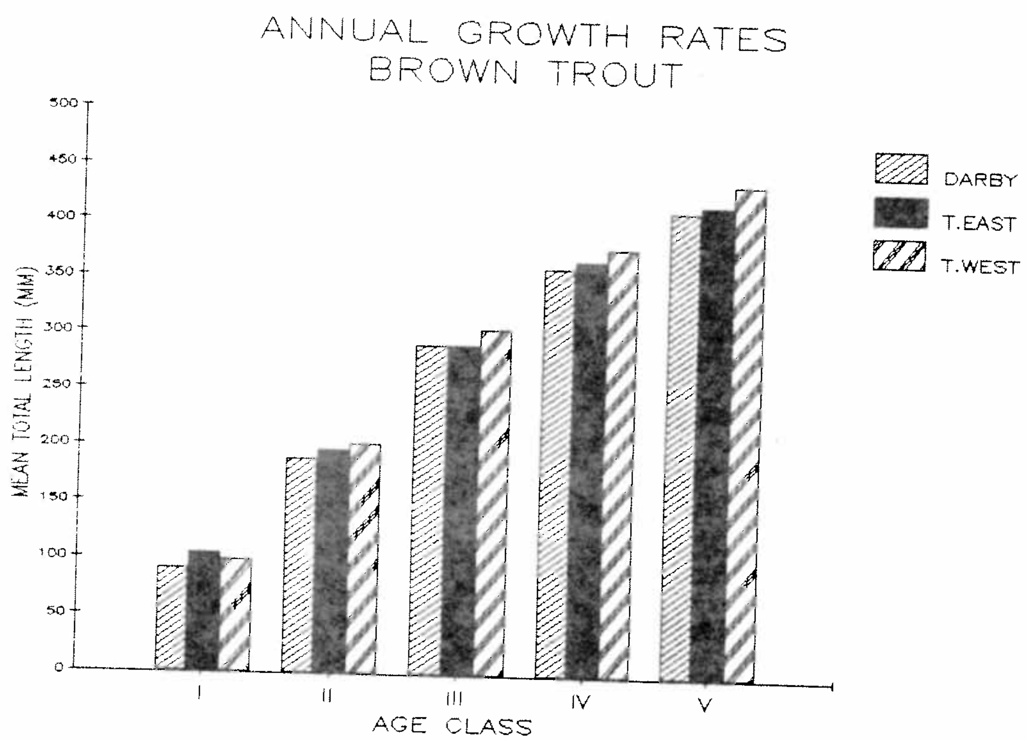


Figure 23. Comparisons of brown and rainbow trout annual growth rates in study sections of the Bitterroot River.

Table 18. Distribution of tags for trout captured in the Bitterroot River from September 1983 to November 1986.

Location (km from mouth)	Number of Tags Distributed				
	Rainbow Trout	Brown Trout	Cutthroat Trout	Brook Trout	Bull Trout
West Fork (>129)	146	48	36	0	21
Darby to Como bridge (126.0 - 115.0)	234	235	13	0	9
Como bridge to Hamilton (115.0 - 92.0)	59	24	2	0	1
Hamilton to Tucker (92.0 - 76.0)	96	124	1	0	0
Tucker to Bell (76.0 - 65.0)	526	840	22	2	4
Bell to Stevensville (65.0 - 53.0)	125	58	10	0	0
Stevensville to Florence (53.0 - 37.0)	409	66	10	1	0
Florence to Clark Fork R. (37.0 - 0.0)	3	4	0	0	0
	1,598	1,399	94	3	35

Table 19. Number and percentage of tagged trout reported harvested or caught and released by anglers in the Bitterroot River from September 1983 to January 1987.

Location	Number Tagged	Number Harvested	Percent Harvested	Number Caught & Released	Percent Caught & Released	Number Tagged	Number Harvested	Percent Harvested	Number Caught & Released	Percent Caught & Released
West Fork	146	1	(0.7)	0	(0.0)	48	0	(0.0)	0	(0.0
Darby to Como	234	6	(2.6)	0	(0.0)	235	3	(1.3)	2	(0.9)
Como to Hamilton	59	3	(5.1)	1	(1.7)	24	2	8.3	0	(0.0)
Hamilton to Tucker	96	6	(6.3)	1	(1.0)	124	9	(7.3)	1	(0.8)
Tucker East	292	9	(3.1)	4	(1.4)	412	12	(2.9)	1	(0.2)
Tucker West	234	6	(2.6)	2	(0.9)	428	17	(4.0)	3	(0.7)
Bell to Stevensville	125	11	(8.8)	2	(1.6)	58	17	(4.0)	3	(0.7)
Stevensville to Florence	409	1	(0.2)	1	(0.2)	66	1	(1.5)	0	(0.0)
Florence to Clark Fork R.	3	3	(100.0)	2	(66.7)	4	1	(25.0)	0	(0.0)
Total	1,598	46	(2.9)	13	(0.8)	1,399	51	(3.6)	8	(0.6)
Other[a]	18	1	(5.6)	0	(0.0)	31	6	(19.9)	0	(0.0)

a/ Includes tags distributed in Siebel Spring Creek and Corvallis ditch.

Table 20. Movement of tagged trout in the Bitterroot River during the period September 1983 to January 1987.

Species	Tagging Location	Number of Relocations	Upstream Movement ≥ 5 km (%)	Downstream Movement ≥ km (%)
Rainbow Trout	West Fork	6	0 (0.0)	0 (0.0)
	Darby-Como	117	3 (2.6)	3 (2.6)
	Como-Hamilton	6	3(50.0)	1(16.7)
	Hamilton-Tucker	14	0 (0.0)	2(14.3)
	Tucker East	141	8 (5.7)	4 (2.8)
	Tucker west	102	5 (4.9)	6 (5.9)
	Bell-Stevensville	21	10(47.6)	1 (4.8)
	Stevensville-Florence	84	16(19.0)	7 (8.3)
	Florence-Clark Fork R.	2	0 (0.0)	0 (0.0)
	Total	493	45 (9.1)	24 (4.9)
Brown Trout	West Fork	1	0 (0.0)	0 (0.0)
	Darby-Como	95	4 (4.2)	1 (1.1)
	Como-Hamilton	3	1(33.3)	0 (0.0
	Hamilton-Tucker	30	2 (6.7)	4(13.3)
	Tucker East	331	6 (1.8)	6 (1.8)
	Tucker West	296	7 (2.4)	9 (3.0)
	Bell-Stevensville	17	11(64.7)	0 (0.0)
	Stevensville-Florence	13	0 0.0	0 (0.0)
	Florence-Clark Fork R.	3	1(33.3)	1(33.3)
	Total	789	32 (4.1)	21 (2.7)

Most (86 percent) relocations of tagged rainbow trout occurred within 5 km (3.1 mi) of the original tagging location. Tagged brown trout were also most frequently (93 percent) recovered within 5 km (3.1 mi) of the tagging location (Table 20). The most significant pattern in rainbow trout movement was that of fish tagged in the lower river during the fall being recovered during the spawning period (spring) in the Tucker section. This trend was evidenced by the relatively high percentages of upstream movement of fish tagged in the Bell to Stevensville and Stevensville to Florence sections (Figure 20).

Relatively few brown trout were tagged or relocated in the lower river (below Stevensville) because of low population numbers. Five tagged brown trout demonstrated movements between the lower river and the Tucker section that were probably related to spawning migrations. These fish, which were tagged in the Tucker section during the spawning period, were relocated in the lower Bitterroot River or the Clark Fork River during a non-spawning period. It was not known, however, whether these fish resided in the lower river prior to being tagged in the Tucker section. In addition to this pattern, two brown trout fin-clipped in the Tucker section during early spring were observed in the Poker Joe section later in the spring. It is suspected that some brown trout over-winter in the Tucker section after spawning, and return to their resident habitat later in the spring when flows increase.

Spawning movements by both brown and rainbow trout from the lower river to the Tucker section and associated tributaries appear to be significant, although difficult to document based solely on tag recoveries. Substantial increases in brown and rainbow trout numbers in the west channel of the Tucker section during respective spawning periods supports the trend observed from tag recoveries (Appendix Figures E4 and E5). Significant movement trends were not observed in the upper river.

Trout Rearing and Recruitment

Potential impacts of reduced stream flows on brown and rainbow trout YOY may be significant. Rearing areas of YOY are typically located along shoreline areas (Gosse and Helm 1979, Sando 1981), and these areas are among the first types of habitat to be effected during flow reductions (Sando 1981). At normal stream flows, YOY rearing habitat is not typically used by larger, piscivorous fish. This isolation is believed to be important (Gosse and Helm 1979). During poor stream flow conditions, YOY are forced out of shoreline areas, and are more likely to encounter predatory fish. Another possibility is that YOY migrate during flow reductions to avoid contact with predators. Fish migrating during periods of stream flow reduction (accompanied by increased irrigation withdrawal) creates the potential problem of significant fish loss to irrigation canals. The decline of yearling numbers in the east channel of the Tucker section (which contains at least five irrigation diversions with gravel dikes) may be an indication that this occurs.

Based on numerous tag recoveries, and observed increases in numbers of brown and rainbow trout during the spawning seasons, it appears that the Tucker section (especially the west channel which has four tributary inflows) is an important source of recruitment for the lower Bitterroot River. If low stream flows within this reach significantly effect the survival of rearing or migrating YOY, reduced trout numbers may occur throughout the lower river; not merely within the dewatered section.

Trout Rearing

The border of the river in the Darby and Tucker sections was extensively electrofished during August and September, 1984, to identify habitat types used as rearing areas by YOY rainbow trout and brown trout. Main channel and side channel borders were categorized into four habitat types. These habitat types were identified as riffle areas with a rock border, riffle areas with a root/brush border, pool areas with a rock border and pool areas with a root/brush border.

Based on catch per unit effort, YOY were more abundant in the Darby section than the Tucker section (Table 21). Rainbow trout YOY were more abundant than brown trout YOY in the Darby section. In contrast, rainbow trout were less abundant than brown trout in the Tucker section. These relationships are similar to comparisons made between the population estimates obtained from the two sections.

Habitat use varied between species and among sections. With the exception of rainbow trout in the Darby section, YOY appeared to prefer the borders of riffle areas for rearing. Juvenile rainbow trout and brown trout captured in the Darby section averaged 53 and 70 mm (2.1 and 2.8 in), respectively, in total length. In the Tucker section, rainbow and brown trout YOY averaged 60 and 89 mm (2.4 and 3.5 in), respectively.

During August and September 1986, additional YOY electrofishing surveys were conducted in the Bitterroot River to determine longitudinal trends in YOY densities from the West Fork of the Bitterroot River (river km 132) to the Chief Looking Glass Fishing Access (river km 35). Densities per ten meters of shoreline were calculated for nine river segments coinciding with existing population estimate sections (Conner, Darby, East Tucker, West Tucker, and Poker Joe) and other areas of interest. For example, the major irrigation return which enters the river 4.8 km (3.1 mi) above Stevensville bridge resulted in changes in YOY abundance and a section break was established there.

Table 21. Numbers of young-of-the-year (YOY) rainbow trout and brown trout collected per ten meters of river border in the Darby and Tucker sections of the Bitterroot River during August and Septemeber, 1984.

	Darby			Tucker (East)			Tucker (West)		
		No. of YOY per 10m electrofished			No. of YOY per 10m electrofished			No. of YOY per 10m electrofished	
Habitat Type	Meters Electrofished	Rainbow Trout	Brown Trout	Meters Electrofished	Rainbow Trout	Brown Trout	Meters Electrofished	Rainbow Trout	Brown Trout
Side Channel									
Riffle rock border	96	3.33	3.12	261	0.38	0.88	76	3.15	3.4
Riffle root/brush border	128	0.78	2.03	180	0.28	2.17	38	1.57	2.89
Pool Rock border	0	--	--	112	0.00	1.16	0	--	--
Pool root/brush border	62								
Subtotal	286	1.68	2.06	587	0.26	1.29	194	1.75	2.06
Main Channel									
Riffle rock border	258	1.75	0.93	158	0.00	0.63	353	1.79	0.37
Riffle, root/brush border	75	7.04	0.53	279	0.14	1.33	107	0.56	3.56
Pool rock border	73	3.69	1.23	125	0.24	1.85	332	0.09	0.39
Pool root/brush border	62	3.74	3.09	0	--	--	158	0.25	2.15
Subtotal	468	3.16	1.20	562	0.12	1.24	950	0.80	1.03
Grand Total	754	2.60	1.52	1149	0.19	1.27	1144	0.96	1.21

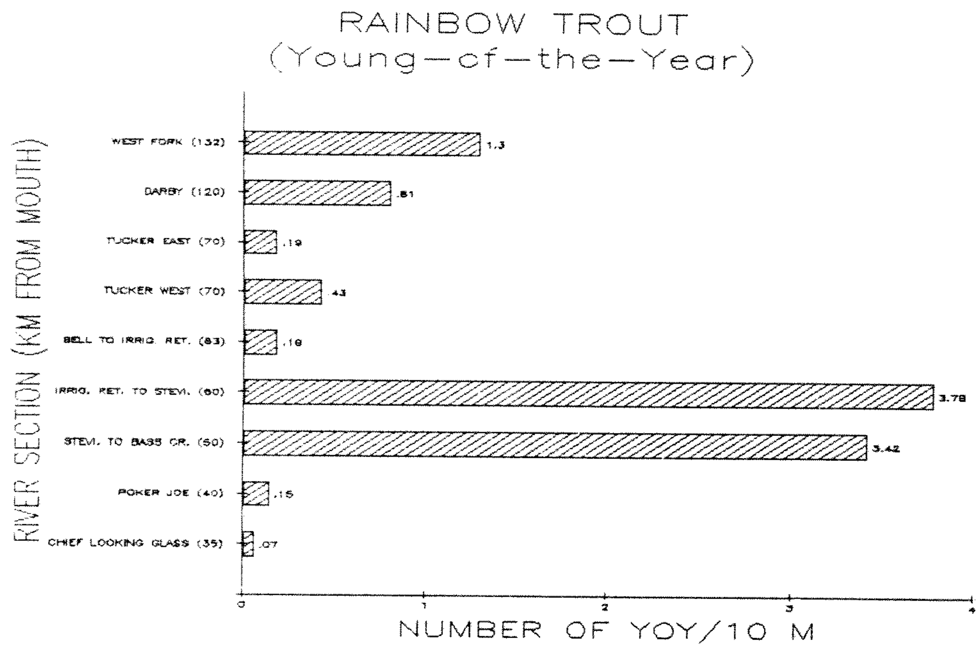
Densities of YOY rainbow trout in the Bitterroot River progressively decreased proceeding downstream, with the exception of the segment of river near Stevensville (Figure 24). The highest density of YOY rainbow trout was observed immediately below the major irrigation return near Stevensville (river km 60). One possible explanation for this is that YOY may be entering irrigation diversions upstream, and an unknown portion of these fish may be re-entering the river via the return canal. It is also possible that the enhanced stream flows below the return canal (the canal carries significant amounts of water) may also be contributing to the higher densities observed in this area. Immediately upstream from the canal, YOY densities were substantially lower and were in accordance with the general trend of decreasing numbers of progressing downstream. The relatively high densities observed between Stevensville and Bass Creek may also be related to Kootenai Creek, which enters the river in this area and is a potential source of recruitment.

The low densities of YOY in the Poker Joe (river km 40) and Chief Looking Glass (river km 35) areas are probably related to the lack of spawning tributaries in the lower river. Suitability of rearing habitat in this area may have also influenced YOY abundance.

The trend in brown trout YOY densities was less easily interpreted. The highest density was observed in the Darby section (river km 120), and the lowest density was in the Chief Looking Glass area (river km 35) (Figure 4). The relatively low densities observed in the Tucker section (particularly the west channel) were likely a result of the extremely low stream flows during August, 1986, when virtually all shoreline cover was dewatered.

In contrast to rainbow trout, brown trout YOY densities did not significantly increase below the irrigation return. The effects of reduced stream flow, and associated fish loss to irrigation diversions, on trout rearing is a very complex issue which requires additional investigation.

Fish losses to ditches in the Bitterroot River was studied during 1984 at Hedge ditch (Good and Kronberg 1986). During their trapping effort, 179 rainbow/cutthroat, 238 brown, and 8 bull trout along with 2,363 mountain whitefish were captured from June 16 to September 27. Most trout were age I+ or older, but 97 percent of the whitefish were age 0+. It did not appear that trout losses to this ditch were associated with a significant amount of YOY migration. This irrigation ditch, however, has the least prominent diversion structure of all the major ditches on the Bitterroot River.



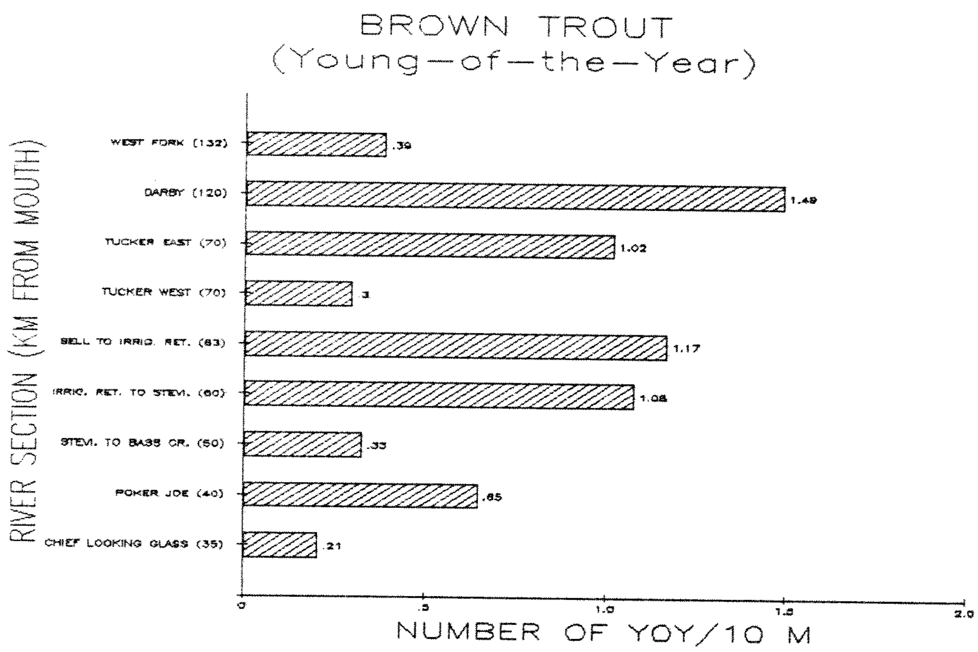


Figure 24. Number of young-of-the-year (YOY) rainbow trout (N=188) and brown trout (N=222) captured per 10 meters of river shoreline in study sections of the Bitterroot River during August and September, 1986.

Migrating YOY, which tend to travel in the thalweg of the stream, would less likely be redirected into this irrigation canal, compared to those that construct large dikes. Additional trapping at diversions in the dewatered reach, where large dikes are constructed, and fish movement may be stimulated by flow reductions, would help determine the extent of this potential problem.

Recruitment from Tributaries

Emigration of YOY trout from six tributaries within or near the dewatered reach was monitored by trapping during 1986 to supplement information on YOY rearing and recruitment in the Bitterroot River. All trout captured in traps near the mouths of Blodgett Creek, Mill Creek, South Fork Bear Creek, North Fork Bear Creek, Sweathouse Creek, and Big Creek were assumed to be migrating to the Bitterroot River. The traps were not 100 percent effective in capturing migrating fish; therefore, only rough estimates of the total number of downstream migrants were possible. During the period of peak migration, the percentages of flow sampled by traps ranged from 5.6 percent (Big Creek) to 29.0 percent (North Fork Bear Creek) (Table 22). The traps successfully captured most fish (87.7 percent) that approached the opening, based on experiments where YOY trout were released immediately upstream from the trap opening.

From May 9 to July 24, 3,971 trout were captured in six tributaries (and one irrigation ditch) during 195 trap-nights (Table 22). The largest number of trout were captured in the North Fork of Bear Creek, although trapping efficiency (percentage of flow samples) was highest in this tributary. Catches of emigrating trout were also high in Big Creek, particularly considering the small percentage of stream flow sampled. Catches were lowest in Mill Creek.

