Water Leases and Yellowstone Cutthroat Trout Fry Outmigration from Four Tributaries of the Upper Yellowstone River, Project Year 2000

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1.0 Summary of Findings

Garcia and Associates (GANDA) was contracted by Montana Fish, Wildlife, and Parks (FWP) to conduct streamflow and biological monitoring related to Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) fry outmigrations from four tributaries of the Yellowstone River in Park County, Montana. Yellowstone cutthroat trout fry outmigration has been monitored on Mill, Cedar, and Mol Heron creeks since 1996 to evaluate the effect of existing water leases on fry recruitment to the Yellowstone River, Montana. Yearly variations in water availability and demand have affected how well the leases have functioned to protect developing and outmigrating fry. Both 1996 and 1997 were record spring runoff years, resulting in plentiful water supplies and little contention over in-stream flows. However, the summers of 1998 and 1999 were warmer and drier than the two previous summers, inducing periods of low flows in both Mill and Cedar creek, and a total dewatering of Mill Creek in mid-September 1998. Draft climatic data suggests that 2000 was much drier than average for all four study streams, especially when evaluated in terms of water year, which takes into account the available moisture from the previous winter, rather than calendar year.

GANDA examined how the existing water leases influenced in-stream flows and Yellowstone cutthroat trout fry outmigration from Mill, Cedar, Mol Heron and Big creeks from July 16 to September 19, 2000. Water levels remained above the minimum amount leased in Big and Mol Heron creeks throughout the summer, but declined below lease levels in Cedar Creek for 24 hour periods at least six times in July and early August. Discharge on Cedar Creek continued to fluctuate near lease level from mid-August through mid-September. Mill Creek stayed above lease level until early August, after which the water commissioner was unable to maintain lease level flows except during the flushing flow. Mill Creek went completely dry in mid-August for at least 100 hours, and was only intermittently connected with the mainstem of the Yellowstone for the remainder of the monitoring period.

Total numbers of Yellowstone cutthroat trout fry captured were down from 1999 surveys conducted in Mill, Cedar, and Mol Heron creeks, but Big Creek showed significant gains. A total of 11,202 Yellowstone cutthroat trout fry were trapped in Big Creek, an increase of approximately 325% from the first year of trapping. Mill Creek experienced a 51% decrease in the number of fry trapped compared to 1999, and a 94% decrease compared to 1998. As compared to 1999 counts, the number of fry trapped decreased 62% in Mol Heron Creek and 22% in Cedar Creek.

2.0 Introduction

In-stream flow water leases between FWP and participating water right holders were in effect in 2000 on Mill, Big, Mol Heron, and Cedar creeks (Table 1). This was the second year that Big Creek has had a water lease in effect. Yellowstone cutthroat trout fry outmigration has been measured for the past four years on Mill, Cedar, and Mol Heron creeks as part of the water leasing effectiveness study completed in 1998, and the first year of this monitoring effort in 1999 (Hennessey 1998, Roulson 1998, Roulson 1999). Byorth (1990) monitored Yellowstone cutthroat trout fry outmigration from Big Creek in 1988 and 1989, but little study of the fishery has taken place since. The four water leases involved in this project were established to provide in-stream flows for Yellowstone cutthroat trout reproduction and to generally benefit the Yellowstone River fishery (Spence 1995). This project sought to examine how well the leases functioned in 2000, a drought year, and to evaluate the effects of potentially lower flows during critical developmental periods on Yellowstone cutthroat trout fry recruitment. The specific objectives of this project were:

1. Monitor fry outmigration from Mill, Big, Cedar, and Mol Heron creeks, and compare results to available data from the previous years;
2. Monitor streamflows during the project and notify FWP if flows drop below water lease levels;
3. Measure streamflow at staff gauges on Mill and Cedar creeks and verify them against existing United States Geological Survey (USGS) rating tables.
4. Measure streamflow at the staff gauge on Mol Heron Creek and verify results against the rating table developed by GANDA in 1999.
5. Assist in the timing for the Mill Creek flushing flow and to monitor fry outmigration to assess its effectiveness.

Table 1. Summary of water lease information for the four water lease project streams (Spence 1995, EQC 1998, K. Williams, FWP, pers. comm. 1999).

Location	Lessor	Priority of right	Total quantity[a]	Period of use	Date lease originated
Mill Creek	Mill Creek Water & Sewer District	95 rights with various priorities	up to 65 cfs	48 hours in August	August 1992
	individual	1880 and 1903	6.13 cfs	May 1 to October 4	October 1992
	individual	1891	2.64 cfs	May 1 to October 19	August 1995
Big Creek	3 individuals	1883	11.0 cfs	May 1 to November 1	April 1999
Cedar Creek	USFS	1890,1893, 1898, 1904, and 1972	1.3 cfs	May 1 to October 15	December 1993
Mol Heron Creek	Church Universal and Triumphant	1880	5 cfs	May 1 to October 15	May 1998[b]

[a] Actual flows leased may differ from the quantity protected at a downstream measuring device. The Mill Creek lease protects up to 4.4 cfs as measured at the East River Road staff gauge. The Big Creek lease protects 11 cfs as measured at the gauge above Highway 89. The Cedar Creek lease protects a minimum of 1.3 cfs as measured at the staff gauge below the Highway 89 culvert.

[b] An initial verbal agreement was reached 1996, but the water lease was not finalized until 1998.

3.0 Project Area

GANDA conducted this project in Park County, Montana on four tributaries of the upper Yellowstone River (Figure 1). Cedar and Mol Heron creeks are considered high quality spawning areas for Yellowstone cutthroat trout as defined by Clancy (1988). Lower Mill Creek and Big Creek were excluded from this distinction because of decades of dewatering during critical times in the Yellowstone cutthroat trout reproductive cycle. A detailed description of Mill, Cedar, and Mol Heron creeks, along with results from electrophoretic testing of fry from 1996 and 1997, is included in the study completed by Hennessey (1998).

Mill Creek, located near Emigrant, drains the largest contributing watershed of the Yellowstone River in Park County (Figure 1). Mill Creek is a fourth order stream based on the occurrence of perennial streams on USGS 1:24,000 scale topographic maps with an approximate length of 21 miles (34 km), and a mean annual discharge of 160 cfs (4.5 m^3/s) (Parrett 1985). Much of the upper reaches of Mill Creek is within the Gallatin National Forest, and its headwaters are all within the Absaroka Beartooth Wilderness. The Mill Creek Water and Sewer District aqueduct, downstream of the National Forest Boundary, is the largest single diversion on the creek and serves over 95 water right holders. There are many additional irrigation diversions in the lower 10 miles (6.2 km) of Mill Creek. A water commissioner is appointed each year to admeasure water rights and flow controls on Mill Creek, including the water leases (EQC 1998). Although the total amount of water involved in the two water leases that are in effect from May to October is 8.77 cfs (0.25 m^3/s), the lease is protected as a flow of 4.4 cfs (0.12 m^3/s) measured at the East River Road Bridge (Table 3); (FWP 1999). The difference in flow is due to water lost to natural seepage into the streambed between the upper headgate where the flow is controlled and the East River Road bridge, where the flow is measured (Nelson 1980).

Big Creek flows out of the Gallatin Mountains from the west, and joins the Yellowstone River approximately 6 mi (9.7 km) south of the town of Emigrant (Figure 1). Big Creek is a second order stream based on the occurrence of perennial streams on USGS 1:24,000 scale topographic maps with an approximate length of 18 mi. (29 km) and a mean annual discharge of 61 cfs (USGS 1986). There are several major diversions within the lower 6 mi (9.7 km) of Big Creek after it leaves National Forest land. Historically, Big Creek has supported significant Yellowstone cutthroat trout spawning runs, and it has been on the state list of designated water lease study streams since March, 1990 (EQC 1998).

Cedar Creek, near Corwin Springs, is a smaller tributary of the Yellowstone with most of its length under U.S. Forest Service jurisdiction and within the Absaroka Beartooth Wilderness (Figure 1). Cedar Creek is a fourth order stream based on the occurrence of perennial streams on USGS 1:24,000 scale topographic maps with an approximate length of 7.5 miles (12 km), and a mean annual discharge of 9.1 cfs (0.26 m^3/s) (Parrett 1985). There are several irrigation diversions within the lower 0.4 miles (0.7 km) of Cedar Creek where it flows through privately held lands. A downstream water lessor assists in the administration of the Cedar Creek water lease.

Mol Heron Creek flows out of the Gallatin Range and enters the Yellowstone River near the town of Corwin Springs. Mol Heron Creek is a fifth order stream based on the occurrence of perennial streams on USGS 1:24,000 scale topographic maps with an approximate length of 11 mi. (18 km), and a mean annual discharge of 25.4 cfs (0.69 m^3/s) (Parrett 1985). There are two irrigation diversions within 0.6 mi (1 km) of the mouth of Mol Heron Creek, and both are controlled by the lessor.

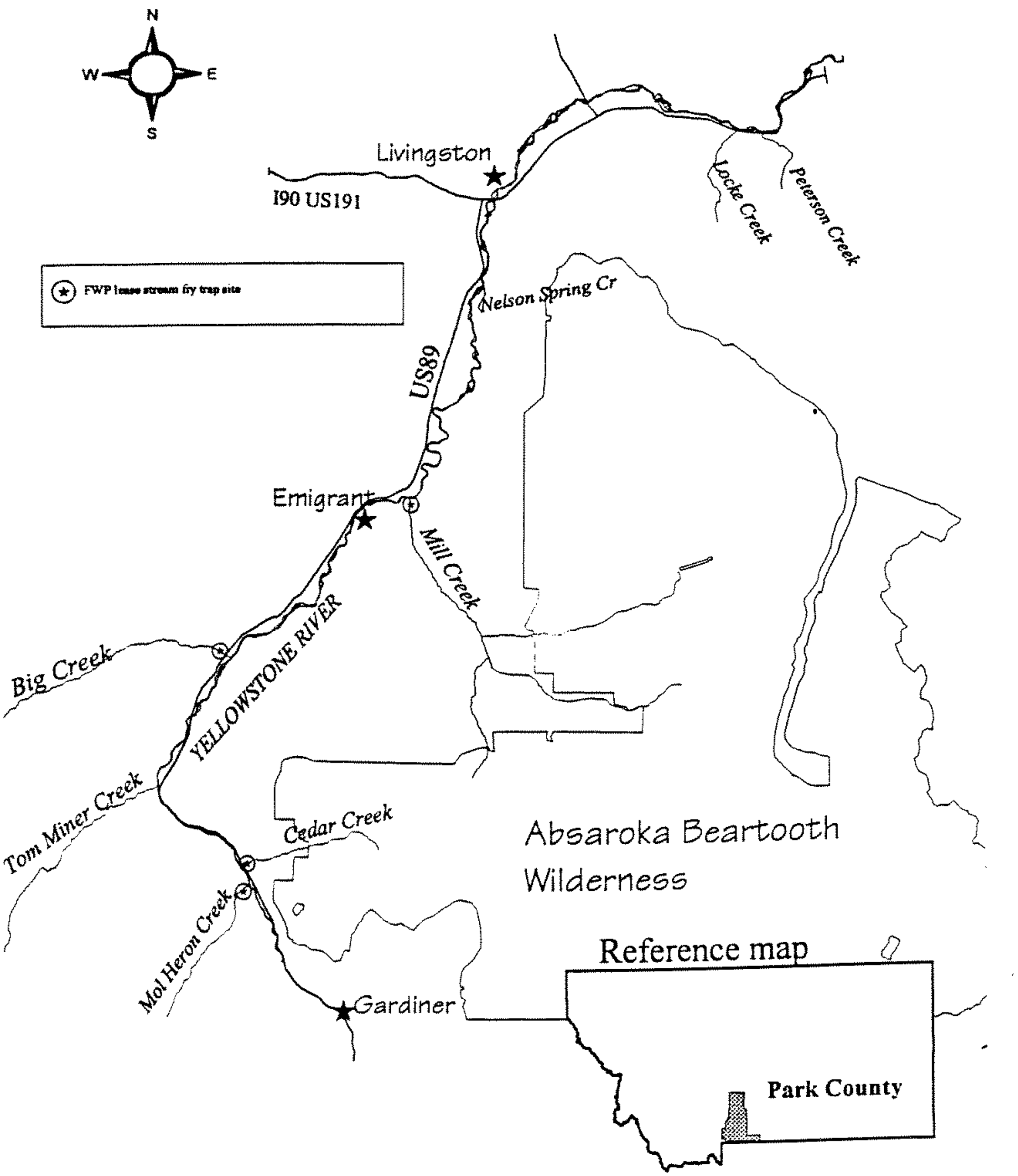

Figure 1. Map of the project area showing the four FWP leasing streams, associated trap sites, and additional high quality spawning tributaries as defined by Clancy (1988).

4.0 Methods

4.1 Stream Discharge and Temperature

Discharge was monitored daily in each study stream. Staff gauge readings were recorded and converted to discharge using USGS rating tables for Mill, Big, and Cedar creeks. The discharge rating table for Mol Heron Creek was based on bi-weekly measurements that GANDA collected in 1999. Creek discharges were measured early in the season with a Gurley AA meter and checked against the existing rating tables to calibrate each gauge for the 2000 field season. Mean, minimum, and maximum seasonal (July to September) discharges were estimated for 2000, and compared to the previous three years for Mill, Cedar, and Mol Heron creeks. The gauge on Big Creek was installed during July of 1999; therefore, a complete comparison to this year's flows is not possible, but all available data is presented. Appendix A includes copies of each creek's rating table used in 2000.

Onset Optic StowAway® thermographs were installed at each staff gauge location on June 12, 2000 and programmed to record at 30 minute intervals. Thermographs measured temperatures ranging from -40 °F to 167 °F (-40°C to 75°C) with an accuracy of +/- 0.36 °F (+/- 0.2 °C) and +/- 0.33 minutes/day. Temperature graphs for each project stream are included in Appendix B.

4.2 Spawning Activity

Spawning was monitored by walking sections of each creek once a week, beginning in late June, until activity was detected. After spawning fish were observed, monitoring was continued for up to 1 week. At each monitoring visit the number of fish observed, their approximate location, whether they were actively spawning, and time and weather information was recorded. Each monitoring visit lasted a minimum of 30 minutes, and observers walked upstream counting fish as they went. As this was a qualitative survey, only a 52 to 110 yard (50 to 100 meter) subsection of each creek was walked at any given visit. Mill and Big creeks were the sites farthest downstream, and they were monitored first and used to gauge approximate spawning times for other project streams.

4.3 Yellowstone Cutthroat Trout Fry Recruitment

4.3.1 Trapping Protocol

Fry recruitment, defined as the number of fry outmigrating from a tributary and entering the mainstem of the Yellowstone River, was estimated by setting fry traps within each study stream, in the first suitable trap site upstream of the creek mouth. Yellowstone cutthroat trout fry begin downstream outmigration after emergence from the gravel, and move into the mainstem within a short time (Thurow, Corsi, and Moore 1988). The number of fry trapped was used as an index of total fry recruitment (Byorth 1990, Shepard 1992, Hennessey 1998).

A consistent pattern in Yellowstone cutthroat trout fry outmigration from Locke, Mill, Cedar, and Mol Heron creeks was documented in 1996 and 1997, and confirmed by work on the same tributaries in 1998 (Hennessey 1998, Roulson 1998). A sampling protocol was developed based on the number of fry caught in each tributary as the outmigration period progressed, with the goal of concentrating sampling effort during the days when fry outmigration peaks (Hennessey 1998).