Of 3,971 trout captured, 3,767 (94.8 percent) were rainbow trout YOY, and 144 (3.6 percent) were brown trout YOY. The remainder of the catch was comprised of yearling trout (Table 22).

The peak period of YOY rainbow trout migration occurred during early July (Figure 25). Due to the uniform size of YOY captured (24-27 mm), it appeared that fish migrated almost immediately upon emergence from the gravel. Emigration patterns from Big Creek and North Bear Creek indicated some response to changes in stream flow, but response was inconsistent (Figure 26). Catches declined sharply after July 15 due to rapidly declining stream flows and/or the end of rainbow trout emergence from redds. By July 22, most of the tributaries reached critically low stream flow levels or were completely dewatered, and all traps were removed by July 24.

Table 22. Number of emigrating brown and rainbow trout captured at six tributaries of the Bitterroot River during 1986.

Water Name	Trapping Period	Number of Trap Nights	Number Captured: Rainbow Trout YOY	Rainbow Trout Yearling	Brown Trout YOY	Brown Trout Yearling	Discharge[a] (ft^3/sec)	Percent of Flow Sampled
Blodgett Creek	5/9 - 7/24	43	53	13	9	5	5.7	15.0
Blodgett Creek[b] Irrig. ditch	7/2 - 7/24	13	264	13	0	0	18.0	20.0
Mill Creek	5/20- 6/30	23	1	1	30	1	--	--
South Fork Bear Creek	7/1 - 7/18	13	54	1	40	0	11.3	21.8
North Fork Bear Creek	5/21- 7/18	39	2622	14	21	9	8.0	29.0
Sweathouse Creek	5/16- 7/18	31	46	1	33	1	27.6	14.3
Big Creek	6/2 - 7/18	33	727	1	11	0	88.1	5.6
		195	3767	44	144	16		

a/ Calculated during peak migration period (July 4).

b/ Irrigation withdrawal 100 meters above mouth of Blodgett Creek.

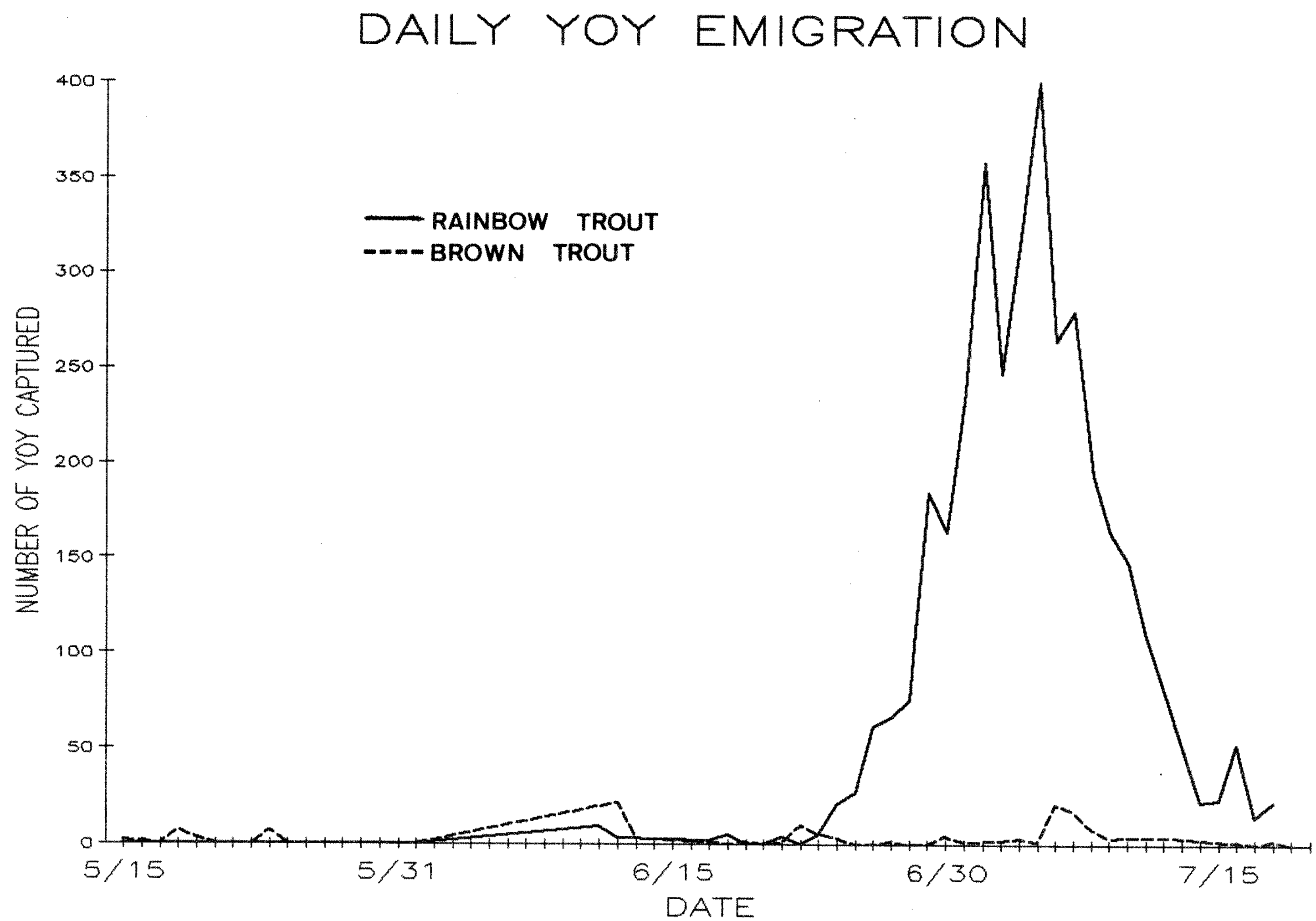
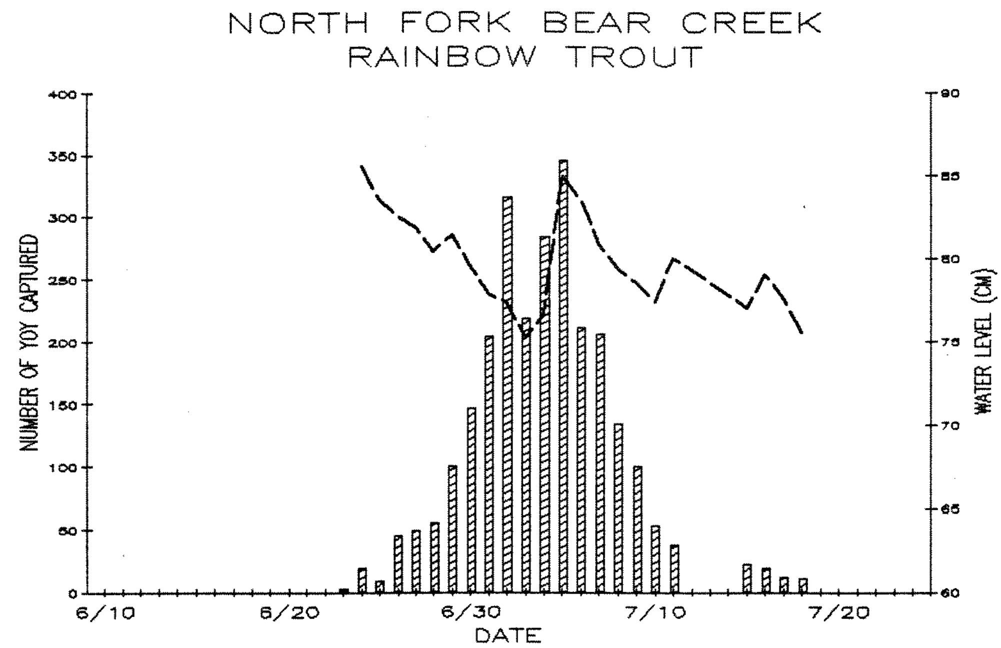


Figure 25. Daily catches of emigrating rainbow trout (N=3,767) and brown trout (N=144) YOY in six tributaries of the Bitterroot River from May 15 to July 20, 1986.



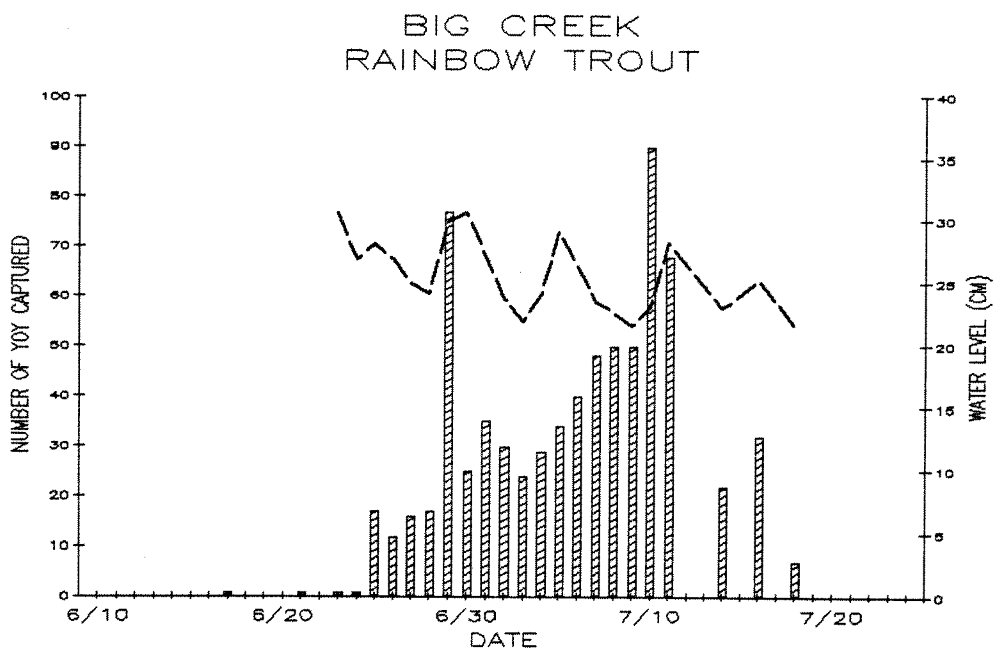


Figure 26. Daily catches of emigrating rainbow trout YOY in the North Fork Bear Creek (N=2,622) and Big Creek (N=727) compared to water level fluctuations during 1986.

No trend in brown trout YOY emigration was observed due to low catch rates (Figure 25). Trapping efforts were sporadic during the high flows of spring runoff because traps filled with debris. If brown trout production is significant in these streams, it is possible that considerable emigration occurred during high stream flows and was undetected. This is also true for yearling rainbow trout. Larger numbers of rainbow trout may be recruited to the Bitterroot River as yearlings than trapping data indicated because traps were ineffective during spring runoff.

Additional trapping with a construction that is effective during relatively high flows would be beneficial. Additional tributaries providing significant recruitment of both rainbow trout and brown trout should be identified. In addition, effective trapping of yearling emigrants (if they do indeed exist in significant numbers) would aid in the understanding of recruitment patterns to the Bitterroot River. As a result of the poor stream flows encountered when emigrating trout reach the river, it is possible that yearlings would more successfully provide recruitment than would YOY. Yearlings are assumed to be more tolerant to stream flow reductions.

In addition to potential fish losses to main stem diversions, fish losses to irrigation diversions during emigration from tributaries may be a significant problem. One trap was placed in an irrigation diversion near the mouth of Blodgett Creek to estimate the loss of emigrating trout to irrigation withdrawal. During 13 trap nights, 264 YOY rainbow trout were captured in the irrigation ditch, while only 43 were captured downstream from the withdrawal (Table 22). This was the only ditch sampled, and the extent of the problem in other tributaries of the Bitterroot River is unknown. Further investigation is needed.

Minimum Flow Recommendations

Instream Flow Needs for Trout

Recommendations for instream flows needed to maintain trout populations in the Bitterroot River were determined using the wetted perimeter/inflection point methodology. This method was applied to 16 riffles of the main stem Bitterroot River, and two riffles of the West Fork to determine wetted perimeter-discharge relationships within various reaches of the river. Four riffles were discarded due to inconclusive results.

The most desirable minimum flow for the West Fork of the Bitterroot River between Piquette Creek and Trapper Creek was chosen from the primary inflection point of riffle #1, which occurred at 5.10 m^3/sec (180 ft^3/sec) (Table 23). Average

Table 23. Summary of instream flow recommendations for the Bitterroot River based on wetted perimeter inflection points.

Riffle Location	Discharge at Inflection Point (ft^3/sec)[a]	Most Desirable Minimum Flow
West Fork #1	180	
West Fork #2	110	
Average =	145	180
Darby #1	225	
Darby #2	275	
Darby #3	412	
Average =	304	304
Hamilton #1	450	
Hamilton #2	450	
Hamilton #3	-- [b]	
Tucker East #1 + Tucker West #2	-- [b]	
Tucker East #2 + Tucker West #1	360 (175 + 185)	
Bell crossing #1	325	
Bell crossing #2	-- [b]	
Bell crossing #3	425	
Average =	402	402
Stevensville #1	300	
Stevensville #2	275	
Stevensville #3	325	
Average =	300	300

[a] 1.0 ft^3/sec = 0.0283 m^3/sec

[b] Riffles not used because of poor stage discharge-relationship or lack of well-defined inflection point.

discharge at the inflection points of riffle #1 and #2 was 4.11 m^3/sec (145 ft^3/sec). The recommendation of 5.10 m^3/sec (180 ft^3/sec), based on the inflection point of riffle #1 rather than averaging the two riffles, was justifiable because of the excellent availability of water during supplemental releases from Painted Rocks Reservoir. The high potential of the West Fork trout fishery also justified a relatively high minimum flow recommendation in this area.

From 1983 through 1986 (the period of supplemental releases), stream flows at the U.S.G.S. gauge were consistently above the recommended minimum flow (Figure 4). In addition, flows in the lower West Fork were always higher than those at the U.S.G.S. station because of significant tributary inflow.

Discharge at the inflection point of riffle #2 was 3.12 m^3/sec (110 ft^3/sec) (Table 23). This flow should be considered the absolute minimum flow recommended for only short periods of time during dam maintenance, or some other unforeseen reason.

Summer stream flows in the West Fork appear to be adequate to maintain fish populations, but the lowest flows occur during the winter. When MDFWP water is not released from the reservoir during the summer because of adequate flow conditions, the remaining water should be held for release until winter. The lowest flows occur in January, February, and March when historic median flows at the U.S.G.S. gauge were 2.86 m^3/sec (101 ft^3/sec), 2.67 m^3/sec (94 ft^3/sec), and 3.00 m^3/sec (106 ft^3/sec), respectively (Brown 1982). Remaining water should be prorated over these three months.

The minimum flow recommendation for the Bitterroot River near Darby was based on the average of the lower inflection points of three riffles (Table 23). The lower inflection points were chosen because discharge values associated with upper inflection points were substantially higher than historic median monthly flows at the U.S.G.S. gauge near Darby. The 8.61 m^3/sec (304 ft^3/sec) minimum flow recommendation for the Darby section is less than the historic median monthly flows for April through October at the Darby U.S.G.S station. During the period of supplemental releases, summer flows were always above the minimum recommendation (Figure 5).

Wetted perimeter-discharge relationships from six riffles were used to recommend a minimum flow value for the dewatered reach (between Hamilton and Stevensville) of the river (Table 23). Discharge at inflection points ranged form 9.20 m^3/sec (325 ft^3/sec) to 12.74 m^3/sec (450 ft^3/sec), with the average of all riffles used being 11.38 m^3/sec (402 ft^3/sec).

In addition to wetted perimeter results, a minimum flow recommendation of approximately 11.33 m^3/sec (400 ft^3/sec) is suggested based on maintaining adequate flows in side channels of the dewatered reach. Two side channels were monitored in the dewatered reach to develop regression models correlating side channel flow to main river flow. River flows of 11.81 m^3/sec (417 ft^3/sec) and 11.70 m^3/sec (413 ft^3/sec) were needed to maintain adequate flows in side channels, which are important for trout spawning (fall and spring) and rearing during the summer.

Instream flow needs derived from wetted perimeter-discharge relationships and side channel observations indicate that 11.38 m^3/sec (402 ft^3/sec) is the most desirable minimum flow for the dewatered reach of the river. At the upstream boundary of the dewatered section near Hamilton, this recommendation is lower than historic median values and should be met most years. The historic data at Hamilton, however, are limited to a relatively short period of record (1968-1979).

At Bell crossing, the minimum recommendation will seldom be met due to extensive irrigation withdrawal between Hamilton and Bell crossing. During 1983 and 1984, flows were above or slightly below the recommended minimum throughout the summer period, but in 1985 and 1986, flows were considerably below 11.38 m^3/sec (402 ft^3/sec) for extended periods of time. Although this recommendation will not be met on frequent occasions, the release schedule from Painted Rocks Reservoir (refer to Water Management Plan in Appendix B) is based on maintaining this flow for the largest amount of time possible.

During periods of extremely low stream flows, as observed in July 1985, an absolute minimum flow which is recognized by irrigators would be desirable at Bell crossing. An absolute minimum flow level should be negotiated with main stem irrigators, with a provision that assures that stream flows will not fall below the minimum value. The provision should require mandatory decreases in withdrawal, or the appointment of a water commissioner.

To ask for such provisions, the absolute minimum flow must be based on a legitimate right to the water. Therefore, it is recommended that this minimum flow value is based on the rate of release of MDFWP water from Painted Rocks Reservoir. A request for the total amount released to reach Bell crossing represents a compromise that takes into account natural losses (which appear to be minimal) and a base flow at Bell crossing that would virtually always occur because of groundwater inflows.

During July 1985, for example, when virtually all flowing water in the dewatered reach was diverted, stream flow did not equal zero at Bell crossing. Groundwater inflows between the last irrigation diversion and Bell crossing resulted in a flow rate of 0.68 m^3/sec (24 ft^3/sec). Consequently, when 2.83 m^3/sec (100 ft^3/sec) is released from the reservoir during extremely low stream flows, requesting an absolute minimum flow of 2.83 m^3/sec (100 ft^3/sec) is not a request for 100 percent of the release to reach Bell crossing because of the base flow that exists from groundwater inflows.

Natural losses (losses not due to irrigation withdrawal) of water released from the reservoir were difficult to quantify, but were not considered to be significant. Evaporation losses, calculated from climatic data of the Bitterroot Valley during the longest days of summer and based on maximum estimates of channel surface area between Painted Rocks Dam and Bell crossing, represented a maximum stream flow loss of 0.37 m^3/sec (13 ft^3/sec). Since the Bitterroot River between Painted Rocks Dam and Bell crossing is, in general, a groundwater gaining stream, major losses due to infiltration are not expected.

The minimum flow recommendation for the Bitterroot River between Stevensville and Florence (the reach rewatered by irrigation returns) was based on wetted perimeter results on three riffles (Table 23). A flow of 8.50 m^3/sec (300 ft^3/sec), the average of the three composite inflection points, appears to be necessary for the maintenance of riffle habitat in this reach of the river.

This recommendation is less than the 11.38 m^3/sec (402 ft^3/sec) recommendation derived for the dewatered reach. This contrast may be due to differences in channel morphology between reaches. The channel in the dewatered section of river is unstable, relatively wide, with poorly defined stream banks. In comparison, the channel in the rewatered reach is relatively stable. Because of this greater stability, the rewatered reach apparently requires lower flows to maintain riffle habitat than the dewatered reach.

A minimum flow recommendation of 8.5 m^3/sec (300 ft^3/sec) for the rewatered reach is substantially less than the median monthly flows (April through October) derived from 12 years of record at the DNRC station near Stevensville. The median values for the low flow months of August, September, and October are 19.7, 20.7, and 23.7 m^3/sec (697, 730, and 836 ft^3/sec), respectively. August flows at the DNRC station averaged less than the 8.5 m^3/sec (300 ft^3/sec) recommendation in only two of the 12 years on record. Consequently, reservoir water would seldom be needed to maintain minimum flows within the rewatered reach of the river.

Recreational Floating Requirements

The minimum depth and width of water required to allow passage of drift boats and rafts, crafts commonly used on the Bitterroot River, is 0.3 m (1.0 ft) and 1.8 m (6.0 ft), respectively (Hyro 1978). Analyses of wetted perimeter transects established in the dewatered section of river indicated that a flow of 4.25 m^3/sec (150 ft^3/sec) would be needed to provide the criteria to float drift boats and rafts over the shallow riffle areas. This level of flow would allow boats to pass over 17 of the 18 cross sections that were evaluated. In the reach of river located downstream from Stevensville, this same flow level would provide the minimum floating criteria for all three of the riffles that were evaluated.

CONCLUSIONS AND RECOMMENDATIONS

Supplemental releases of Painted Rocks Reservoir water significantly enhanced summer stream flows of the upper Bitterroot River from the dam to approximately Hamilton, and substantial increases in juvenile trout numbers resulted from the enhanced stream flows. Higher summer flows have apparently increased recruitment and/or improved juvenile rearing habitat in the upper river. Adult trout populations, however, appeared to be limited by factors other than stream flow, and did not respond to supplemental releases.

The dewatered reach (Hamilton to Stevensville) of the Bitterroot River has not significantly benefited from supplemental releases because of irrigation withdrawals. Supplemental water is most needed, and least likely delivered, during periods of low stream flow when irrigators are forced to construct gravel dikes to divert water. Consequently, supplemental releases during 1985 and 1986 failed to offset the adverse effects of below normal snowpack levels and below average rainfall during early summer.

Poor survival of young-of-the-year (YOY) trout may limit trout populations in the dewatered reach. The number of yearling trout (the first age class effectively sampled) was influenced by stream flow levels of the previous summer, increasing after the good water years of 1983 and 1984 and decreasing after the drought of 1985. Low stream flows reduce rearing habitat, and possibly increase fish loss to irrigation canals. In contrast, adult populations were not significantly influenced by stream flow in the dewatered reach. During periods of extremely low flows, deep pools fed by groundwater appeared to provide adequate habitat for adults.

Trout numbers in the lower Bitterroot River were relatively low despite adequate flow levels. Juvenile trout abundance was low in this area, indicating that the fishery may be limited by recruitment. The dewatered reach and associated tributaries, however, appeared to be an important spawning area and source of recruitment for the lower river fishery. Consequently, enhanced flows in the dewatered reach, which improve YOY survival, may benefit the fishery in the dewatered reach as well as the fishery in the lower river.

Supplemental water will not improve stream flows in the dewatered reach without the cooperation of main stem irrigators. The MDFWP should continue to negotiate with the irrigators to arrive at a mutually acceptable minimum flow at which irrigators would voluntarily adjust headgates or, as in 1985, agree to the appointment of a water commissioner. As an absolute minimum, the flow at Bell crossing should not fall below the flow rate of MDFWP water released from Painted Rocks Reservoir.

In an attempt to provide optimum benefits to the river, a cooperative agreement has been tentatively reached in which MDFWP would give 3,000 AF of purchased water annually to the main stem irrigators to use as necessary. In return, irrigators would lower headgates during the last half of September if flows fell below minimum recommendations and would agree not to oppose the appointment of a water commissioner to insure that a substantial percentage of the purchased water released from the reservoir remained instream.

This agreement, which was tested during 1986, provided benefits for the fishery as well as the irrigators because it allows increased flexibility in the release of Painted Rocks water. The water management plan developed during this study was designed to release purchased water from the reservoir in a conservative manner to insure that supplemental water would be available for the entire summer. Historical flow records indicate dewatering in the Bitterroot River may occur as early as July or as late as September. A conservative approach is necessary because the timing and duration of dewatering in the river cannot be predicted. With the 3,000-AF exchange, however, more water will be available for release during early summer when irrigation needs tend to be highest, while reducing the concern of depleting storage during a dry September. It is recommended that MDFWP continue with this agreement. However, before a final agreement is made, it should be determined whether voluntary irrigation cutbacks in September will be successful in maintaining adequate flow levels during dry years. Although not experienced during this study, dry September periods with low stream flows are not uncommon.

Stream flows in the dewatered reach of the Bitterroot River will not be improved significantly unless there is universal cooperation from irrigators. Agreements between the major ditches and MDFWP have been beneficial, but the numerous smaller diversions also have a significant influence on the river. On occasion, cooperation by major ditches is offset by the withdrawals of smaller ditches. For future agreements to be effective, the irrigators must have representation that has authority over the entire body.

Irrigator cooperation is also limited by the poor efficiency of the irrigation system. Water distribution, rather than water quantity, is the major problem in the Bitterroot drainage. Although willing to cooperate, some irrigators cannot be expected to comply with agreements when they have difficulties regulating withdrawals due to poor headgates or an absence of headgates. In addition, water measuring devices at withdrawals are very rare throughout the drainage. It is recommended that MDFWP provide technical assistance to the irrigators for improving headgate location and design. Methods for stabilizing the stream channel associated with diversions should also be evaluated with the assistance of MDFWP.

Portable irrigation diversions

The present network of irrigation canals is very complex. The system has a large number of diversions, and many of the diversions require gravel dikes that disturb river bottom materials. The large number of diversions, accompanied by a lack of coordination between canal systems, appears to result in large amounts of wastewater. MDFWP should help initiate studies to determine the feasibility of coordinating or consolidating ditch systems. The potential for reusing wastewater should also be investigated. The greatest potential for improving the Bitterroot River fishery exists with encouraging more efficient management and distribution of irrigation water.

Tributary spawning provides a significant source of trout recruitment to the Bitterroot River. The loss of emigrating trout to irrigation canals is a potential problem that needs further investigation. Since emigration occurs for a confined period of time, it is possible to identify and monitor important tributaries with minimal cost.

Periodic trout population surveys should be continued in the Bitterroot River. Additional estimates in the lower river may help determine the reason(s) for the relatively low population levels observed there. Occasional population estimates at Conner, Darby, and Tucker will help evaluate effectiveness of water releases for enhancing the trout fishery, and provide a basis for future adjustments in the management of the water and the fishery.

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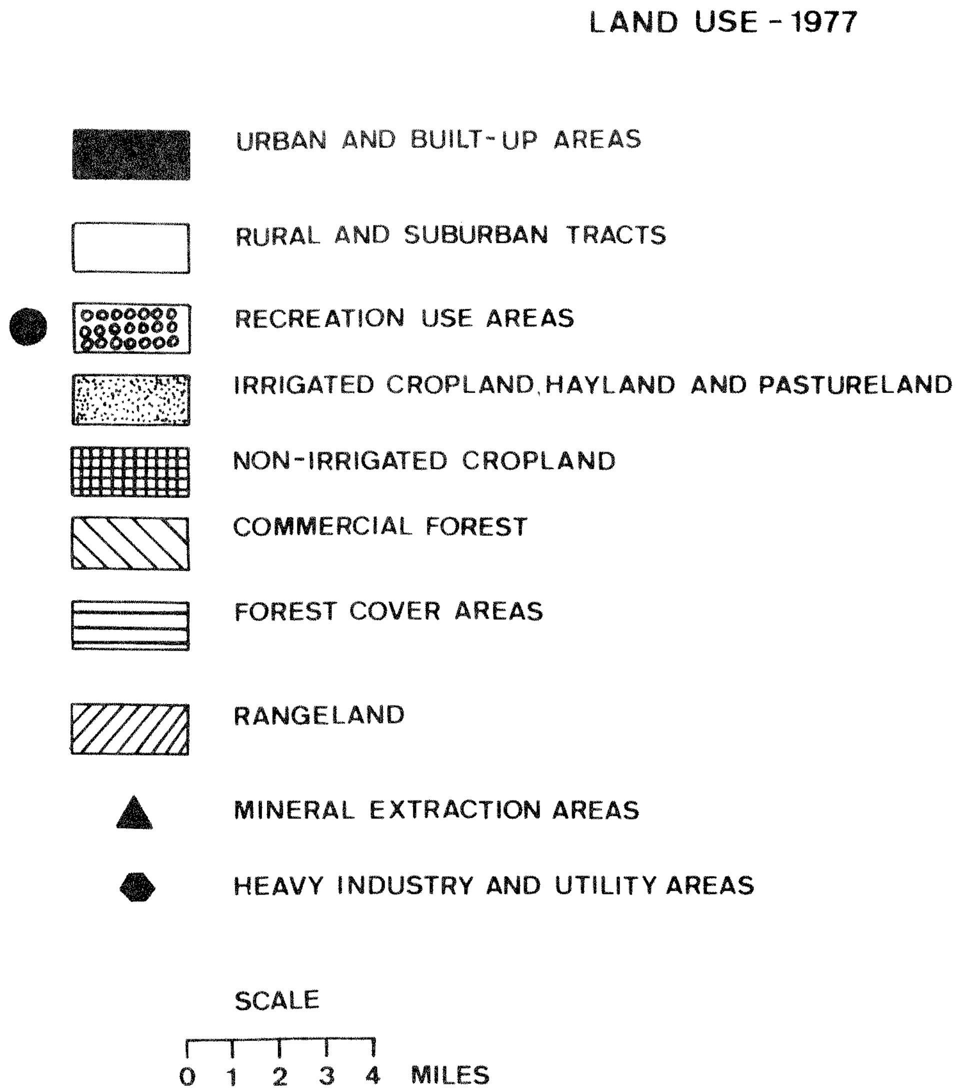
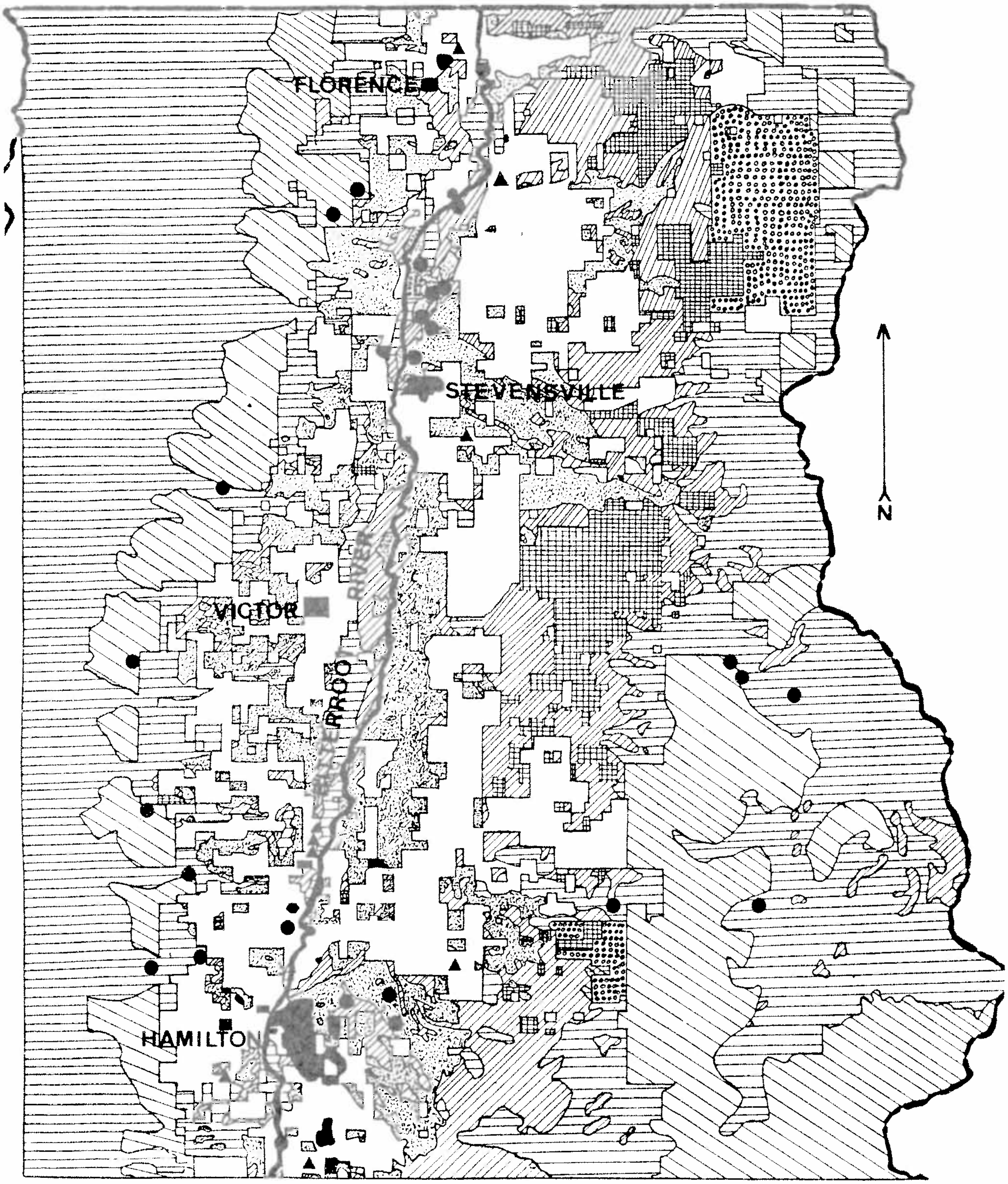
APPENDIX A

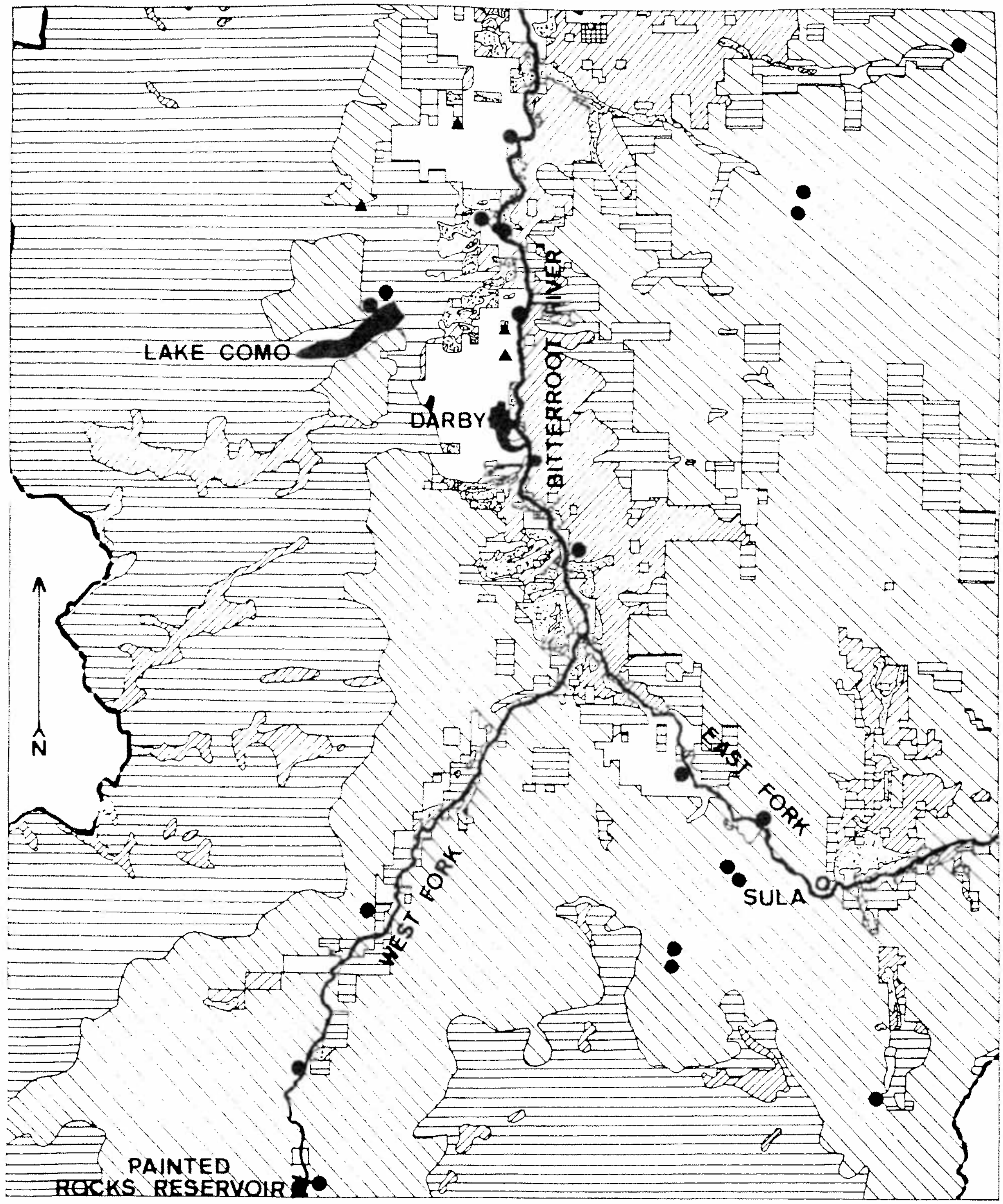
Land Use Maps for the Bitterroot River Basin



Appendix Figure A1. Key to the features of the land use maps for the Bitterroot River.



Appendix Figure A2. Land use patterns of the central Bitterroot basin.



Appendix Figure A3. Land use patterns of the upper Bitterroot basin.

APPENDIX B

Water Management Plan for Supplemental Releases From Painted Rocks Reservoir, Bitterroot River, Montana

Water Management Plan

Introduction

In 1984, a draft water management plan was developed for the 15,000 AF of Painted Rocks Reservoir water controlled by MDFWP (Lere 1984). The primary objective of the plan was to determine a release schedule, based on historic stream flow data, that would maximize the amount of time which minimum flow recommendations would be met in the Bitterroot River at Bell crossing (the location where the most severe dewatering occurs).

To determine the frequency and quantity of need for supplemental water, the following information was needed:

1). The level of instream flow required at the Bell crossing;

2). Long-term summer flow characteristics of the Bitterroot River at Bell crossing;

3). The relationship between supplemental releases of water from the reservoir and subsequent changes in stream flow at Bell crossing.

The recommended minimum instream flow level for the Bitterroot River at Bell crossing is 11.38 m^3/sec (402 ft^3/sec) (refer to instream flow section of this report). Water releases in the draft water management plan (Lere 1984) were based on a minimum flow level of 10.60 m^3/sec (375 ft^3/sec), but additional data indicated that a higher minimum flow was appropriate.

To determine supplemental water needs at Bell crossing, long-term stream flow data in the dewatered reach of the river would be most desirable. These data are not available. Consequently, water needs at Bell crossing were predicted from long-term data at other stations.

Long-term flow data have been collected in the upper Bitterroot River at U.S.G.S. stations established on the West Fork near Painted Rocks Reservoir (No. 124325), the East Fork near Conner (Nos. 123434 and 123435), and the main stem near Darby (No. 123440). Characteristics of flow at the three stations have been summarized by Brown (1982). In addition, data collected from Department of Natural Resources and Conservation (DNRC) gauging stations at Hamilton (immediately upstream from critically dewatered section) and Stevensville (downstream from dewatered section) provide the longest term of record for Bitterroot River discharge in the vicinity of the dewatered section. These gauges monitored flow for a 12-year period from 1968 through 1979 (Tables B1 and B2).

Appendix Table B1. Mean biweekly flows and minimum daily discharge recorded for the summer period at Hamilton.

Year	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15	Sept. 16-30	Oct. 1-15	July 16 -Oct 15
	Mean Discharge (ft^3/sec) at Hamilton						
1968	750	382	512	449	1,217	805	684
1969	470	188	85	74	252	555	271
1970	1,163	495	391	460	554	542	605
1971	1,116	515	390	374	370	363	526
1972	1,234	546	404	410	431	433	582
1973	259	191	187	361	496	289	295
1974	1,613	814	693	482	603	620	812
1975	1,891	839	1,160	726	642	888	1,035
1976	1,593	861	784	707	754	697	906
1977	406	153	280	233	342	608	337
1978	1,353	429	417	493	455	354	590
1979	282	183	399	276	115	386	275
Number of years mean flow was:							
≤ 500	4	7	8	10	7	5	4
≤ 400	2	5	6	5	4	4	4
≤ 375	2	4	3	5	4	3	4
≤ 300	2	4	3	3	2	1	3
≤ 200	0	4	2	1	1	0	0
≤ 100	0	0	1	1	0	0	0

Year	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15	Sept. 16-30	Oct. 1-15	July 16 -Oct 15
	Minimum Daily Discharge (ft^3/sec) at Hamilton						
1968	325	325	425	375	825	712	325
1969	278	130	62	62	100	485	62
1970	875	370	390	390	390	460	370
1971	600	390	390	370	370	350	350
1972	805	410	390	410	410	430	390
1973	190	145	115	290	430	250	115
1974	910	735	430	330	540	570	330
1975	1,150	625	575	625	600	650	575
1976	875	725	700	675	625	650	625
1977	325	113	125	113	125	575	113
1978	663	350	375	350	313	313	313
1979	175	150	238	175	75	200	75

Appendix Table B2. Mean biweekly flows and minimum daily discharge recorded for the summer period at Stevensville.