FWP decided to use Hennessey's (1998) protocol during the 1999 and 2000 surveys to monitor Yellowstone cutthroat trout fry numbers. This protocol allows a reduction in the overall field effort without compromising the accuracy of the index of total fry outmigration (Hennessey 1998, Roulson 1998).

Hennessey's (1998) protocol was used on Mill, Cedar, and Mol Heron creeks. The protocol prescribes trapping each creek 2 days, then skipping 2 days until fry are caught. Once fry are caught a 3 day running mean is calculated, but the trapping pattern is maintained. When trap catch exceeds 1.5 times the 3 day running mean or is greater than 50 fry, sampling increases to every day for the next 10 days. If trap catch on the 11^{th} sampling day is greater than 0.25 times the previous 3 day running mean, then sampling continues for the next 5 days and then stops for the season. If trap catch does not meet this criteria, trapping stops with the 11^{th} day. Hennessey's protocol was shown to sample 83-98% of the total outmigration, as measured by trap catch, on

Mill, Cedar, and Mol Heron creeks from 1996-1998 (Hennessey 1998, Roulson 1998). Although data analysis of the 1999 survey results showed that Hennessey's protocol would have sampled 95.7% of the total fry caught, GANDA continued to sample Big Creek every day after fry were first caught to ensure a complete record of fry outmigration and to confirm the protocol's effectiveness.

Traps were placed on each study stream approximately 25 to 30 days after spawning activity was observed (Benson 1960). In Mill Creek, where no spawning was observed, temperature and historical fry trapping data were used to estimate the spawning date (Shepard 1992, Hennessey 1998, Roulson 1998). Beginning on July 15, 2000, fry traps were set overnight for two nights, then pulled for two nights, until protocol criteria for increasing sampling was met. Thereafter, traps were set and checked daily for the prescribed number of days. An effort was made to check traps early in the morning to minimize fry stress (Hennessey 1998). Number and species of fry caught, individual total lengths of a random subsample of 10 fry, water temperatures, and staff gauge readings were recorded.

4.3.2 Trapping Equipment and Locations

Fry outmigration was estimated using fry traps with openings 2.3 ft (80 cm) by 1.5 ft (47 cm), framed with ¼ inch (5 mm) diameter metal rods (McMullin and Graham 1981). A 4.5 ft (1.4 m), 1/16 inch (1.6 mm) mesh, net was sewn around the frame. The tapered net ended in a 4 inch (10 cm) threaded PVC and metal collar connected to the tail of the trap by screwing into a matching PVC pipe. The tails were approximately 3 ft (1m) in length, made of the same netting as the trap, and had a drawstring closure (Hennessey 1998).

Traps were placed by pounding a 3 ft (1m) length of rebar into the streambed on either side of the trap mouth. The frame rested against the rebar and was secured with wire. Current flowing through the trap kept it open and straight. The bottom of the trap frame was covered with rocks to prevent fry from swimming under the trap. Captured fry were retained in the tail of the trap where the PVC collar presented a velocity barrier to escapement.

Traps were placed near the first suitable pool upstream from the mouth, so that the tails sat in the deepest portion of the pool just below a riffle. Care was taken not to place the trap over an active redd. Whenever possible, traps were placed in the same location as in previous surveys to maintain comparable trap efficiencies (Hennessey 1998, Roulson 1998).

The main channel of Mill Creek was blocked by a rock berm constructed by a landowner in 1998, and all of the flow was diverted to the North channel. A pool at the end of a low velocity run section in the newly widened North channel of Mill Creek was chosen as the1998 trap site, and was used again in 1999 and in 2000. A second trap was set on the opposite side of the North channel in 2000, in an attempt to catch a larger percentage of fry. The two traps used in Mill Creek spanned a total of approximately 20% of the channel width.

Spring flows altered the stream channel in Big Creek and obliterated the pool that had formed the 1999 trap site. This prompted GANDA to move the trap downstream to a small eddy behind a snag on the outside of a bend, near the south bank of the creek, approximately 55 yards (50 m) upstream from the mouth. The Big Creek trap sampled approximately 30% of the channel width.

The single trap in Cedar Creek was placed in the same location as the past four years, and sampled approximately 50% of the width at higher flows; however, during lower flow periods in 2000 the trap sampled the majority (approximately 65 to75%) of the actual flow. In Mol Heron Creek, a single trap was placed in the thalweg near the left bank in approximately the same site as 1999. The thalweg site was chosen to increase trap efficiency, and a plywood box was constructed around the trap tail to reduce stream velocity and stress on the fry. The Mol Heron trap sampled approximately 25% of the creek width.

4.4 Mill Creek Flushing Flow

An annual 48 hour flushing flow is included in the Mill Creek lease, and is intended to help move recently emerged fry out to the Yellowstone River before flows drop to critically low levels during late summer irrigation. The flushing flow occurred from August 22 to 24 in 2000. Ideally, the flushing flow should coincide with expected end of peak fry emergence based on outmigration patterns in other study area streams. During the flushing flow, all diversions maintained by the Park County Water and Sewer District were closed.

The success of 2000 flushing flow was evaluated with two traps at the previously described Mill Creek trap sites. The staff gauge was read and the traps were checked at 6 hour intervals for the first 12 hours, and every 24 hours throughout the remainder of the flush. Catch records before and after the flush were used to evaluate its timing and effectiveness.

4.5 Climatic Data

Climate data from the two weather stations in the upper Yellowstone River region, Livingston 12S (USGS station number 245080), and Gardiner (USGS station number 243378), were collected for 2000 and compared to the average readings over the life of the climate stations. The Gardiner station has been gathering data for 52 years, while the Livingston 12S station has records dating back 18 years for temperatures and 49 years for precipitation (WRCC 2000). Data examined included average maximum and minimum daily temperature, monthly precipitation, and annual precipitation. This report examines data for trends from January to July for Livingston 12 S station, and from January to October for the Gardiner station (WRCC 2000).

5.0 Results

5.1 Stream Discharge and Temperature

5.1.1 Discharge

Below average snowpack combined with warm spring temperatures resulted in earlier and shorter duration runoff flows in Mill Creek in July, with the 2000 peak on July 14 at 49 cfs (1.39 m^3/s) considerably lower and earlier than seasonal peaks in previous years (Table 2). Flows declined rapidly from this seasonal peak, falling to below the lease quantification level of 4.4 cfs (0.12 m^3/s) by August 9 (Figure 2). The rate of decline in discharge was similar to that seen in 1999, but occurred approximately one week earlier, dewatering much of the main channel width by early August (Figure 3). Mill Creek was completely dry from above the East River Road bridge to the mouth with little interstitial flow from August 16 to 17. GANDA telephoned the water lease enforcement contact for Mill Creek daily to request additional flows from August 8 until August 10, and from August 13 to August 20. Despite these communications and the subsequent numerous attempts to restore flows consistent with the lease, after the creek's initial dewatering on August 16, the high permeability of the substrate and extended dry period prevented the creek from reaching its confluence with the Yellowstone for most of the remainder of the trapping season, except during the flushing flow (Figure 2). Mill Creek's highly permeable substrate causes it to be a "losing stream" when flows are low (Nelson 1991). In essence, this means that water percolates into the substrate and into the groundwater zone, leaving the creek's surface dry. FWP estimates that Mill Creek loses approximately 44% of its surface flow between the Allen-Sexton Ditch, located just upstream from the East River Road Bridge, and the mouth (Nelson 1991). There were several occasions when there was water at the East River Road Bridge gauge, but no flow at the mouth. For the purposes of this report, Mill Creek was designated as "dry" or having a flow of 0 cfs when there was no measurable flow at the East River Road Bridge gauge.