Year	Mean Discharge (ft^3/sec) at Stevensville						
	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15	Sept. 16-30	Oct. 1-15	July 16 -Oct 15
1968	1,176	484	1,121	798	2,227	1,429	1,205
1969	572	212	173	168	390	815	388
1970	1,643	689	285	495	891	785	802
1971	1,583	413	245	317	288	312	535
1972	2,531	991	691	583	900	880	1,107
1973	319	290	263	570	1,023	617	509
1974	2,195	887	993	610	827	793	1,063
1975	2,557	1,016	1,951	1,142	833	1,263	1,478
1976	2,113	1,303	1,219	933	1,084	977	1,280
1977	523	340	361	515	630	932	548
1978	2,095	805	800	907	1,021	835	1,077
1979	809	490	687	665	575	680	653
Number of years mean flow was:							
≤ 500	1	6	5	3	2	1	1
≤ 400	1	3	5	2	2	1	1
≤ 375	1	3	5	2	1	1	0
≤ 300	0	2	4	1	1	0	0
≤ 200	0	0	1	1	0	0	0
≤ 100	0	0	0	0	0	0	0

Year	Minimum Daily Discharge (ft^3/sec) at Stevensville						
	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15	Sept. 16-30	Oct. 1-15	July 16 -Oct 15
1968	525	400	925	525	1,200	1,260	525
1969	212	212	100	138	212	625	100
1970	1,140	325	175	250	625	675	175
1971	625	250	213	250	250	287	213
1972	1,590	600	550	500	700	800	500
1973	150	100	150	350	900	500	100
1974	1,000	800	650	350	750	750	350
1975	1,340	700	650	600	550	750	550
1976	1,300	1,050	1,050	863	938	938	863
1977	413	300	300	338	450	900	300
1978	1,250	600	638	638	825	788	600
1979	675	375	450	563	488	638	375

Due to the large number of unmeasured inflows (tributaries and irrigation returns) and outflows (irrigation withdrawals) in the Bitterroot River, determining flow relationships between gauging stations is difficult. Parrett (1984) attempted to simulate Bitterroot River stream flows using a routing model, but model results were not sufficient to accurately predict flows. It was concluded that installation of a gauging station at Bell crossing was the most practical means for obtaining the required data for the dewatered reach of the river.

The MDFWP has contracted U.S.G.S. to operate a stream flow gauge at Bell crossing beginning in 1987. In the future, stream flow characteristics at this station will provide the most reliable basis for determining supplemental water needs in the dewatered section. In the meantime, regression models derived during this study provide the best available information to determine water needs at Bell crossing.

Simulated Discharge at Bell Crossing

Due to the absence of historic flow data at Bell crossing, two regression models were used to simulate stream flows within the dewatered section of the river. The first model described flow relationships between the Darby (U.S.G.S.) and Hamilton (DNRC) stations during the period of matching records (1968-1979). The second model was used to relate stream flows at Woodside and Bell crossing during 1983. Discharge at the temporary station at Woodside is representative of the discharge at Hamilton. The Hamilton station was not operated in 1983.

The Darby-Hamilton model was developed to provide a statistical base for analyses, using the long term record (1937-1981) of the Darby station to estimate exceedence frequencies at Hamilton. Linear regression equations relating mean bimonthly discharge at Darby and Hamilton were developed for the period of July 16 to October 15 (Figures B1 and B2).

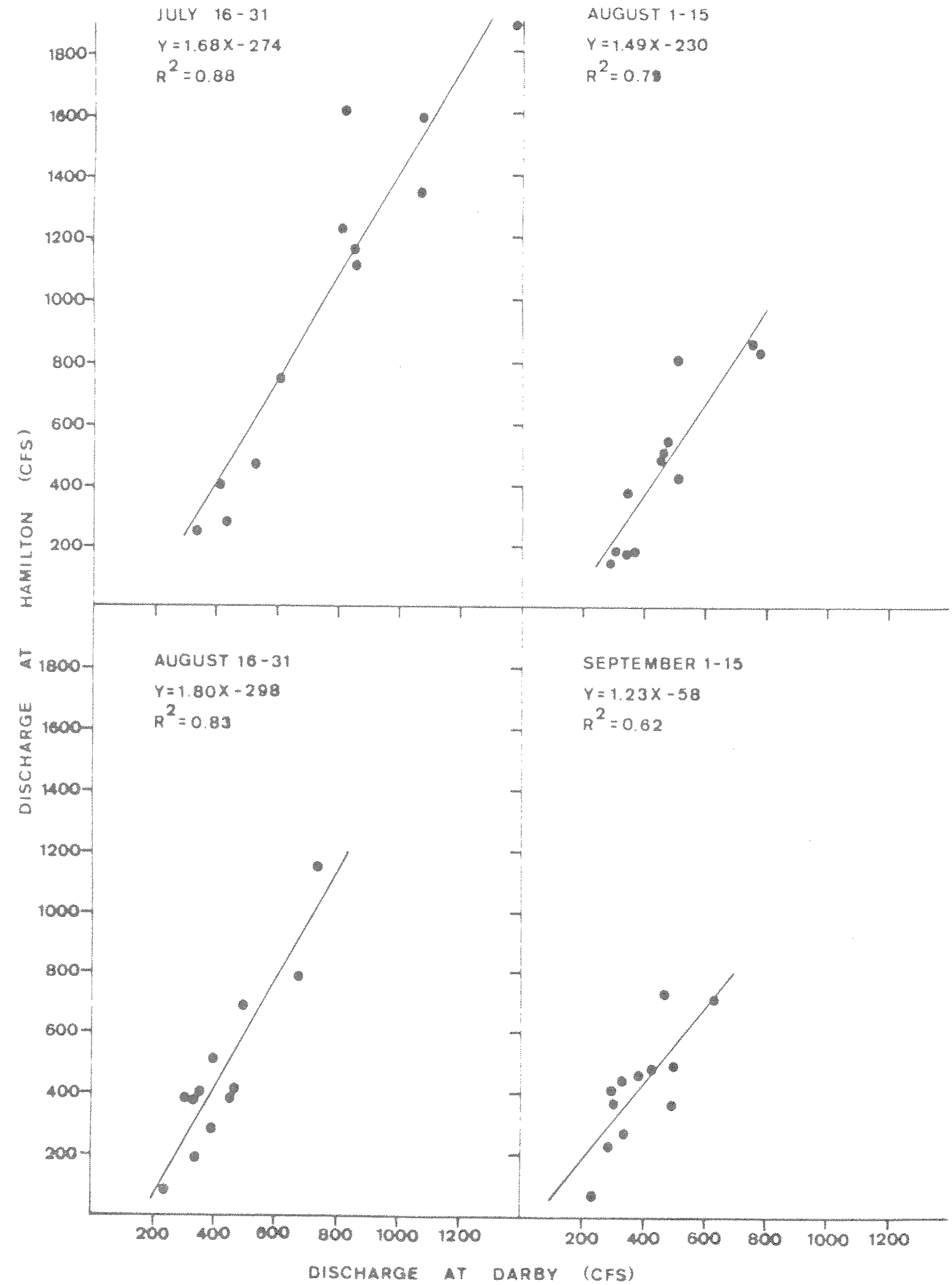
The Woodside-Bell crossing model was developed to relate daily discharge at Woodside (which is similar to Hamilton) to daily discharge at Bell crossing. The equation derived during 1983 was:

$$Q_B = 1.089\ Q_w - 92.0$$

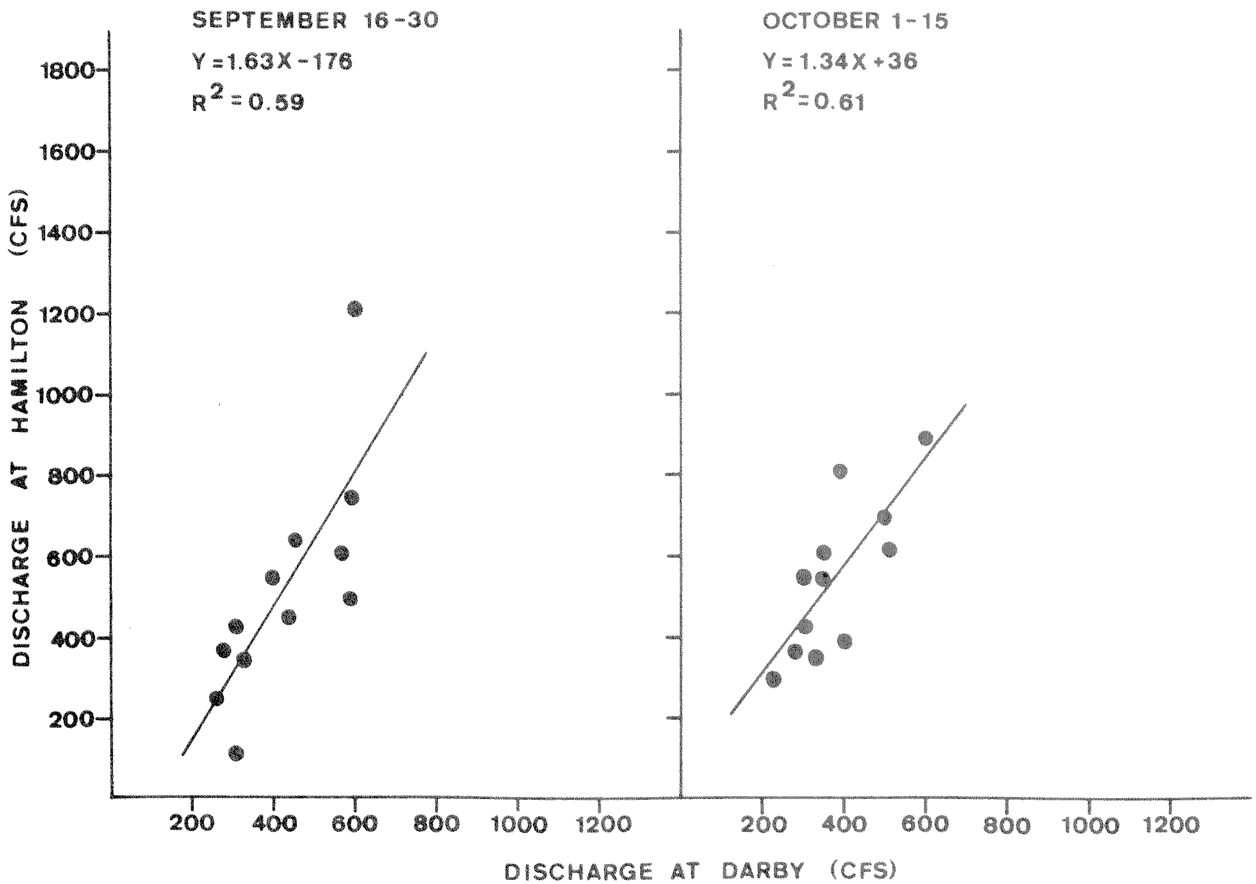
$$r^2 = 0.98$$

where Q_B = daily discharge at Bell crossing

and Q_w = daily discharge at Woodside crossing



Appendix Figure B1. Relationships between mean biweekly discharge at Darby and Hamilton from July 16 to September 15.



Appendix Figure B2. Relationships between mean biweekly discharge at Darby and Hamilton from September 16 to October 15.

Considering the large number of irrigation withdrawals and tributary inflows between Woodside and Bell crossing, this model predicted discharge at Bell crossing with an acceptable degree of error in 1983. Differences between actual and predicted values ranged from +33.3 percent to -44.7 percent. The average daily difference was +9.3 percent, and absolute differences averaged 12.7 percent.

The 1983 Woodside-Bell model predicted discharge at Bell crossing with a similar degree of error in 1984 (Table B3). Flow characteristics between the two stations were similar during 1983 and 1984, as evidenced by the similar regression equations derived during the two years (Table B3). These two years were characterized by above-average summer discharges and moderate irrigation withdrawals (unmeasured) between Hamilton and Bell crossing. Dike construction by irrigators, which greatly influence stream flow characteristics, was minimal during these two years.

Limitations of the 1983 Woodside-Bell crossing model were most evident during 1985 and 1986 when Bitterroot River stream flows were below normal and diking by irrigators was extensive. The 1983 model predicted discharge at Bell crossing with poor accuracy during 1985 and 1986, and regression equations developed during these years were substantially different from the 1983 model (Table B3). Comparisons between actual discharge and predicted (from 1983 model) differed by as much as -846 and -224 percent in 1985 and 1986, respectively.

Without extensive efforts to monitor tributary inflows and irrigation outflows between Woodside and Bell crossing, the Woodside-Bell model will not adequately predict discharge at Bell crossing during years with low stream flows. Combining data from 1983 to 1986 to develop a model relating stream flows at Woodside (or Hamilton) to Bell Crossing during a range of stream flow levels would only result in a model with an unacceptable degree of error. For the purpose of determining the frequency of water needs at Bell crossing, the Woodside-Bell crossing model developed from 1983 stream flow data was selected because it was reasonably accurate during 1983 and 1984 when stream flows were relatively high and the effects of irrigation on flow characteristics were moderate.

Another reason for selecting the 1983 model is that discharge at Hamilton and Bell crossing are similar using the 1983 model. Since minimum flow recommendations at these two stations are identical (11.38 m^3/sec; 402 ft^3/sec), the frequency of supplemental water needs will be similar. Given the difficulty in predicting water needs in the critically dewatered reach (Bell crossing) it may be more appropriate to base water needs on flows at the upstream portion of the dewatered reach (Hamilton). A combination of delivering water to Hamilton during periods of greatest need and working with irrigators to maximize the amount of supplemental water reaching Bell crossing, will provide the

Appendix Table B3. Comparisons of regression equations for discharge at Hamilton and Bell crossing, 1983 through 1986.

Year	Regression Equation Hamilton[b] vs. Bell Crossing	R^2	Actual minus Predicted[a] discharge at Bell Crossing Average (Range)
1983	y = 1.098(x) - 92.0	0.98	+9.3% (+33 to -45%)
1984	y = 1.10(x) - 93.11	0.92	-4.3% (+45 to -81%)
1985	y = 1.405(x) - 260.98	0.95	-112.0% (+29 to -846%)
1986	y = 1.539(x) - 315.82	0.65	-31.0% (+40 to -224%)

a/ Bell crossing discharge (1983-1986) predicted from 1983 regression equation.

b/ Hamilton and Woodside data were interchangable.

greatest benefit to the river. Empirical data from the Hamilton station (1968-1979) was used to determine whether water needs based on modeling efforts reasonably predicted periods of greatest need at Hamilton.

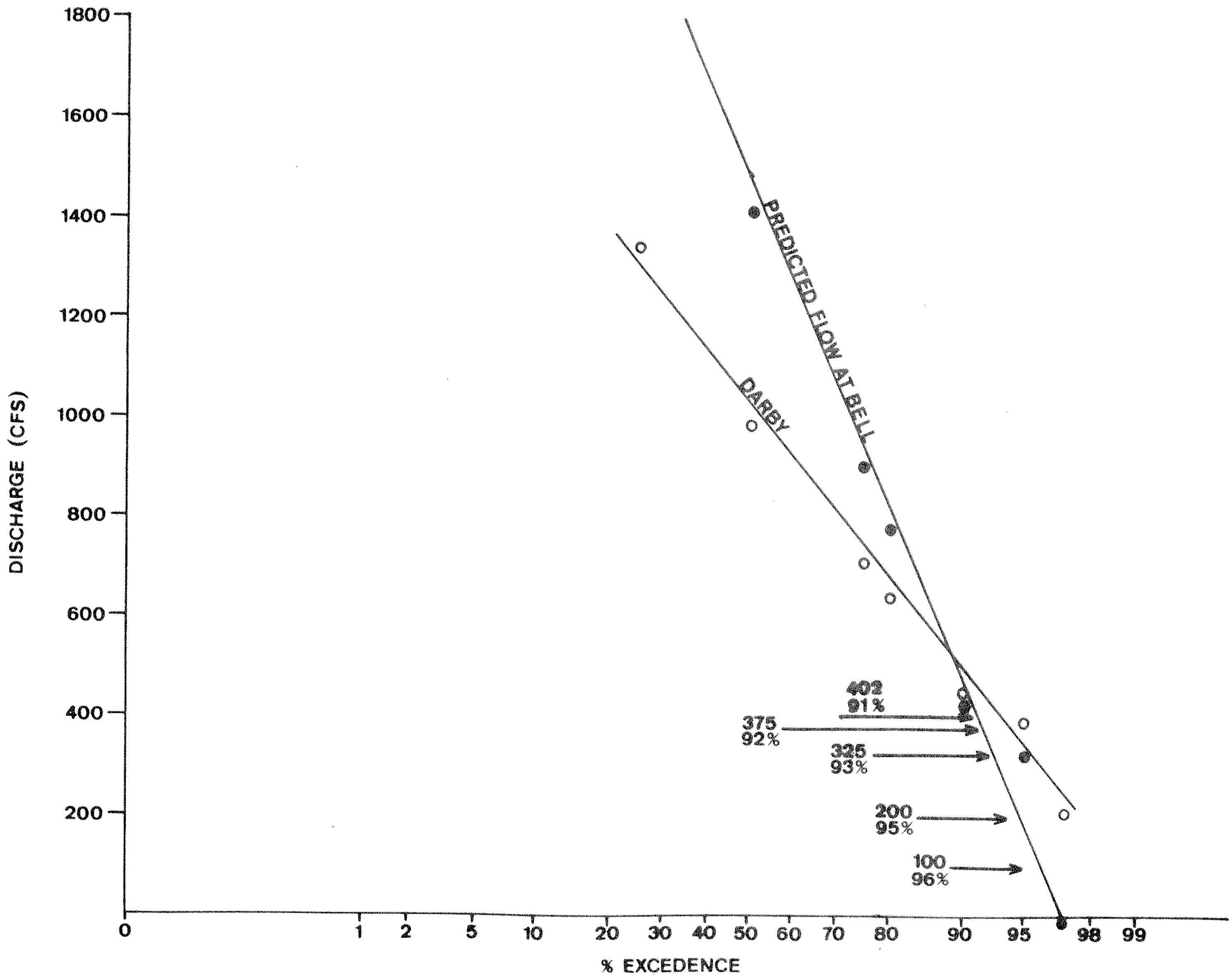
Frequency of Need for Supplemental Water

The frequency that stream flows at Bell crossing do not meet the minimum recommended flows was estimated for July 16-31, August 1-31, and September 1-30. Flows at Bell crossing would be expected to exceed the minimum recommended level (11.38 m^3/sec; 402 ft^3/sec) about 91, 21, and 24 percent of the time, respectively, in late July, August, and September (Figures B3, B4, and B5). A 5.66-m^3/sec (200-ft^3/sec) minimum would be met or exceeded about 95, 64, and 71 percent of the time for the respective periods.