After August 18th, flows on Mill Creek remained at or below lease level until the flush on August 22, and returned to sub-lease levels soon after the flush subsided. 2000 discharge readings from the beginning of the field season in June through final observations made in September ranged from 0 cfs to 49.1 cfs (0.0 m^3/s to 1.39 m^3/s); (Appendix B, Table 2).

Flows on Big Creek remained above lease level throughout the entire summer (Figure 4). Early season peak flows declined rapidly until mid-August when flows stabilized just above the lease level of 11.0 cfs (0.31 m^3/s). Based on Byorth's (1990) work, it is unlikely that any redds were dewatered during the 2000 season under these flow conditions.

Flows on Cedar Creek dropped below the lease quantification level of 1.33 cfs (0.04 m^3/s) at least five times between July 15 and August 10 (Figure 5). Flows were usually restored to lease quantification level within 12 to 24 hours of notifying the water lease liaison which may have minimized adverse effects to redds and newly emerged fry. No redds were marked in 2000, but based on previous years' data, short-term dewatering of redds can be assumed (Byorth 1990, Hennessey 1998). Discharge was erratic during the 2000 field season, but flows met the water lease quantification level the majority of the time, and never dropped as low as they have in the past two years. In 2000, flows during August and September ranged from 0.97 cfs (0.027 m^3/s) to 2.08 cfs (0.06 m^3/s), compared with the 1999 range of 0.6 cfs (0.02 m^3/s) to 2.3 cfs (0.06 m^3/s) (Figure 6) (Table 2).

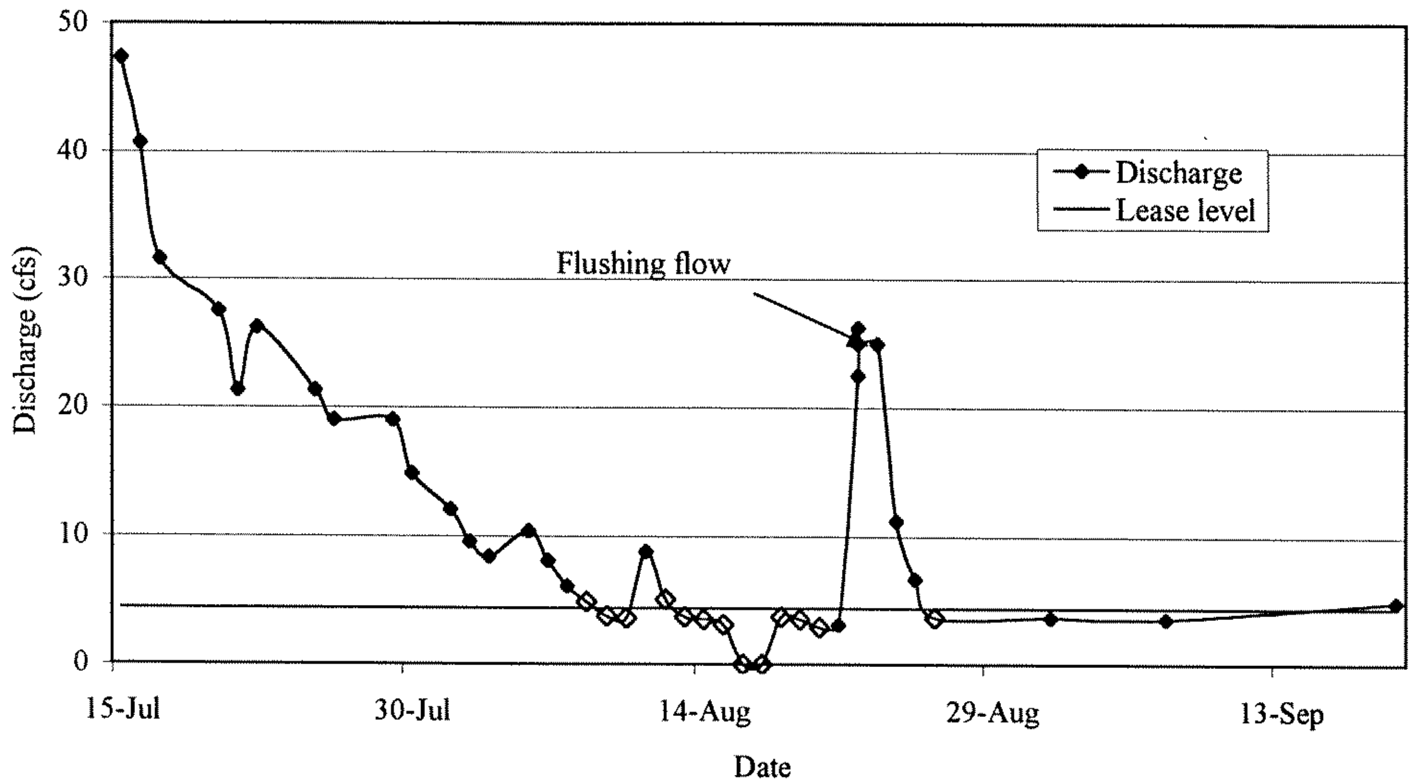

Figure 2. Comparison of daily flows on Mill Creek, Montana, during the 2000 Yellowstone cutthroat trout fry trapping season with the water lease level (4.4 cfs). Open squares indicate dates when the water lease enforcement contact was notified to improve flows. The peak of the flushing flow is also indicated.

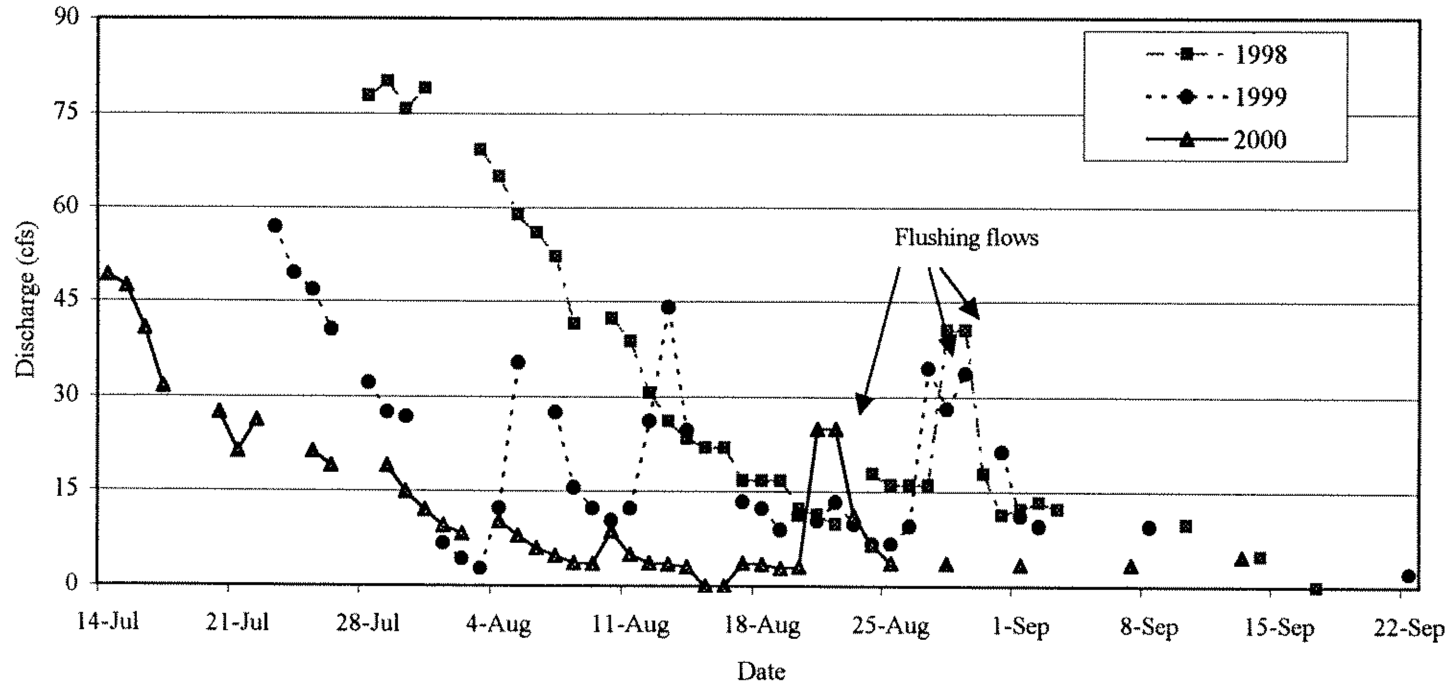

Figure 3. Comparison of daily discharge readings for Mill Creek, Montana, during the 1998, 1999, and 2000 Yellowstone cutthroat trout fry trapping seasons. The annual flushing flows are indicated by arrows.

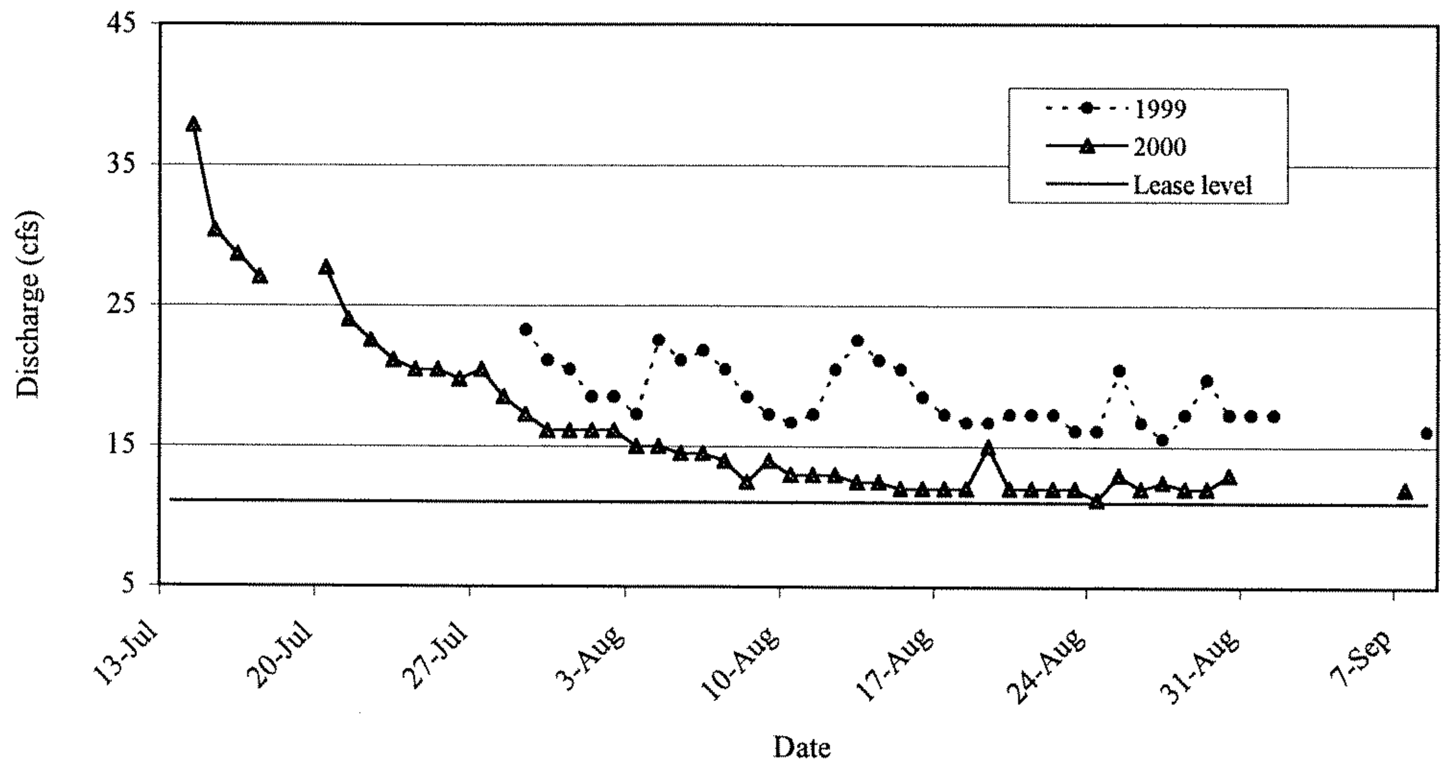

Figure 4. Comparison of daily discharge readings for Big Creek, Montana, during the 1999 and 2000 Yellowstone cutthroat trout fry trapping seasons and the lease level (11 cfs).

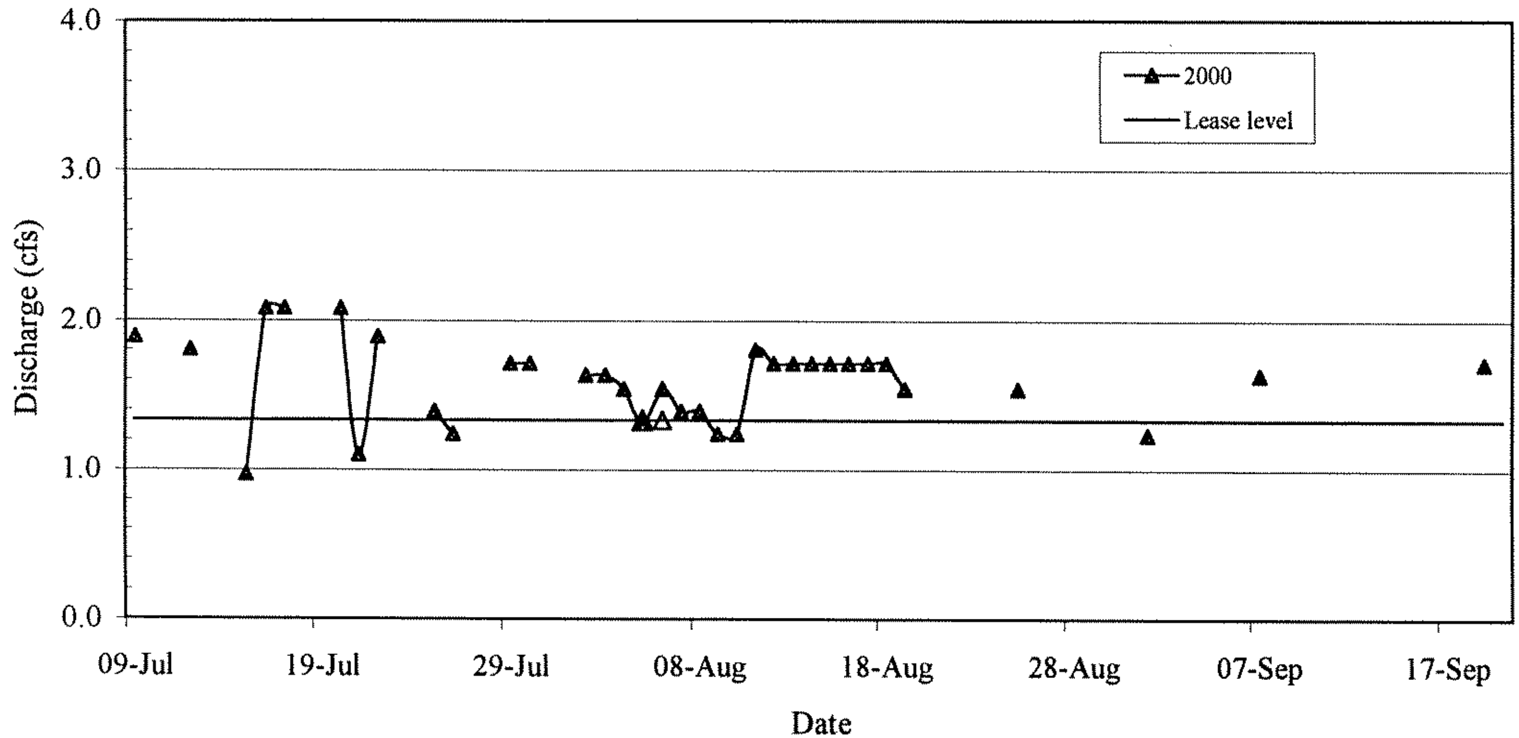

Figure 5. Comparison of daily flows on Cedar Creek, Montana, during the 2000 Yellowstone cutthroat trout fry trapping season with the water lease level (1.33 cfs). Open triangles indicate dates when the water lease enforcement contact was notified to improve flows.