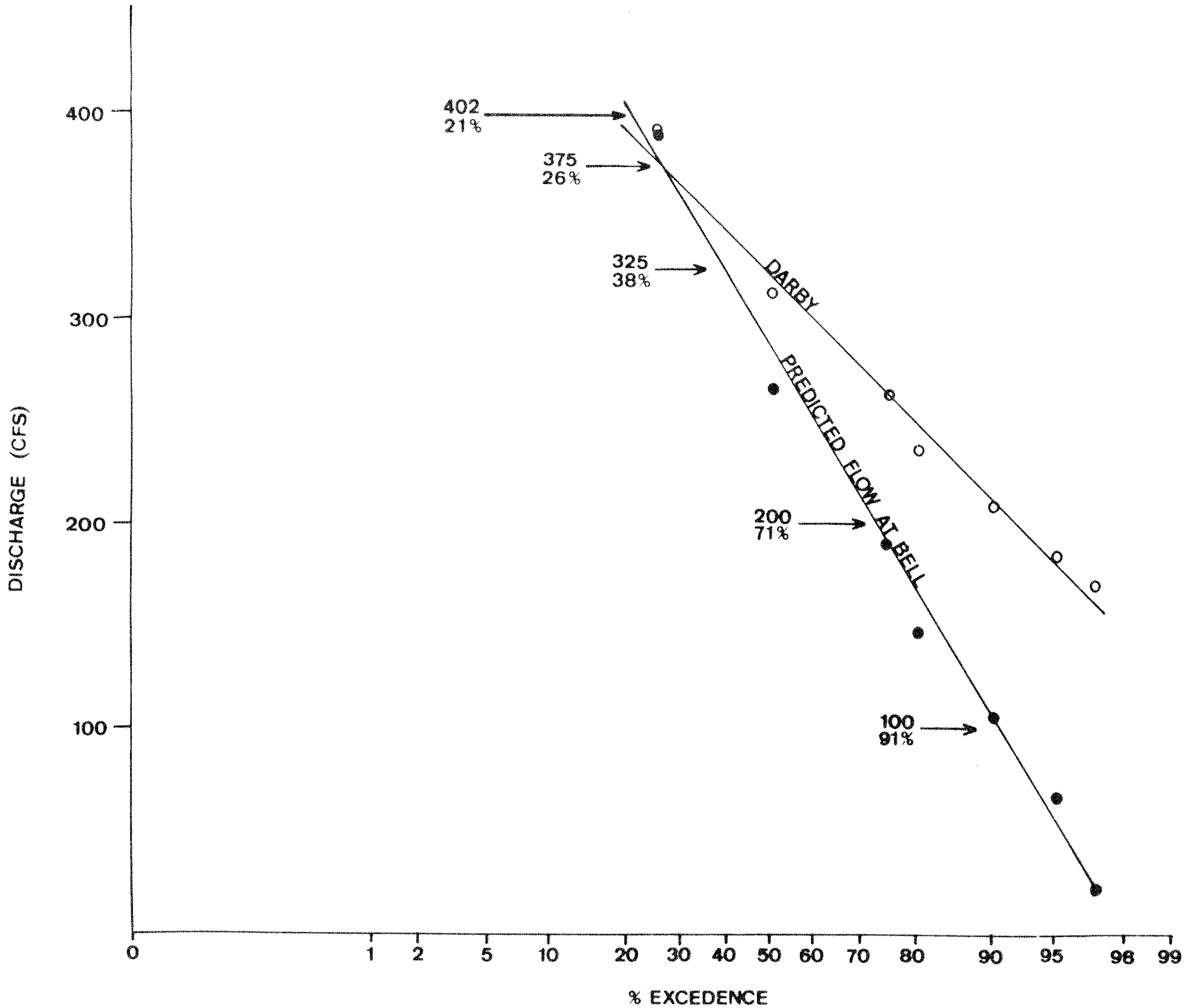
Other researchers have derived somewhat lower exceedence values for a 5.66-m^3/sec (200 ft^3/sec) flow at Bell. Brown (1982) estimated that flows of 200 ft^3/sec at Bell crossing would be met or exceeded about 95, 30, and 25 percent of the time in late July, August and September, respectively. Odell (1981), using 21 years of historic flow data recorded at Darby, estimated flows at Bell crossing would exceed 200 ft^3/sec about 60 percent of the time during the irrigation season. Exceedence values derived from Brown and Odell were based on the assumption that 400 ft^3/sec at Darby represented 200 ft^3/sec at Bell crossing. A discharge of 11.32 m^3/sec (400 ft^3/sec) at Darby, however, can be accompanied by Bell crossing flows as low as 0.7 m^3/sec (25 ft^3/sec) (July 1985) or as high as 12.1 m^3/sec (427 ft^3/sec) (August 1985).

Supplemental Flows Needed to Maintain Minimum Recommendations

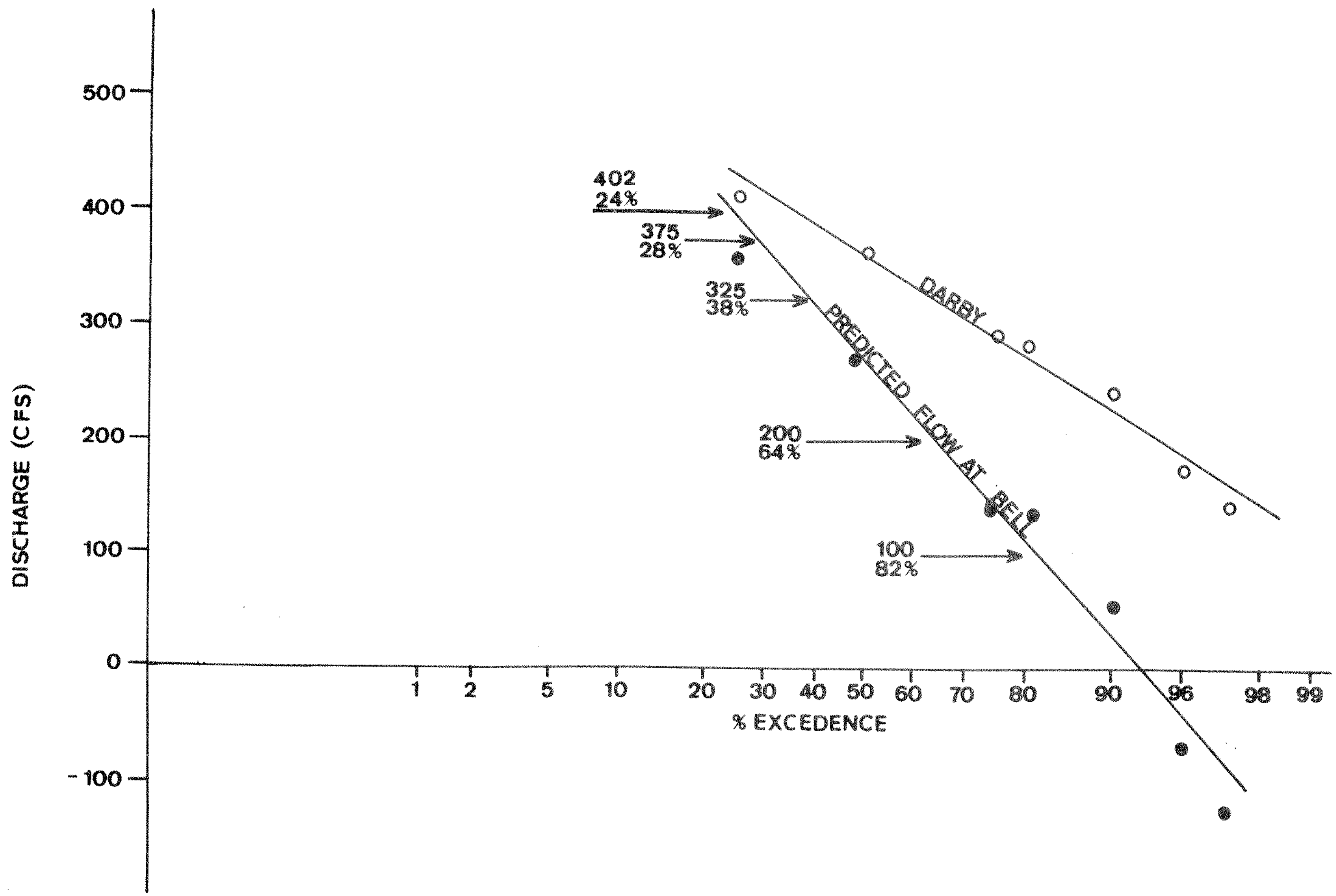
The percentage of water released from Painted Rocks Reservoir that reaches target areas must be determined to estimate the amount of time that minimum flows can be met with supplemental releases. Four test spills of reservoir water were conducted to determine the percentage of released water that could be expected to reach various stations (refer to Test Release section of this report). Results of test spills varied depending on stream flow levels, irrigation demands, and degree of cooperation by irrigators to avoid withdrawing test spill water. Since the primary purpose of this water management plan is to determine a release schedule that delivers water during periods of greatest need, it was assumed that releases reach target areas in equal amounts, regardless of water losses to irrigation withdrawals or other reasons. It was assumed that 100 percent of the releases reach all stations. As a result of this assumption, estimated flows during releases will be overestimated, although estimates of quantity of additional water needs will be accurate. The long-term goal of this plan should be to minimize the amount of supplemental water lost to irrigation diversions.



Appendix Figure B3. Exceedence values for discharge at Darby and for predicted flow at Bell crossing, July 16-31.



Appendix Figure B4. Exceedence values for discharge at Darby and for predicted flow at Bell crossing, August 1-31.



Appendix Figure B5. Exceedence values for discharge at Darby and for predicted flow at Bell crossing, September 1-30.

Quantities of additional water needed to maintain minimum flows at Bell crossing were calculated using the exceedence values derived by the Darby-Hamilton/Woodside-Bell regression models. Water needs estimated for July were calculated only for the last 16 days of the month. In addition, the negative flows derived for Bell crossing were treated as 0 ft^3/sec for computation purposes. Amounts of additional water, based on percent exceedence, needed to maintain flows of 402, 375, 325, 200, and 100 ft^3/sec at Bell crossing during July, August, and September are presented in Table B4. These estimates indicate flows during August and September require supplemental water most of the time to meet the 11.38-m^3/sec (402-ft^3/sec) minimum recommendation. July flows require additional water only about ten percent of the time to meet this minimum recommendation.

For the summer period (July 16 - September 30), supplemental releases of 15,000 AF of water would raise stream flow exceedence values by about 25 percent, assuming 100 percent of releases reached Bell crossing. The minimum flow recommendation of 11.38 m^3/sec (402 ft^3/sec) would be maintained 49 percent of the time (Figure B6). A flow of 5.66 m^3/sec (200 ft^3/sec) could be maintained about 90 percent of the time.

In addition to frequency analyses based on Darby-Hamilton and Woodside-Bell crossing models, historic flow data was used to assess supplemental water needs at Hamilton. Quantities of water needed to maintain minimum flows during July, August, and September were determined for four flow levels (Table B5). Water quantities were computed from daily discharge records for a 12-year period.

Based on data from 1968 to 1979, supplemental water would be needed all but two years to maintain a minimum flow of 11.38 m^3/sec (402 ft^3/sec) at Hamilton. During 8 of 12 years, the 15,000 AF supplement would be adequate to maintain the minimum flow level, even considering a 20 to 50 percent loss of supplemental water between Painted Rocks Reservoir and Hamilton. In addition, supplemental water would virtually assure a discharge of 5.66 m^3/sec (200 ft^3/sec) at Hamilton (Table B5).

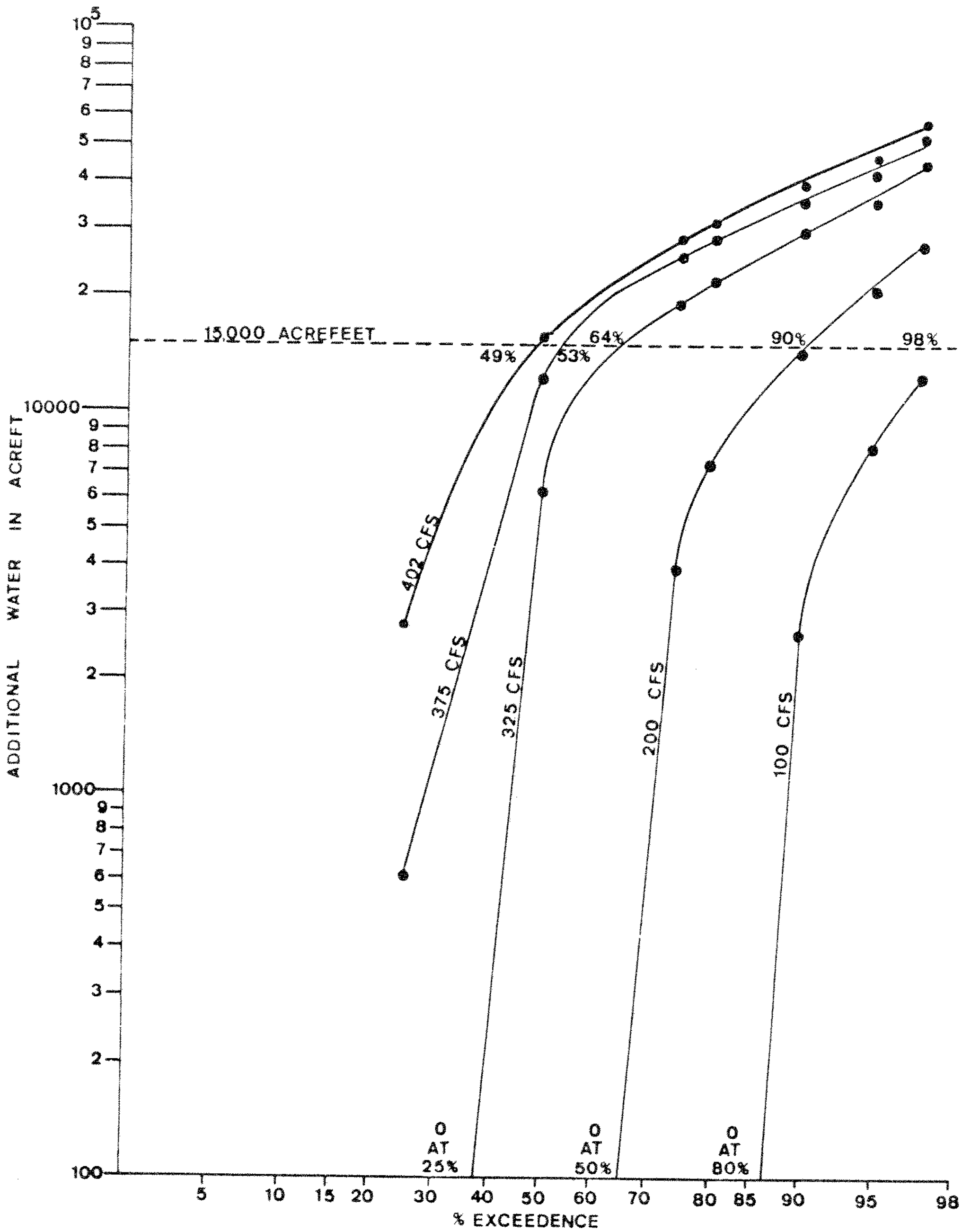
Empirical data from Hamilton supports modeling data, indicating that the need for supplemental water is greatest in August. An average of 997, 4,271, and 3,275 AF of additional water would be needed during late July, August, and September, respectively (Table B5). The release schedule recommended by this water management plan, however, was based on modeling results because of the relatively short period of record at the Hamilton station.

Appendix Table B4. Estimates of the quantity of additional water needed to maintain mimimum flow levels in the Bitterroot River at Bell crossing during July, August, and September.

Month	Percent Exceed-ence	Predicted Flow[a] Darby	Predicted Flow[a] Hamilton	Predicted Flow[a] Bell Crossing	Additional Water Needed to Maintain Respective Minimum Flows: 402 ft^3/sec — ft^3/sec	402 ft^3/sec — (AF/month)	375 ft^3/sec — ft^3/sec	375 ft^3/sec — (AF/month)	325 ft^3/sec — ft^3/sec	325 ft^3/sec — (AF/month)	200 ft^3/sec — ft^3/sec	200 ft^3/sec — (AF/month)	100 ft^3/sec — ft^3/sec	100 ft^3/sec — (AF/month)
July[b]	25	1344	1984	2062	0	--	0	--	0	--	0	--	0	--
	50	990	1389	1421	0	--	0	--	0	--	0	--	0	--
	75	711	920	910	0	--	0	--	0	--	0	--	0	--
	80	640	801	780	0	--	0	--	0	--	0	--	0	--
	90	448	478	429	0	--	0	--	0	--	0	--	0	--
	95	397	393	336	66	(2094)	39	(1235)	0	--	0	--	0	--
	97	210	78	-7	402	(12758)	375	(11898)	325	10,312	200	(6,346)	100	(3,173)
August	25	416	421	365	27	(2,275)	10	(615)	0	--	0	--	0	--
	50	367	340	278	124	(7,624)	97	(5,963)	47	(2,889)	0	--	0	--
	75	294	219	146	256	(15,741)	229	(14,077)	179	(11,004)	54	(33,20)	0	--
	80	285	205	131	271	(16,663)	244	(14,999)	194	(11,926)	69	(4,242)	0	--
	90	244	137	57	345	(21,213)	318	(19,548)	268	(16,475)	143	(8,791)	43	(2,643)
	95	176	25	-65	402	(24,718)	375	(23,052)	325	(19,979)	200	(12,295)	100	(6,147)
	97	141	-32	-127	402	(24,718)	375	(23,052)	325	(19,979)	200	(12,295)	100	(6,147)
September	25	393	445	393	9	(535)	0	--	0	--	0	--	0	--
	50	313	330	267	135	(8,033)	108	(6,425)	58	(3,450)	0	--	0	--
	75	263	259	190	212	(12,614)	185	(11,006)	135	(8,031)	10	(595)	0	--
	80	236	220	148	254	(15,114)	227	(13,504)	177	(10,530)	52	(3,093)	0	--
	90	209	182	106	296	(17,613)	269	(16,003)	219	(13,028)	94	(5,592)	0	--
	95	184	146	67	335	(19,933)	308	(18,323)	258	(15,348)	133	(7,912)	33	(1,963)
	97	170	126	45	357	(21,243)	330	(19,632)	280	(16,657)	155	(9221)	55	(3,272)
Totals for July 16 - September 30 (AF/month)														
	25				2,810		615		0		0		0	
	50				15,657		12,388		6,339		0		0	
	75				28,355		25,083		19,035		3,915		0	
	80				31,777		28,503		22,456		7,335		0	
	90				38,826		35,551		29,503		14,383		2,643	
	95				46,745		42,610		35,327		20,207		8,110	
	97				58,719		54,582		46,948		27,862		12,592	

a/ Negative values considered 0 for AF calculation

b/ July 16-31



Appendix Figure B6. Estimated exceedence values for five flow levels at Bell crossing with releases of 15,000 AF of Painted Rocks Reservoir water from July 16 to September 30.

Appendix Table B5. Quantities of additional water (AF) needed to maintain minimum flows at Hamilton from July 16 to September 30 for the period of record 1968-1979.

	Minimum Flow of 402 ft^3/sec[a]				Minimum Flow of 375 ft^3/sec[a]			
Year	July	August	Sept.	Total	July	August	Sept.	Total
1968	305	791	161	1,257	198	297	0	495
1969	1,289	16,437	14,229	31,955	914	14,777	12,622	28,313
1970	0	491	167	658	0	0	0	0
1971	0	452	1,785	2,237	0	0	268	268
1972	0	167	0	167	0	0	0	0
1973	5,092	13,102	1,451	19,645	4,075	11,442	952	16,469
1974	0	0	483	183	0	0	198	198
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	891	11,734	7,737	20,362	397	10,181	6,542	17,120
1978	0	472	938	1,410	0	50	444	494
1979	4,387	7,607	12,350	24,344	3,690	6,369	10,851	20,910
Avg.	997	4,271	3,275	8,543	773	3,593	2,656	7,022

	Minimum Flow of 325 ft^3/sec[a]				Minimum Flow of 200 ft^3/sec[a]			
Year	July	August	Sept.	Total	July	August	Sept.	Total
1968	0	0	0	0	0	0	0	0
1969	408	11,704	9,746	21,858	0	4,440	4,144	8,584
1970	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	2,290	8,368	248	10,906	59	1,616	0	1,675
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	7,405	4,807	12,212	0	2,100	1,535	3,635
1978	0	0	24	24	0	0	0	0
1970	2,501	4,535	8,174	15,210	198	942	2,677	3,817
Avg.	433	2,688	1,917	5,018	21	758	696	1,477

a/ 1.0 ft^3/sec = 0.0283 m^3/sec

Release Schedule

Recommendations for the quantity and timing of the release of additional water were developed using results derived by modeling. This release schedule was based on a 15,000 AF supplement and was formulated to provide a 402 ft^3/sec flow at Bell crossing for the greatest possible amount of time.

The percent of time flows at Bell crossing would meet or exceed minimum recommendations resulting from the release of differing quantities of water during July, August, and September are presented in Table B6. Values in this table were derived from Figure B6, which displays the predicted amount of additional water, based on percent exceedence needed to maintain flows of 402, 375, 200, and 100 ft^3/sec at Bell crossing for each month. An additional 50 ft^3/sec during July, August, and September would add about 34, 8, and 9 percent, respectively, to the time that flows meet or exceed 402 ft^3/sec. An additional 100 ft^3/sec during the respective months would add about 4, 22, and 19 percent to the time that flows meet or exceed 402 ft^3/sec.