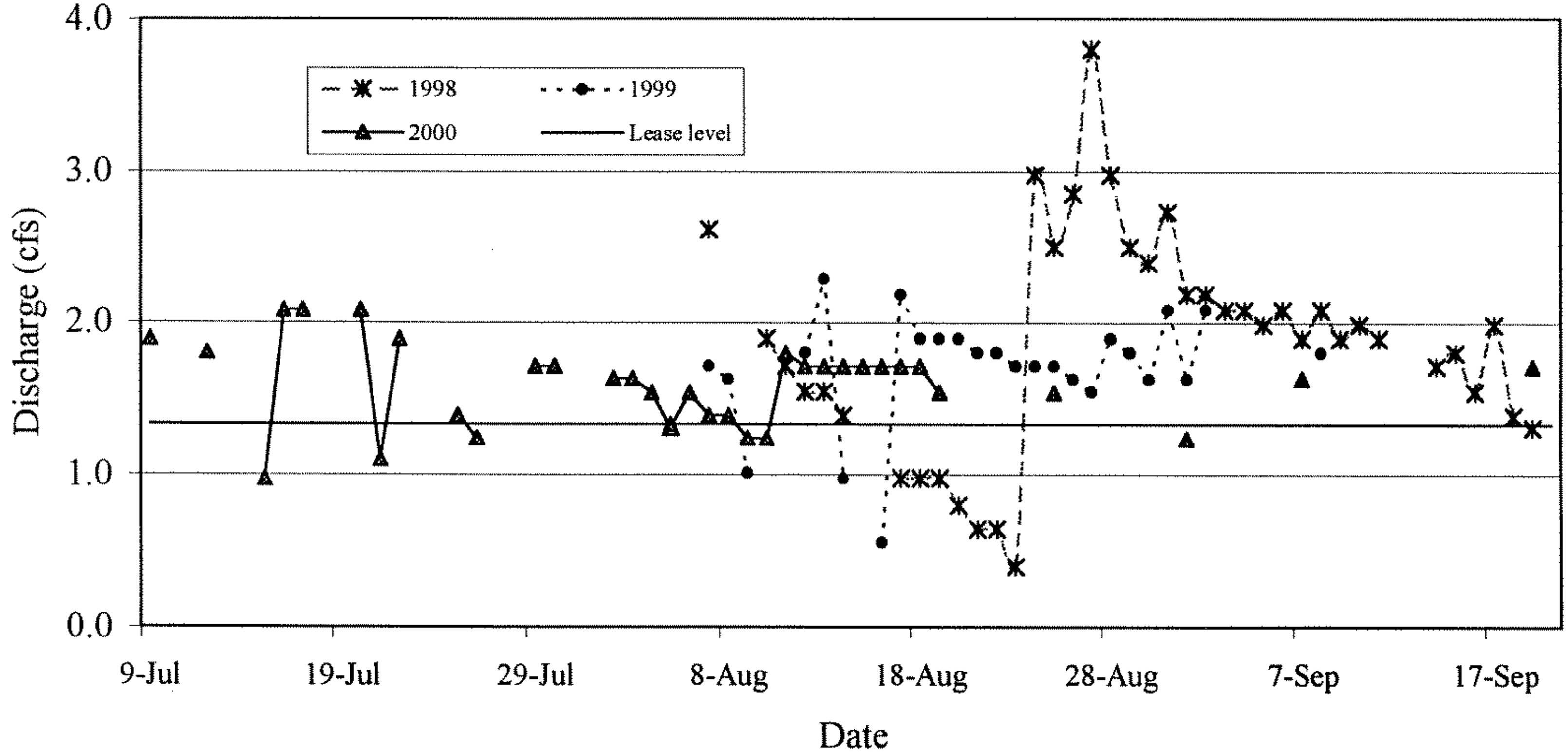

Figure 6. Comparison of daily flows on Cedar Creek, Montana, during the 1998, 1999, and 2000 Yellowstone cutthroat trout fry trapping seasons with the water lease level (1.33 cfs).

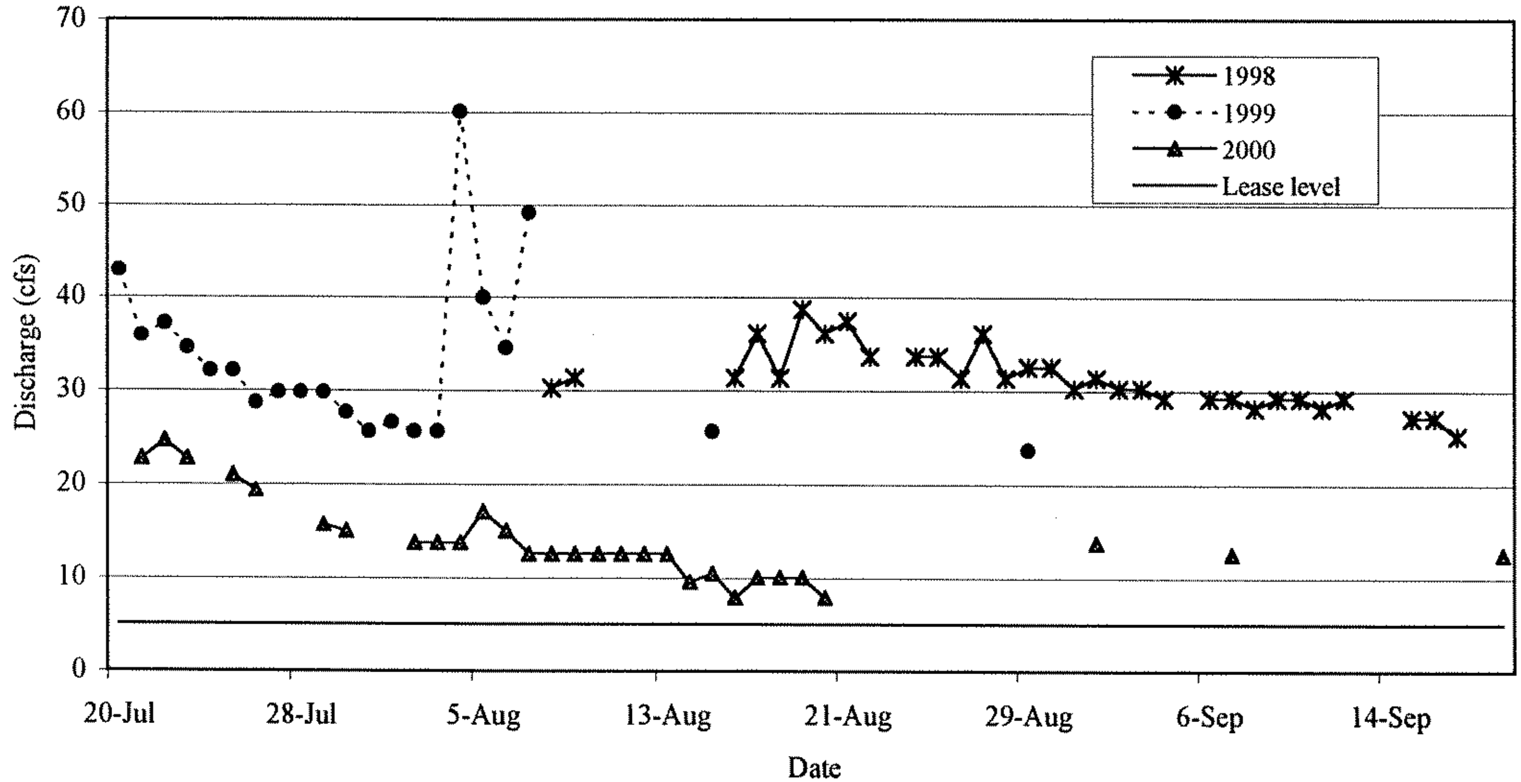

Figure 7. Comparison of daily flows on Mol Heron Creek, Montana, during the 1998, 1999, and 2000 Yellowstone cutthroat trout fry trapping season with the water lease level (5.0 cfs).