Recommendations for the release of additional water during July 16-31, August, and September are given in Table B7. A release of 50, 112, and 110 ft^3/sec during July 16-31, August, and September, respectively, approximately the maximum amount of time a 15,000 AF supplement could maintain a 402 ft^3/sec flow at Bell crossing. The quantity of water available for July, August, and September would total 1,586, 6,885, and 6,544 acre ft, respectively. Releases of additional water should not exceed the volume available for each month. Water not utilized during a specific month would be proportionally applied to the following month(s).

During years of high stream flow, the release of additional water to maintain minimum flows may not be necessary. Unless irrigators request water to prevent dike construction, supplemental water should be withheld to maintain reservoir levels for recreation on Painted Rocks Reservoir. Since the lowest winter flow levels occur during January, February, and March, the remaining supplemental water should be released evenly over this period.

During extremely dry years, a 11.38 m^3/sec (402 ft^3/sec) minimum flow will not be met at Bell crossing. An agreement should be negotiated with the irrigators to assure that Bell crossing flows, at the minimum, meet or exceed the rate of release of MDFWP water from the reservoir (refer to minimum flow recommendations section of this report).

Due to the tentative agreement between MDFWP and irrigators, the 3,000 AF of water reserved for release during late September will be given to the irrigators for release earlier in the summer. In return, irrigators are to help maintain minimum flows in late

Appendix Table B6. The estimated percent of time flows at Bell crossing would meet or exceed minimum flow recommendations resulting from differing supplemental releases.

	Additional Release[a]		Percent of time flow (cfs) Bell would be met or exceeded with release[b]			
Month	ft^3/sec	Acre ft	402	375	200	100
July (16-31)	0	0	91	92	95	96
	50	1,586	94	96	97	97
	75	2,380	95	96	97	97
	100	3,173	95	96	97	100
August	0	0	21	24	64	80
	50	3,074	29	42	75	90
	75	4,610	36	47	81	92
	100	6,147	43	51	84	100
	125	7,684	51	56	88	100
	150	9,221	55	61	90	100
	175	10,758	60	66	92	100
	200	12,295	64	70	100	100
September	0	0	24	26	71	90
	50	2,975	33	42	79	97
	75	4,462	38	44	85	100
	100	5,949	43	48	89	100
	125	7,436	48	55	94	100
	150	8,924	55	60	96	100
	175	10,411	63	68	100	100
	200	11,898	71	75	100	100

a/ Assume all of release would reach Bell crossing.

b/ Based on exceedence values from Darby U.S.G.S. gauge (Appendix Table B4).

Appendix Table B7. Release schedule for the optimal management of a 15,000-AF supplement from Painted Rocks Reservoir.

Month	Maximum Release[a/]		Percent of time flow (ft^3/sec) at Bell would be met or exceeded with release[b/]			
	ft^3/sec	Acre ft	402	375	200	100
July (16-31)	50	1,586	94	96	97	97
August	112	6,885	47	53	86	100
September	110	6,544	45	51	91	100
Total		15,015				

a/ Not to exceed 402 ft^3/sec at Bell crossing.

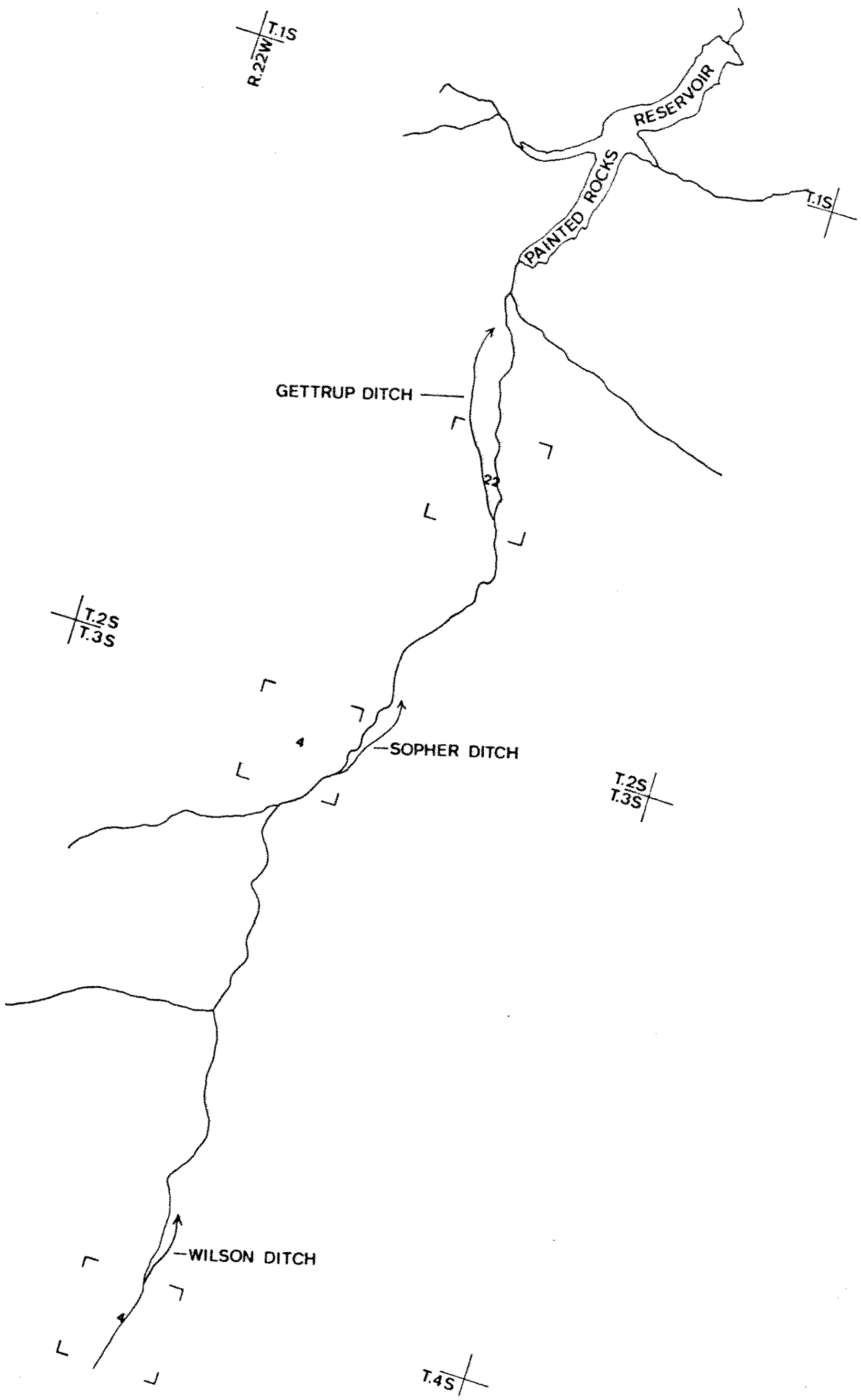
b/ Assume all of release would reach Bell crossing.

September by reducing withdrawals. A dry September, which is not uncommon, was not experienced during this study. Before finalizing the agreement, it should be determined whether irrigation cutbacks will be successful in maintaining adequate flow levels for late September.

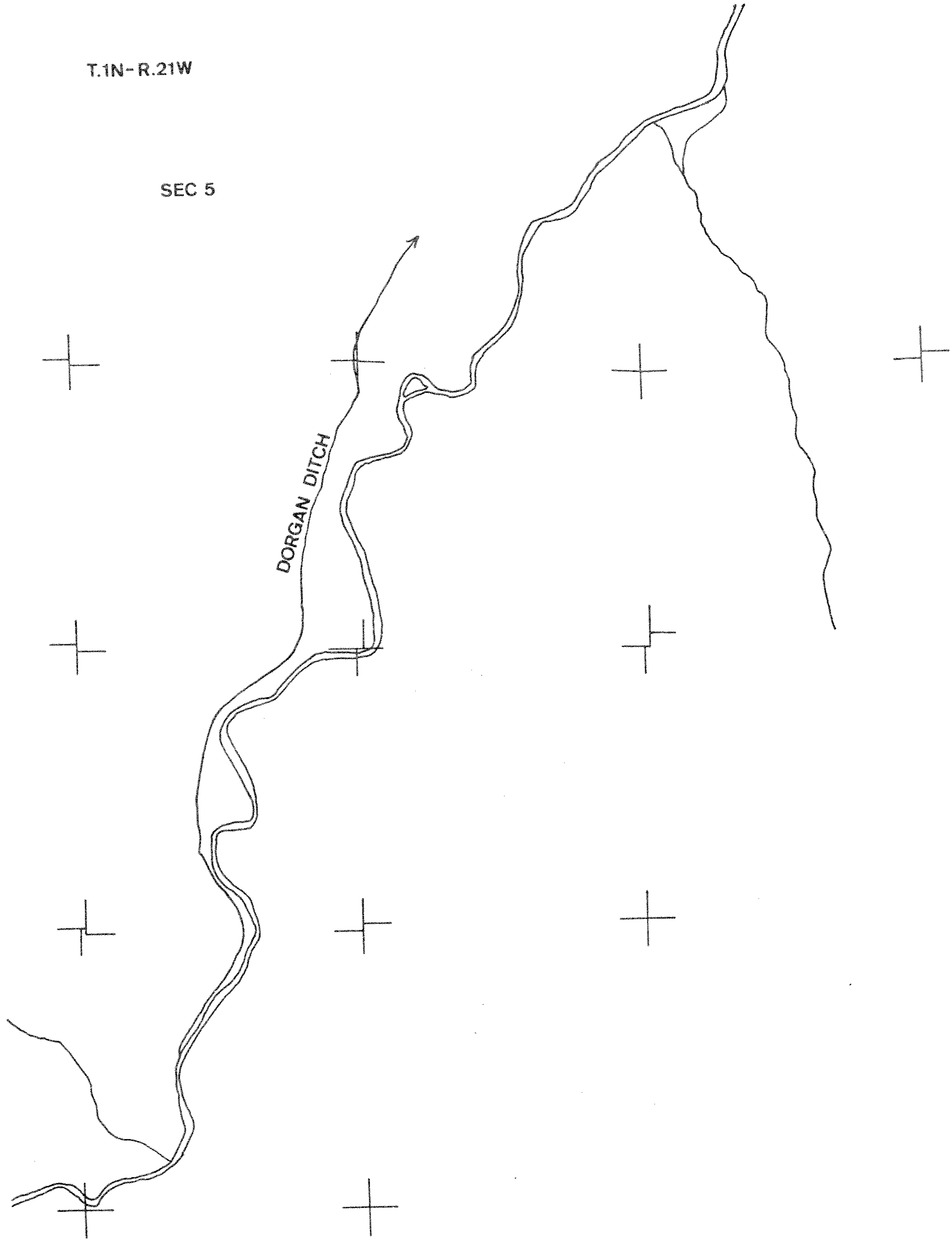
Analyses of end of month contents in Painted Rocks Reservoir conducted by Brown (1982) indicated stored volumes are usually sufficient to provide the quantities of supplemental water scheduled for release. July volumes have always exceeded 29,550 AF. The 1,586-AF supplement planned for release in July would have little affect on storage. Supplemental releases scheduled during August and September would impact levels in the reservoir to a greater extent. However, volumes in the reservoir during these months are typically sufficient to meet these needed quantities. Volumes in the reservoir during August have always exceeded 19,850 AF. During September, reservoir volumes have exceeded 12,850 AF 90 percent of the time.

APPENDIX C

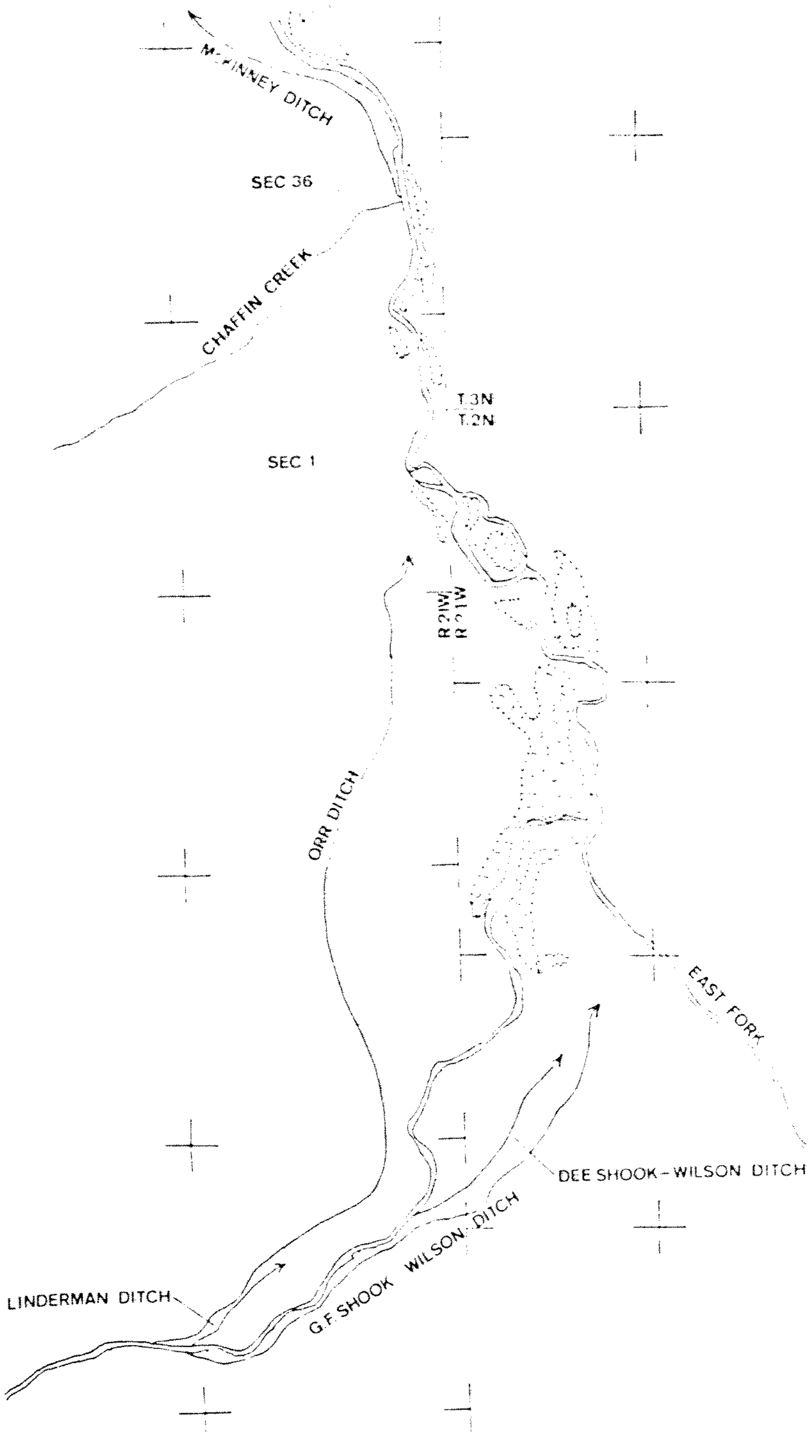
Maps of Selected Irrigation Diversion Locations



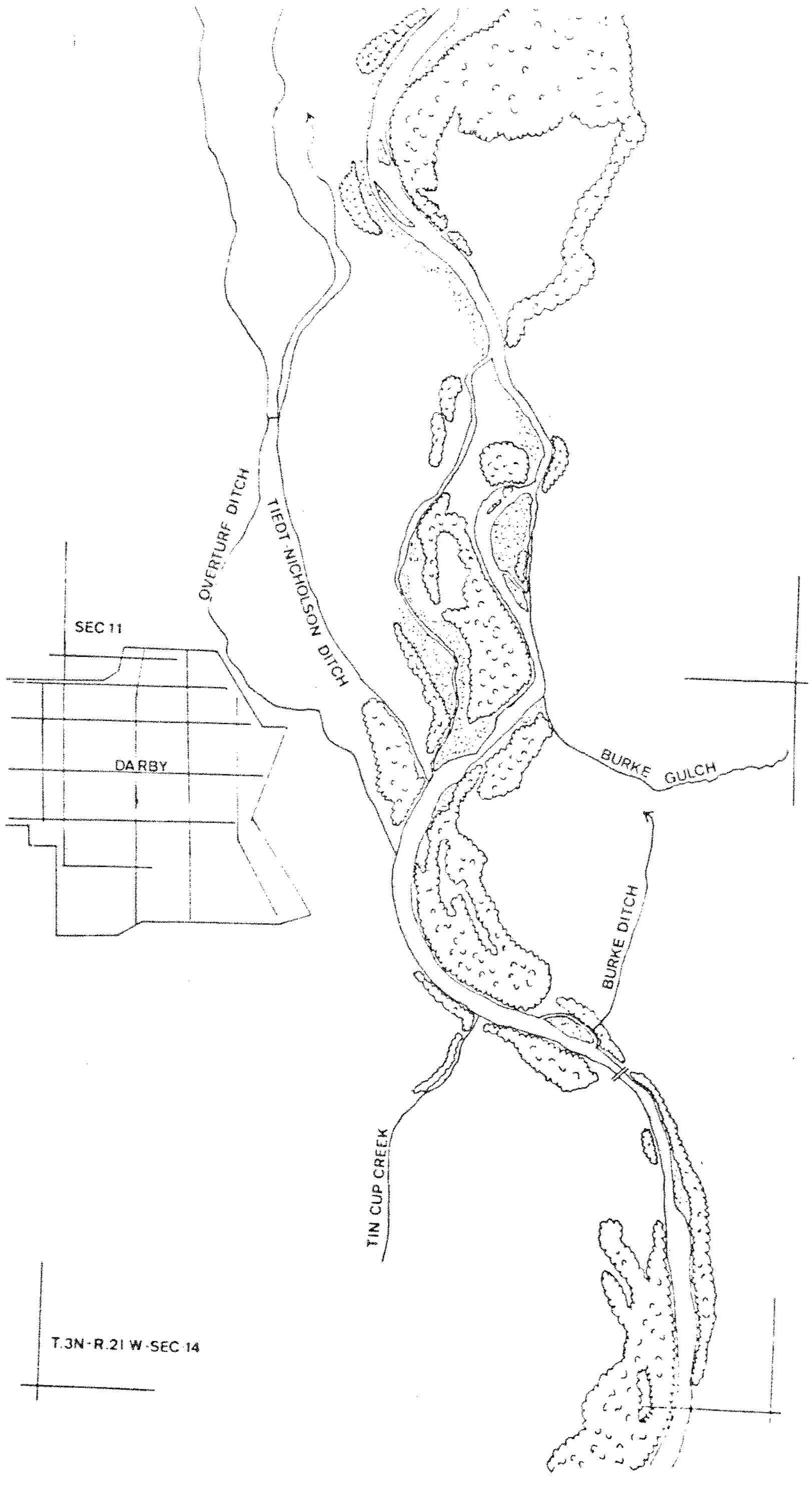
Appendix Figure C1. Map of the Wilson, Sopher, and Gettrup ditches.



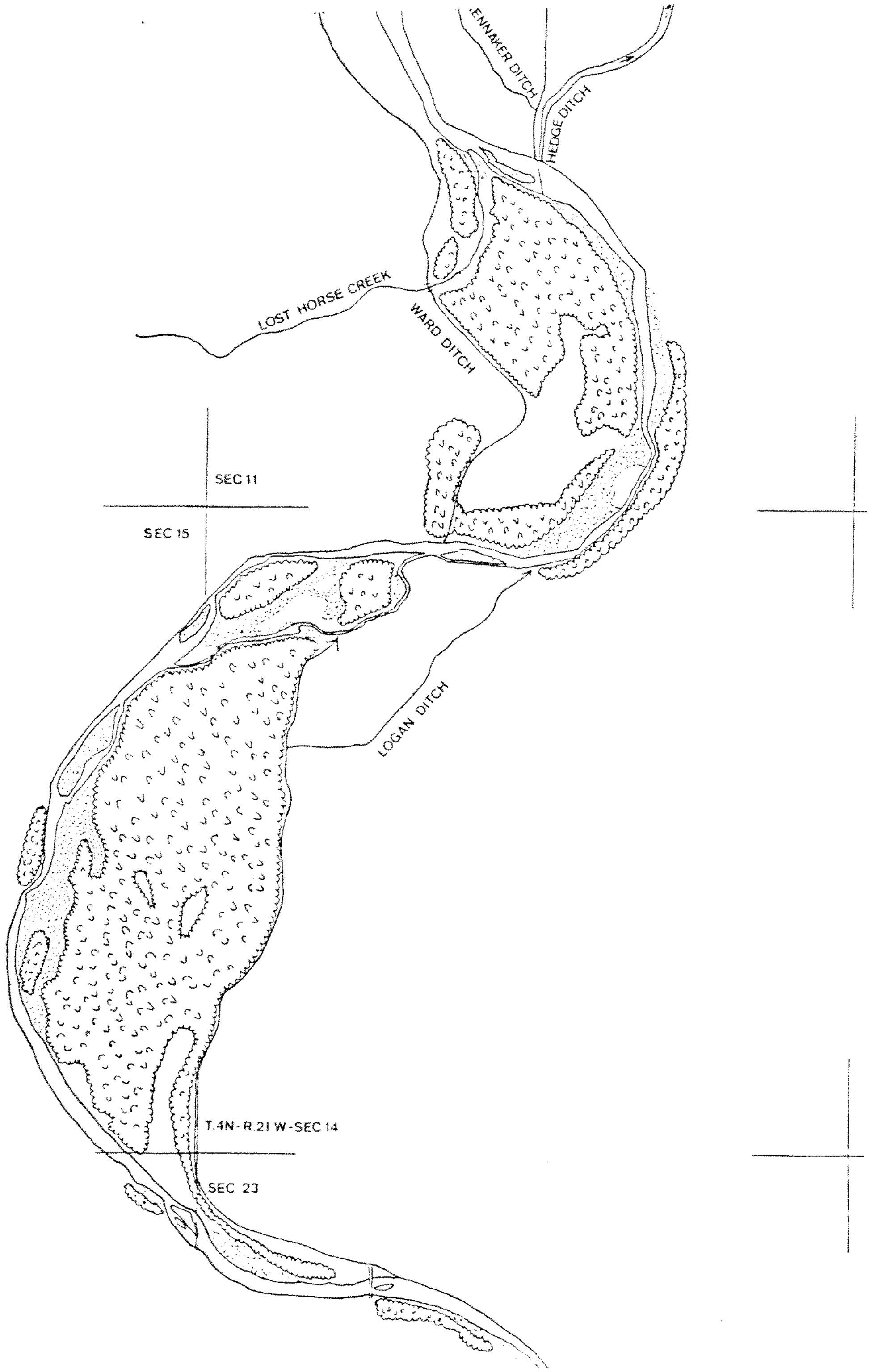
Appendix Figure C2. Map of the Dorgan ditch.



Appendix Figure C3. Map of the Orr, Linderman, Shook-Wilson, and McKinney ditches.



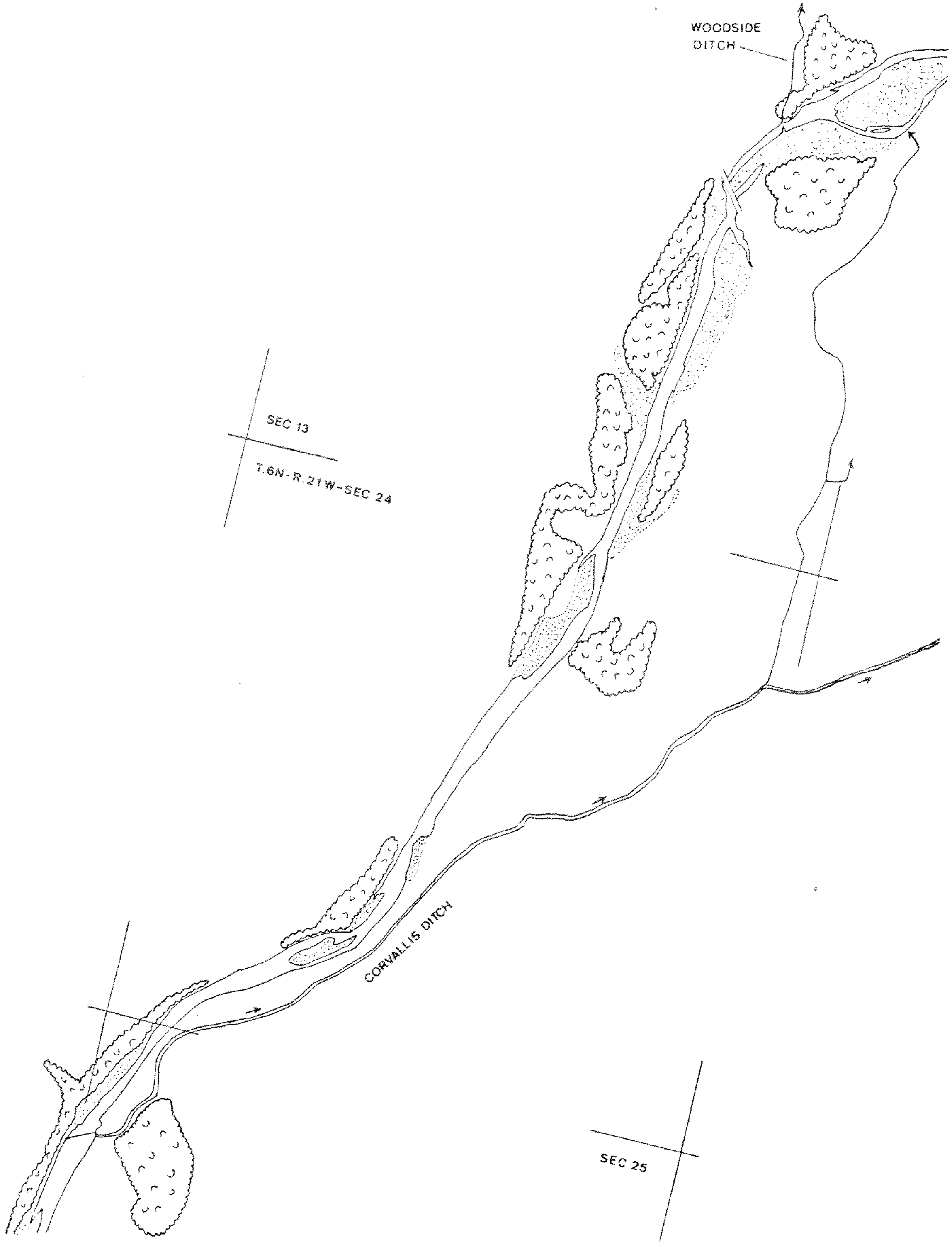
Appendix Figure C4. Map of the Burke , Overturf, and Tied-Nicholson ditches.



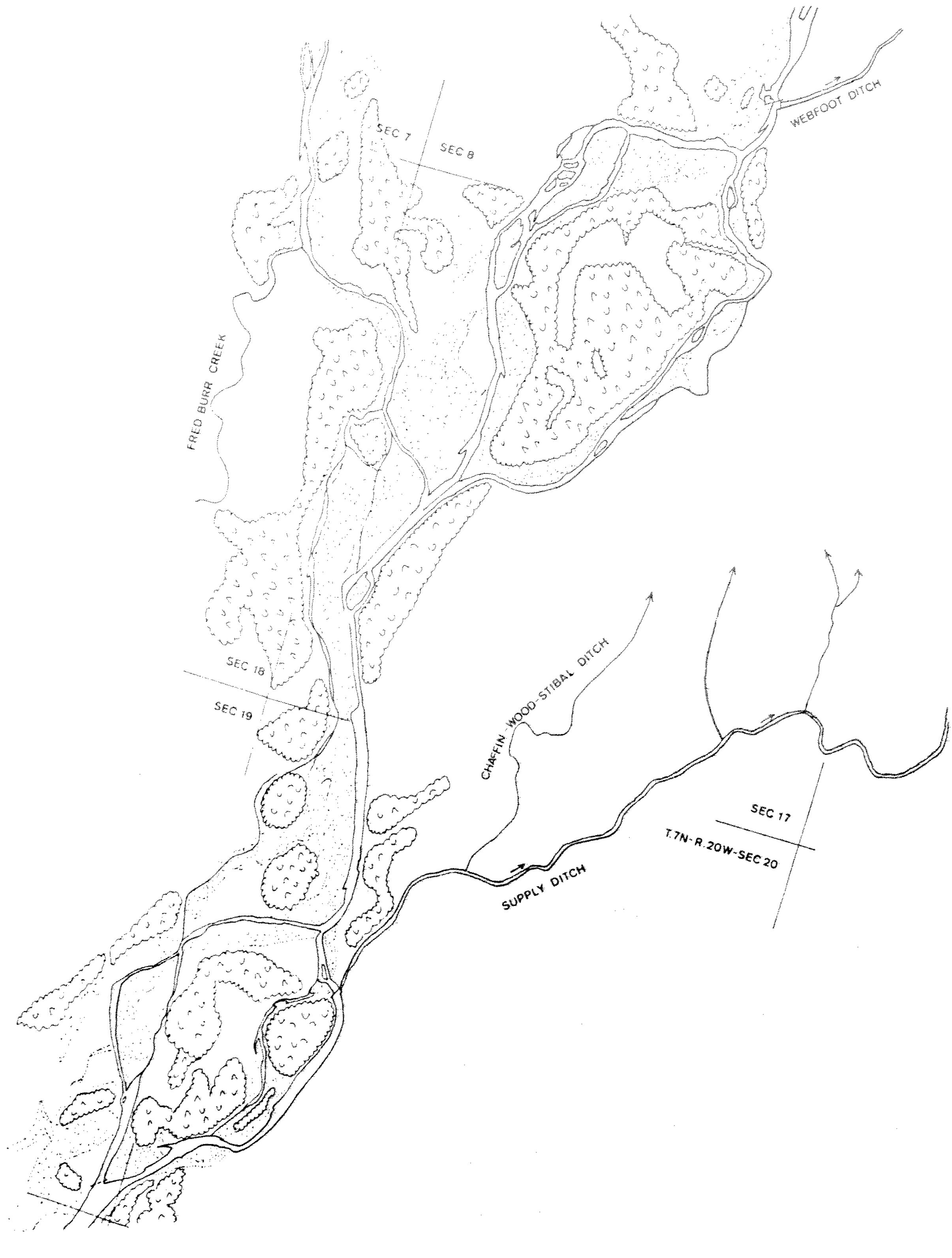
Appendix Figure C5. Map of the Logan, Ward, Hedge, and Rennaker ditches.

Appendix Figure C6. Map of the Gilmore, Vance, and Republican ditches.

Appendix Figure C7. Map of C and C ditch.

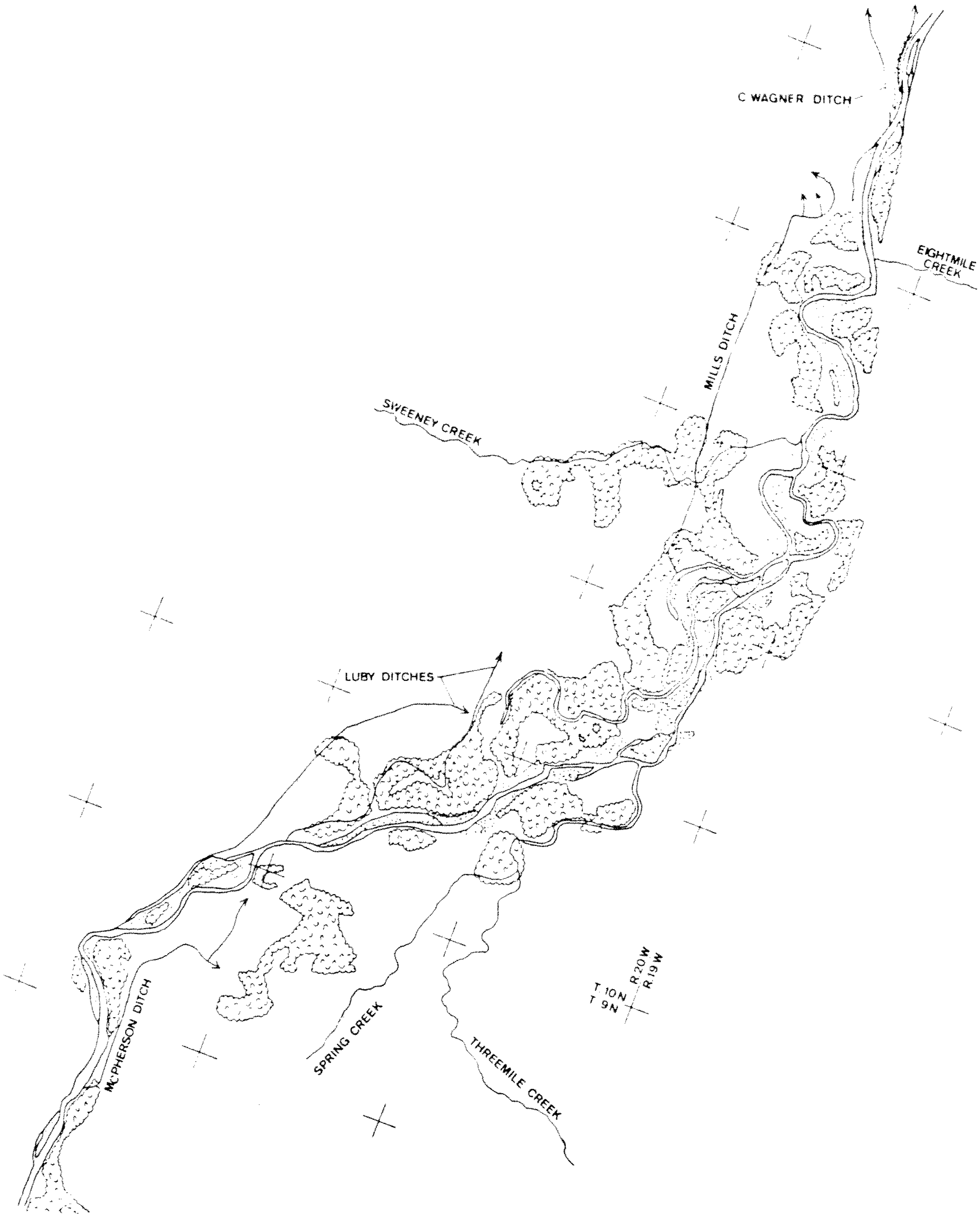


Appendix Figure C8. Map of Corvallis and Woodside ditches.

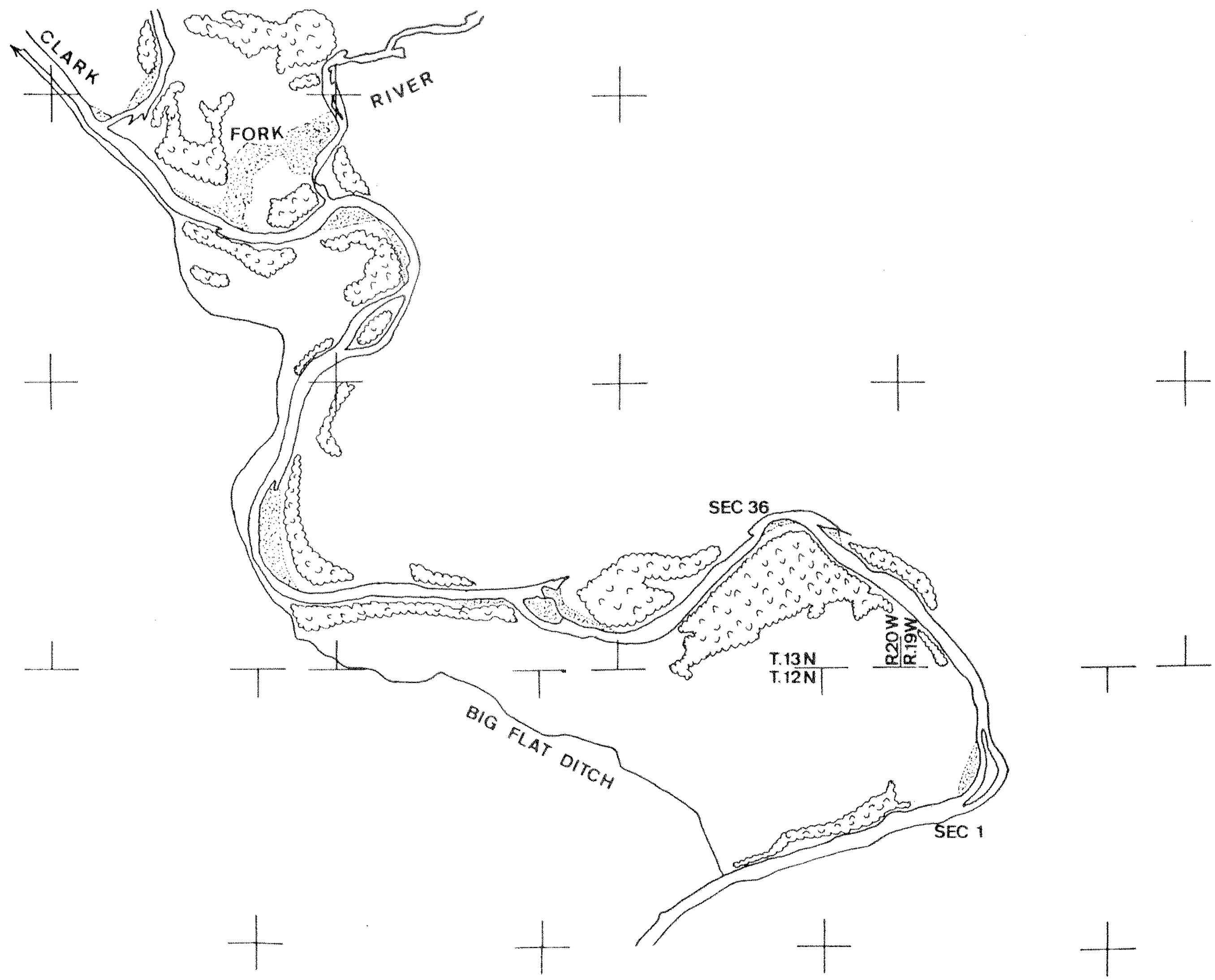


Appendix Figure C9. Map of Supply and Webfoot ditches.

Appendix Figure C10. Map of Spooner and River ditches.



Appendix Figure C11. Map of McPherson, Luby, Mills, and Wagner ditches.



Appendix Figure C12. Map of Big Flat ditch.

APPENDIX D

Listing of Irrigation Withdrawals

Appendix Table D1. Listing of irrigation withdrawals on the West Fork and main stem Bitterroot River (From V. Woolsey 1985).