Table 2. Summary of discharge readings for the four project streams from mid-July to September 1997-2000. These statistics do not include flow measurements gathered during spawning surveys, for pre-trapping season flows, please see Appendix B.

Project stream	Year	Seasonal mean cfs	Seasonal mean m^3/s	Maximum cfs	Maximum m^3/s	Date	Minimum cfs	Minimum m^3/s	Date
Big	1999	18.7	0.53	23.3	0.66	July 29[a]	15.6	0.44	August 27
	2000	**18.9**	**0.54**	**61.7**	**1.75**	**July 1**	**11.24**	**0.32**	**August 24**
Mill	1997	38.5	1.09	95.3	2.70	September 12	17.7	0.50	August 31
	1998	27.9	0.79	78.7	2.23	July 31	0	0	September 17 & 18
	1999	21.64	0.61	56.95	1.61	July 23	2.75	0.08	August 3
	2000	**12.94**	**0.37**	**40.7**	**1.15**	**July 15**	**0**	**0**	**August 16 & 17[b]**
Cedar	1997	2.6	0.075	3.8	0.108	August 8	1.56	0.06	September 15
	1998	1.9	0.053	2.8	0.08	August 24	0.4	0.01	August 23
	1999	1.1	0.03	1.54	0.04	August 13	0.4	0.01	August 16
	2000	**1.58**	**0.04**	**2.1**	**0.06**	**July 16**	**0.97**	**0.03**	**July 15**
Mol Heron	1997	52.0	1.474	54.7	1.55	August 16 &19	49.2	1.39	September 15
	1998	31.3	0.886	38.7	1.10	August 19	25.2	0.71	September 17
	1999	32.3	0.92	60.1	1.70	August 28	21.9	0.62	August 8
	2000	**14.1**	**0.40**	**24.6**	**0.70**	**July 21**	**7.9**	**0.22**	**August 16 & 20**

[a] July 29, 1999 was the day that the staff gauge was installed on Big Creek.
[b] Mill Creek also had no flow at the mouth of the creek on August 10, 14, 15, 16, 17, and 26, 2000.

Discharge in Mol Heron Creek in 2000 was much lower than in 1999 or 1998, and the seasonal mean stream discharge was less than half of that seen in 1999 (Figure 7, Table 2). Discharge varied from 7.9 cfs (0.22 m^3/s) to 24.6 cfs (0.70 m^3/s) in 2000, and 21.9 cfs (0.62 m^3/s) to 60.1 cfs (1.70 m^3/s) in 1999 (Table 2). Flows declined sharply in mid-July, and remained low, but above the 5.0 cfs (0.14 m^3/s) protected by the lease (Figure 9).

5.1.2 Stream Temperatures

Mean daily water temperatures in all creeks climbed as flows declined and air temperatures warmed in mid-June to early July. All creeks warmed much earlier than in 1999, with most reaching temperatures comparable to 1999 seasonal peaks in late June, a full two to three weeks earlier than in 1999 (Appendix B). When creek temperatures did peak in late July, Mill, Big, and Mol Heron were more than 4° F (2.2 °C) warmer than in 1999. All creeks showed a decline in mean daily water temperature on or around August 28, 2000, but stream temperatures increased again in early September, and were at least 4° F (2.2 °C) warmer than levels seen in 1999 (NOAA 1999, NOAA 2000) (Appendix B). Mean daily stream temperature in Mill Creek fluctuated greatly and was often above 63°F (17°C) throughout August. In fact, for most of the last week in August, mean stream temperature exceeded 68° F (20 °C). Although Yellowstone cutthroat trout have been known to exist in temperatures as high as 80.6° F (27° C) within the thermally affected streams of Yellowstone National Park, their optimal temperature range is much lower at 41 to 60° F (5 to 15.5°C) (Carlander 1969, Varley and Gresswell 1988). The Upper Incipient Lethal Temperature (UILT) for most trout species is in the range of 68 to 79 °F (20 to 26 °C) (Allan 1995). The average daily water temperature in Mill Creek fluctuated 13.7° F (7.6° C) in 2000 compared to 12.6° F (6.7°C) in 1999 (Roulson 1999).

Mean daily water temperatures in Big Creek varied little throughout the field season and only exceeded 60.8° F (16 °C) a few times in early July despite higher than average air temperatures. Daily water temperature fluctuation averaged 11.3°F (6.3°C), compared to 8.8° F (4.9 °C) in 1999 (Roulson 1999).

Mean daily water temperatures in Cedar Creek exceeded 57° F (14 °C) briefly in late July, 2000. Daily water temperature fluctuation averaged 7.9°F (4.4 °C) in 1999, compared to 7.7° F (4.3° C) in 1999 (Appendix B)(Roulson 1999).

Mean daily water temperatures in Mol Heron Creek remained below 60.8° F (16 °C) in 2000. Although temperatures were higher than in 1999, the pattern of temperature fluctuation in Mol

Heron Creek was the most consistent with previous years of all the project streams in 2000. Daily water temperature fluctuation averaged 10.6° F (5.9 ° C) compared to 10.3° F (5.7 ° C) in 1999 (Roulson 1999).

5.2 Spawning Activity

GANDA sighted spawning Yellowstone cutthroat trout in all creeks at least seven days earlier than in the 1999 surveys. GANDA monitored Mill Creek from June 16 to July 2, but flows were too high and turbulent for locating spawning fish. Mean discharge during spawning surveys on Mill Creek was 267 cfs (7.56 m^3/s) (Appendix B). Big Creek was monitored from June 16 to July 3 with a total of 168 fish observed with 18 actively spawning. GANDA saw spawning fish seven days earlier than in 1999, and many more fish were observed in Big Creek in 2000 than in 1999. However, the number of fish observed actually excavating or otherwise actively spawning was comparable to that observed in 1999. Mean water temperature during spawning observations on Big Creek was 49.8°F (9.8°C). Mean discharge during spawning surveys on Big Creek was 67.8 cfs (1.92 m^3/s). Spawning activity was concentrated near the Highway 89 bridge, and no spawners were observed above the Bar X diversion. The distribution of spawners was consistent with what was observed in 1999 and with Byorth's (1990) report; however, the timing of spawning was approximately one week earlier than in Byoth's 1988 surveys.

Cedar Creek was monitored on June 19, and from June 23 to July 3. No fish were observed on June 19, and a total of 377 fish were observed during the later surveys with 43 observed actively spawning. GANDA first observed actively spawning fish seven days earlier in 2000 than in 1999. Mean water temperature during spawning observations on Cedar Creek was 46.0° F (7.8 °C), and mean discharge was 11.2 cfs (0.32 m^3/s), less than half the average discharge during the 1999 survey. Field crews observed actively spawning fish above and below the Highway 89 culverts, but the majority of fish were observed below the culvert. The culverts have degraded significantly as the stream has downcut its channel over the past four years, and the installed fish ladder is no longer functional; however, it appears that some fish are still able to negotiate it and move upstream successfully. Approximately 10 to 12 fish were seen holding below the culverts during each spawning survey, and only one fish was actually seen moving through the culverts successfully. No spawners were observed at the upper gauge sites near the OTO Ranch or above the main ditch upstream of the Highway 89 culverts.