Name of withdrawal	Location	Comments	Ditch Manager
1. Wilson ditch	NWNE Sec 4,4S,22W		
2. Sopher ditch	NWSE Sec 4,3S,22W		
3. Sopher ditch	SWSW Sec 34,2S,22W		
4. Settreys ditch	SESE Sec 22,2S,22W		
5. Dorgan ditch	SENW Sec 17,1N,21W	not used	Tom Dunbar
6. Orr ditch	SESE Sec 23,2N,21W		Perry Hannon
7. GF Shook, Wilson ditch	SESE Sec 23,2N,21W		
8. Linderman, Hart ditch	SESE Sec 23,2N,21W		
9. Dee Shook, Wilson ditch	NENE Sec 24,2N,21W	presently not used	Dee Shook
10. Bill Rowley pump	NWNW Sec 34,2N,21W	3/4 hp pump	
11. Hannon Cooper ditch	NENE Sec 1,2N,21W	not in use	
12. McKinney ditch (also called Spurlock)	NESE Sec 36,3N,21W	not used	
13. Conner ditch	NWNE Sec 36,3N,21W	used part time	Steve Conner
14. Printz ditch	NENE Sec 26,3N,21W	25 hp pump	D.L. Graves
15. Waltus pump	SWSE Sec 14,3N,21W	25 hp pump	G. Otten
16. Jim Duus pump	NESWSE Sec 11,3N,21W	7-1/2 hp pump	
17. Jim Duus pump	W1/2NE Sec 2,3N,21W		
18. Abbey pump	NWNWSE Sec 2,3N,21W	5 hp pump	
19. Overturf ditch	NENW Sec 14,3N,21W		Ken Roy
20. Liedt Nocholson ditch	NENW Sec 14,3N,21W		Darwin Titeca
21. Logan ditch	NENW Sec 23,4N,21W	not used	Rennaker
22. Abbey pumps	SESE Sec 15.4N,21W	5 hp pump	
23. Ward ditch	NENW Sec 14,4N,21W		Ralph Springer
24. Hedge ditch	SENE Sec 11,4N,21W		Dean Hyatt
25. Rennaker ditch	SESE Sec 11,4N,21W		Rennaker
26. Gilmore ditch	NWNE Sec 2,4N,21W	not in use	
27. Vance ditch	NENE Sec 36,5N,21W	not in use	F.J. Bell
28. Republican ditch	SENE Sec 25,5N,21W		Tom Holling
29. C & C ditch	SWNE Sec 1,5N,21W		Dr. Melvin Johnson
30. Corvallis ditch	NWNW Sec 25,6N,21W		Lee Erickson
31. Woodside ditch	SENE Sec 13,6N,21W		Jack Inman
32. Supply ditch	NWSW Sec 20,7N,20W		John Joost
33. Woods Parkhurst ditch	NWSW Sec 20,7N,20W		Jack Morris
34. Union ditch	SWSW Sec 4,7N,20W		Bill Strange
35. Double Fork-Wood	N1/2SW Sec 4,7N,20W	3 ditches	Don White
36. Etna ditch	NESW Sec 4,7N,20W		Jack Pfau
37. Spooner ditch	NENE Sec 32,8N,20W		Ralph Simonsen
38. Goff pump	SWSW Sec 28,8N,20W	20 hp pump	John Lewis
39. Webfoot ditch	NESE Sec 28,8N,20W		John Weigand

Appendix Table D1 (continued)

Name ofwithdrawal	Location	Comments	Ditch Manager
40. Mendal, Rehorts, Johnson ditch	SENW Sec 21,8N,20W		
41. Weigand pump	SENE Sec 21,8N,20W	10 hp pump	John Weigand
42. River ditch	SWNW Sec 20,8N,20W		Kyle Brinkerhoff
43. Mrs. John Monroe pump	NENENW Sec 36,3N,21W	2 hp pump	Louise Stephens
44. Kurtis & Joyce Fruit pump	NENE Sec 26,3N,21W	10 hp pump	
45. Bud & Shirly Larkin pump	SWNENE Sec 23,3N,21W	7-1/2 hp pump	
46. Raymond & Marguret Fiske pump	SWNENE Sec 23,3N,21W	2 hp pump	
47. Dick Neville pump	E1/2 Sec 6,7N,20W	30 hp pump	
48. Bill Amos	NWNENE Sec 28,8N,20W		
49. Don Wark pump	SWNWSE Sec 28,8N,20W	5 hp pump	
50. Gerlinger ditch	NESESE Sec 29,8N,20W		Lyn Gerlinger
51. Richard & Daisy Myers pump	NWSESE Sec 29,8N,20W	25 hp pump	
52. Siebel	NWNESE Sec 9,8N,20W	15 hp pump	
53. Siebel	NENENE Sec 9,8N,20W	15 hp and 25 hp pumps	
54. Siebel	SESESE Sec 4,8N,20W	25 hp pump	
55. Siebel	NENESE Sec 4,8N,20W	15 hp pump	
56. Siebel	NWNWNW Sec 16,8N,20W	30 hp pump	
57. Siebel	NENESE Sec 4,8N,20W	25 hp pump	
58. Siebel	SWNW Sec 3,8N,20W	25 hp pump	
59. Siebel	SWNW Sec 3,8N,20W	10 hp pump	
60. Mike Doyle	SWSE Sec 21,8N,20W	10 hp pump	
61. McPherson ditch	SWNE Sec 10,9N,20W		
62. Luby ditch	NWNE Sec 3,9N,20W		
63. Luby ditch	SWSW Sec 35,10N,20W		
64. Mills ditch	SESW Sec 24,10N,20W		
65. Wagner ditch	SWNE Sec 12,10N,20W		
66. Wemple-Oglivie ditch	NWNE Sec 12,10N,20W		
67. Slack ditch	NWNE Sec 12,10N,20W		

APPENDIX E

Trout and Whitefish Population Estimates

Appendix Table E1. Estimates of population number and biomass for rainbow trout and brown trout in the Darby section of the Bitterroot River from 1982 to 1985 (80 percent confidence intervals in parentheses).

		Estimated Number Per Mile[a]					Biomass (lbs)[b]
		Age Group					
Season	Year	I	II	III	IV+	Total	Per Mile
			Rainbow Trout				
Spring	1984	---	18	94	149	261 (219-303)	207 (176-238)
	1985	---	3	33	83	119 (71-167)	110 (69-151)
Fall	1982	194	178	103	35	510 (370-650)	226 (168-284)
	1983	279	239	190	85	793 (585-1001)	389 (313-465)
	1984	378	183	214	79	854 (599-1109)	340 (248-432)
	1985	742	278	155	81	1256 (831-1681)	378 (284-472)
			Brown Trout				
Spring	1984	---	22	39	31	92 (67-117)	73 (61-85)
	1985	---	---	12	42	54 (37-71)	74 (48-100)
Fall	1983	86	67	38	34	225 (184-266)	159 (133-185)
	1984	167	65	35	29	296 (236-356)	138 (108-168)
	1985	120	87	44	39	290 (233-347)	170 (133-207)

a/ Section Length = 5.816 mi (9.36 km)

b/ 1.0 lb = 0.45 kg

Appendix Table E2. Estimates of population number and biomass for rainbow trout and brown trout in the West Tucker section of the Bitterroot River from 1983 to 1986 (80 percent confidence intervals in parentheses).

		Estimated Number Per Mile[a/]					Biomass (lbs)[b/]
		Age Group					
Season	Year	I	II	III	IV+	Total	Per Mile
		Rainbow Trout					
Spring	1984	---	13	37	71	121 (87-155)	140 (108-172)
	1985	---	8	33	135	176 (98-254)	206 (114-298)
	1986	---	---	---	---	152 (113-191)	219 (154-284)
Fall	1983	7	25	21	25	78 (60-96)	61 (47-75)
	1984	61	72	21	20	174 (120-228)	68 (50-86)
	1985	34	62	40	59	195 (136-254)	131 (97-165)
	1986	52	93	55	47	247 (174-319)	148 (110-186)
		Brown Trout					
Spring	1984	---	21	40	39	100 (81-119)	100 (87-113)
	1985	---	4	25	51	80 (60-100)	102 (78-126)
	1986	---	5	19	37	61 (51-71)	83 (71-95)
Fall	1983	20	32	25	42	119 (101-137)	136 (120-152)
	1984	66	62	48	53	229 (181-277)	207 (151-263)
	1985	59	47	38	48	192 (163-221)	172 (141-203)
	1986	53	51	54	71	229 (176-282)	263 (186-340)

a/ Section Length = 5.562 mi (8.95 km)

b/ 1.0 lb = 0.45 kg

Appendix Table E3. Estimates of population number and biomass for rainbow trout and brown trout in the East Tucker section of the Bitterroot River from 1983 to 1986 (80 percent confidence intervals in parentheses).

Season	Year	Estimated Number Per Mile[a/] Age Group I	II	III	IV+	Total	Biomass (lbs)[b/] Per Mile
			Rainbow Trout				
Spring	1984	---	6	38	84	128 (89-167)	150 (104-196)
	1985	---	8	36	35	79 (54-104)	71 (50-92)
	1986	---	---	---	---	95 (66-124)	107 (77-137)
Fall	1983	---	24	38	42	104 (85-123)	102 (86-118)
	1984	69	82	26	28	205 (140-270)	107 (84-130)
	1985	---	---	---	---	237 (157-317)	234 (155-313)
	1986	37	52	37	31	156 (120-192)	113 (92-134)
			Brown Trout				
Spring	1984	---	16	30	44	90 (74-106)	114 (99-129)
	1985	---	14	24	27	65 (50-80)	82 (67-97)
	1986	---	13	34	35	82 (64-100)	109 (88-130)
Fall	1983	19	20	22	43	104 (93-115)	136 (119-153)
	1984	34	37	27	30	128 (108-148)	111 (93-129)
	1985	37	44	45	43	169 (142-196)	177 (147-207)
	1986	12	15	21	49	97 (81-113)	153 (135-171)

a/ Section length = 5.518 mi (8.88 km)

b/ 1.0 lb = 0.43 kg

Appendix Table E4. Estimates of population number and biomass for rainbow trout and brown trout in the Tucker section (east and west channels combined) of the Bitterroot River from 1983 to 1986 (80 percent confidence intervals in parentheses).

Season	Year	Number Per Mile[a]	Biomass Per Mile (lbs)[b]
		Rainbow Trout	
Spring	1984	249 (197-301)	290 (233-346)
	1985	255 (173-337)	277 (183-372)
	1986	247 (200-294)	326 (270-382)
Fall	1983	182 (156-208)	164 (142-185)
	1984	379 (295-463)	174 (145-203)
	1985	432 (333-531)	364 (279-449)
	1986	402 (321-483)	262 (219-305)
		Brown Trout	
Spring	1984	190 (165-215)	214 (194-235)
	1985	145 (120-170)	185 (156-213)
	1986	143 (122-164)	192 (165-219)
Fall	1983	223 (202-244)	272 (248-296)
	1984	357 (304-410)	319 (260-378)
	1985	361 (321-401)	349 (303-392)
	1986	326 (270-382)	419 (334-504)

a/ Section Length = 5.540 mi (8.91 km)

b/ 1.0 lb = 0.45 kg

Appendix Table E5. Estimates of population number and biomass for rainbow trout and brown trout in the Poker Joe and Conner sections of the Bitterroot River (80 percent confidence intervals in parentheses).

	Rainbow Trout			Brown Trout		
Year	Age Group	Number Per Mile	Biomass (lbs)[a] Per Mile	Age Group	Number Per Mile	Biomass (lbs)[a] Per Mile
			Poker Joe[b]			
Fall 1985	I	90	---			
	II	124	---		NO ESTIMATE	
	III	45	---			
	IV+	64	---			
		323 (228-418)	230 (177-283)			
Spring 1986	I	---	---	I	---	---
	II	70	---	II	---	---
	III	64	---	III	---	---
	IV+	74	---	IV+	---	---
		208 (161-255)	165 (132-198)		12 (9-15)	16 (12-20)
			Conner[c]			
Fall 1986	I	602	---	I	---	---
	II	376	---	II	---	---
	III	61	---	III	---	---
	IV+	64	---	IV+	---	---
		1103 (718-1488)	224 (177-271)		44 (32-56)	38 (28-48)

a/ 1.0 lb = 0.45 kg

b/ Poker Joe Section Length = 5.226 mi (8.41 km)

c/ Conner Section Length = 2.85 mi (4.59 km)

Appendix Table E6. Estimates of population number and biomass for mountain whitefish in the Darby and Tucker sections of the Bitterroot River during spring 1984 (80 percent confidence intervals in parentheses).

	Estimated Number Per Mile					
	Age Group					Biomass (lbs)[a]
Section	III[b]	IV	V	VI+	Total	Per Mile
Darby	145	2,148	7,978	2,081	12,352 (6,991-17,713)	5,829 (3,435-8,222)
Tucker (East Channel)	382	1,640	1,771	434	4,227 (2,792-5,662)	2,116 (3,455-2,777)
Tucker (West Channel)	504	599	976	543	2,622 (2,008-3,236)	1,432 (1,090-1,774)
Tucker (Combined)	886	2,239	2,747	977	6,849 (5,288-8,410)	3,548 (2,804-4,292)

a/ 1.0 lb = 2.205 kg.

b/ Partial estimate for this age class.

APPENDIX F

Growth Rates

Appendix Table F1. Mean total length (TL) at time of capture and back-calculated mean total length at age for rainbow trout in study sections of the Bitterroot River during the fall of 1983. Standard deviations in parentheses.

Section	Age Group	N	Mean TL at Capture (mm)	Calculated Length (mm) at Age					
				I	II	III	IV	V	VI
Darby	0+	8	72						
	I+	92	172	74					
	II+	89	257	74	159				
	III+	81	325	78	163	259			
	IV+	42	374	77	161	260	329		
	V+	10	406	77	159	255	325	378	
Mean back-calculated length (mm)				76(±13)	161(±31)	259(±32)	328(±27)	378(±29)	
Mean increment of back-calculated length (mm)				76	85	98	69	50	
Tucker (E. Channel)	0+	9	83						
	I+	10	100	75					
	II+	33	241	80	168				
	III+	54	316	79	167	241			
	IV+	30	395	89	164	252	330		
	V+	31	429	85	152	243	309	373	
	VI+	6	435	80	135	210	290	343	393
Mean back-calculated length (mm)				82(±14)	162(±32)	242(±35)	317(±43)	368(±34)	393(±41)
Mean increment of back-calculated length (mm)				82	80	80	75	51	25
Tucker (W. Channel)	0+	3	89						
	I+	12	157	82					
	II+	45	223	76	147				
	III+	38	325	83	169	243			
	IV+	33	390	81	150	245	328		
	V+	18	427	90	145	225	305	373	
	VI+	2	434	69	143	188	276	357	410
Mean back-calculated length (mm)				81(±15)	154(±33)	239(±34)	318(±35)	371(±24)	410(±44)
Mean increment of back-calculated length (mm)				81	73	85	79	53	39
Pooled Total	0+	20	80						
	I+	114	164	75					
	II+	167	245	76	158				
	III+	173	322	79	166	250			
	IV+	105	385	82	158	253	329		
	V+	59	424	85	151	240	310	374	
	VI+	8	435	77	137	205	287	347	397
Mean back-calculated length (mm)				78(±14)	159(±32)	248(±35)	320(±36)	370(±30)	397(±40)
Mean increment of back-calculated length (mm)				78	81	89	72	50	27

Appendix Table F2. Mean total length (TL) at time of capture and back-calculated mean total length at age for brown trout in study sections of the Bitterroot River during the fall of 1983. Standard deviations in parentheses.

Section	Age Group	N	Mean TL at Capture (mm)	Calculated Length (mm) at Age I	II	III	IV	V	VI
Darby	0+	21	89						
	I+	73	187	88					
	II+	71	275	88	185				
	III+	44	358	95	202	300			
	IV+	38	412	102	213	313	372		
	V+	9	465	100	204	324	387	430	
	VI+	1	500	96	141	257	389	431	477
Mean back-calculated length (mm)				92(±17)	197(±39)	307(±41)	375(±33)	430(±24)	477
Mean increment of back-calculated length (mm)				92	105	110	68	55	47
Tucker	0+	30	110						
(E. Channel)	I+	42	206	96					
	II+	39	282	94	176				
	III+	37	359	101	185	278			
	IV+	27	421	112	194	288	368		
	V+	16	468	104	192	304	369	431	
	VI+	5	531	119	213	313	373	440	488
Mean back-calculated length (mm)				101(±18)	186(±35)	288(±33)	369(±34)	433(±34)	488(±22)
Mean increment of back-calculated length (mm)				101	85	102	81	64	55
Tucker	0+	20	111						
(W. Channel)	I+	36	193	83					
	II+	56	261	87	167				
	III+	56	348	97	182	267			
	IV+	28	425	100	174	276	359		
	V+	23	477	97	193	289	374	431	
	VI+	6	542	116	221	307	392	444	500
Mean back-calculated length (mm)				93(±18)	179(±39)	276(±39)	368(±40)	433(±46)	500(±94)
Mean increment of back-calculated length (mm)				93	86	97	92	65	67
Pooled Total	0+	71	104						
	I+	151	194	89					
	II+	166	273	89	177				
	III+	137	354	97	189	281			
	IV+	93	420	104	196	295	367		
	V+	48	472	100	195	301	375	431	
	VI+	12	534	116	211	305	384	441	
Mean back-calculated length (mm)				95(±18)	187(±39)	289(±40)	371(±36)	433(±38)	493(±65)
Mean increment of back-calculated length (mm)				95	92	102	82	62	60

Appendix Table F3. Mean total length (TL) at time of capture and back-calculated mean total length at age for rainbow trout in study sections of the Bitterroot River during the Fall, 1984.

Section	Age Group	N	Mean TL at Capture (mm)	Calculated Length (mm) at Age I	II	III	IV	V	VI
Darby	0+	7	75						
	I+	121	162	79					
	II+	66	242	85	164				
	III+	68	312	78	156	255			
	IV+	43	369	82	161	258	327		
	V+	12	402	76	159	255	325	370	
	VI+	1	392	75	142	243	290	331	372
Mean back-calculated length (mm)				80	160	256	326	367	372
Mean increment of back-calculated length (mm)				80	80	96	70	41	5
Tucker (E. Channel)	0+	4	91						
	I+	43	200	82					
	II+	59	236	88	172				
	III+	39	336	91	193	278			
	IV+	30	391	91	188	271	339		
	V+	21	429	92	178	258	332	388	
	VI+	1	475	105	212	272	356	420	458
Mean back-calculated length (mm)				88	182	271	337	389	458
Mean increment of back-calculated length (mm)				88	94	89	66	52	69
Tucker (W. Channel)	0+	10	85						
	I+	55	177	77					
	II+	62	220	79	154				
	III+	25	320	83	191	274			
	IV+	30	380	87	185	274	337		
	V+	7	425	91	208	279	344	393	
	VI+	1	437	81	133	277	322	390	410
Mean back-calculated length (mm)				81	171	275	338	393	410
Mean increment of back-calculated length (mm)				81	90	104	63	55	17
Pooled Total	0+	21	83						
	I+	219	173	79					
	II+	187	233	84	163				
	III+	132	321	82	174	265			
	IV+	103	379	86	176	266	333		
	V+	40	420	87	177	261	332	383	
	VI+	3	435	82	162	264	323	380	413
Mean back-calculated length (mm)				82	170	265	333	383	413
Mean increment of back-calculated length (mm)				82	88	95	68	50	30

Appendix Table F4. Mean total length (TL) at time of capture and back-calculated mean total length at age for brown trout in study sections of the Bitterroot River during the Fall, 1984.

Section	Age Group	N	Mean TL at Capture (mm)	Calculated Length (mm) at Age I	II	III	IV	V	VI	VII
Darby	0+	19	89							
	I+	98	171	90						
	II+	74	249	86	177					
	III+	46	340	96	196	290				
	IV+	19	403	97	209	292	359			
	V+	17	453	106	204	299	368	417		
	VI+	3	453	85	162	265	328	394	424	
Mean back-calculated length (mm)				92	189	292	361	413	424	
Mean increment of back-calculated length (mm)				92	97	103	69	52	11	
Tucker (E. Channel)	0+	38	109							
	I+	55	206	102						
	II+	55	261	99	193					
	III+	46	345	105	196	285				
	IV+	23	419	121	210	305	370			
	V+	12	460	114	188	288	362	415		
	VI+	4	498	117	210	300	368	425	465	
	VII+	1	529	121	258	326	389	425	467	506
Mean back-calculated length (mm)				105	197	292	368	418	465	506
Mean increment of back-calculated length (mm)				105	92	95	76	50	47	41
Tucker (W. Channel)	0+	15	106							
	I+	66	203	94						
	II+	66	265	94	184					
	III+	55	356	101	213	302				
	IV+	30	421	107	213	306	375			
	V+	12	481	118	232	328	394	440		
	VI+	2	516	111	215	298	347	421	477	
Mean back-calculated length (mm)				99	203	306	379	437	477	
Mean increment of back-calculated length (mm)				99	104	103	73	58	40	
Pooled Total	0+	72	103							
	I+	219	189	94						
	II+	195	258	91	184					
	III+	147	348	101	202	293				
	IV+	72	415	109	211	302	369			
	V+	41	463	112	207	304	374	423		
	VI+	9	487	105	195	288	350	414	454	
	VII+	1	529	121	258	326	389	425	467	506
Mean back-calculated length (mm)				98	196	297	370	421	455	506
Mean increment of back-calculated length (mm)				98	98	101	73	51	34	51

Appendix Table F5. Mean total length (TL) at time of capture, and back-calculated mean total length at age for rainbow trout in the Poker Joe section during fall, 1985.

Group	N	Capture (mm)	Calculated Length at Age I	II	III	IV	V
0	3	75	0	0	0	0	0
1	54	227	78	0	0	0	0
2	68	274	75	177	0	0	0
3	34	346	77	182	275	0	0
4	28	378	76	159	257	326	0
5	24	408	78	143	235	304	366
Mean back-calculated length (mm)			77	170	258	316	365
Mean increment of back-calculated length (mm)			77	93	88	58	49