Mol Heron Creek was monitored on June 19, 23 and from June 26 to July 3. GANDA first observed actively spawning fish eight days earlier in 2000 than in 1999. No fish were observed on June 19, and a total of 119 fish were observed during the later surveys with 19 observed actively spawning. Fish were seen spawning approximately 100 yards upstream of the trap site and above the newly constructed infiltration gallery at the main ditch site. Mean water temperature during spawning observations on Mol Heron Creek was 51.6° F (10.9 °C), and mean discharge was 34.9 cfs (0.98 m^3/s).

5.3 Yellowstone Cutthroat Trout Fry Recruitment

Fewer fry were trapped per day of trapping in Mill, Cedar, and Mol Heron creeks in 2000 than in 1999 (Table 3). Outmigration began and peaked at least one week earlier in all creeks in 2000. Big Creek continued to follow the modified, bell-shaped curve outmigration pattern similar to that seen in the other project streams (Byorth 1990, Hennessey 1998, Roulson 1998). Incidental trapping mortalities decreased in all creeks from 1999 levels, but Mol Heron Creek still had a greater than 10 percent mortality rate.

5.3.1 Mill Creek

Fry trap catch continued to decline in 2000, with a total trap catch of less than 49% of the number captured in Mill Creek in 1999. Catch per unit of effort (CPUE) averaged 2.4 fry per day in 2000, compared to 5 fry per day in 1999. Peak outmigration occurred in early August, approximately 12 days earlier than in 1999 (Figure 8). Fry outmigration was first detected on July 15, a full month earlier than in 1999 and peaked on August 7, with 19 fry captured. Outmigration was much more erratic than in previous years. Over half of the fry captured were caught over two days in early August, with a large percentage of fry being caught during the flush in late August. Dewatering and insufficient flows precluded trapping from August 16 until August 22, when the flush began. August 25 was the last successful trapping day in 2000 (Figure

8). A total of 61 fry were caught over 24 trapping days (Table 3). Incidental mortality due to trapping was 0% this season, compared to 5.9% in 1999 (Table 3)

5.3.2 Big Creek

This was the second year of monitoring on Big Creek and CPUE showed a dramatic increase from 98 fry per day in 1999 to 254 in 2000. Fry were first captured in Big Creek on July 15, a full two weeks earlier than in 1999, at a mean water temperature of 58.1°F (14.5 °C), and trap catch peaked on August 8 with 1436 fry. August 29 was the last successful trapping day, and the majority of fry (90%) were trapped over the 11 days from August 1 to 12 (Figure 9). A total of 11,202 fry were trapped in Big Creek in 2000 compared to 3,429 in 1999 (Table 3). Incidental mortality declined to 1.0% in 2000 from 2.6% in 1999.

5.3.3 Cedar Creek

Total fry captured in Cedar Creek in 2000 was 12% less than that that captured in 1999 (Table 3). CPUE was 479 fry per day in 2000, and 637 fry per day in 1999. The first fry was captured July 17, at a mean water temperature of 54.2°F (12.3 °C). The 2000 outmigration began approximately twenty-six days earlier than in 1999, and the 2000 trap catch peak was twenty days earlier than the 1999 peak (Figure 10); (Byorth 1990, Hennessey 1998, Roulson 1998). When the two years are plotted on the same graph, the peak regions do not even overlap.In fact, the 2000 trapping period ended only two calendar days after the 1999 peak region began. Outmigration peaked on August 8 with 1,411 fry captured, and trapping was suspended on September 2 when trap catch dropped to 296 fry (Figure 10). A total of 12,940 fry were caught over 27 trapping occasions (Table 3). Incidental mortality decreased from 10.6% in 1999 to 0.6%, returning to a level more consistent with previous years (Table 3).

Table 3. Summary of fry trapping results from July to September 1996-2000, for the four Yellowstone water leasing project streams.

Project Stream	Year	Total fry caught	Total days trapped	CPUE[a] (fry/day trapped)	Total days fry caught	Incidental mortalities	% mortality
Mill Creek	1996	59	26	2.2	19	66	9.9
	1997	2,316	46	50	36	109	4.7
	1998	752	36	21	20	7	0.9
	1999	125	28	5	11	7	5.9
	2000	**61**	**25**	**2.4**	**11**	**0**	**0**
Big Creek	1999	3,429	35	98	28	87	2.6
	2000	**11,202**	**44**	**254**	**41**	**116**	**1.0**
Cedar Creek	1996	13,251	24	552	20	74	0.5
	1997	25,781	41	629	35	89	0.3
	1998	3,791	38	100	27	49	1.3
	1999	14,658	23	637	20	1,413	10.7
	2000	**12,940**	**27**	**479**	**23**	**82**	**0.6**
Mol Heron Creek	1996	1,865	10	187	10	200	23.1
	1997	1,128	35	32	29	87	7.7
	1998	1,251	31	40	20	3	0.2
	1999	4,159	25	166	22	778	26
	2000	**1,586**	**26**	**61**	**24**	**258**	**16**

[a] Catch per unit effort

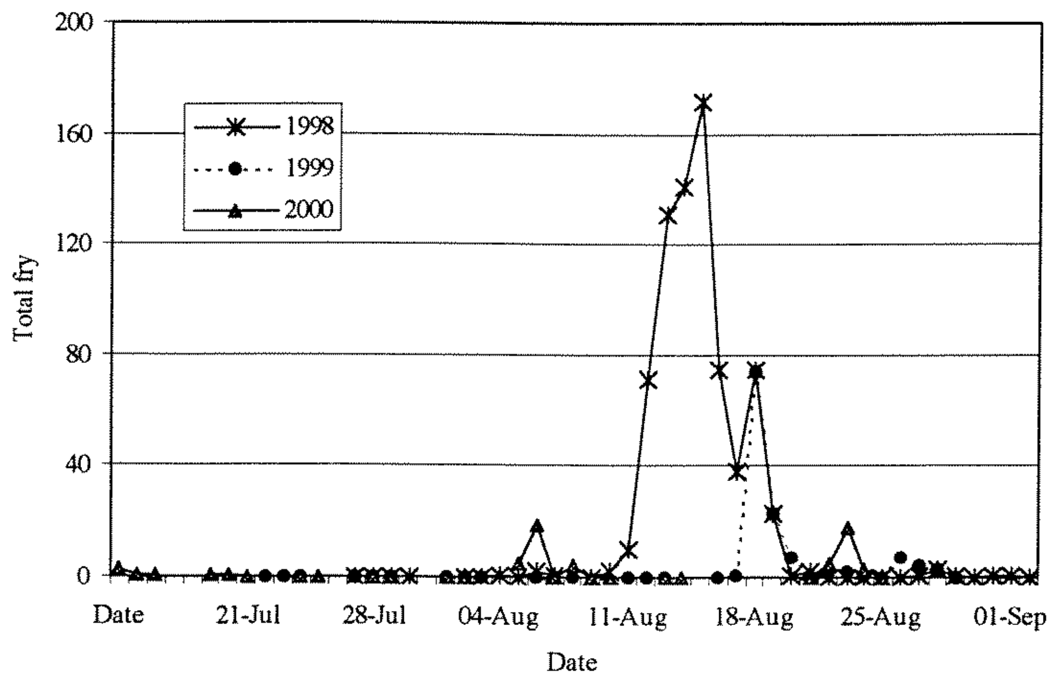

Figure 8. Comparison of total fry captured each day in Mill Creek, Montana, from July to September 1998, 1999 and 2000.

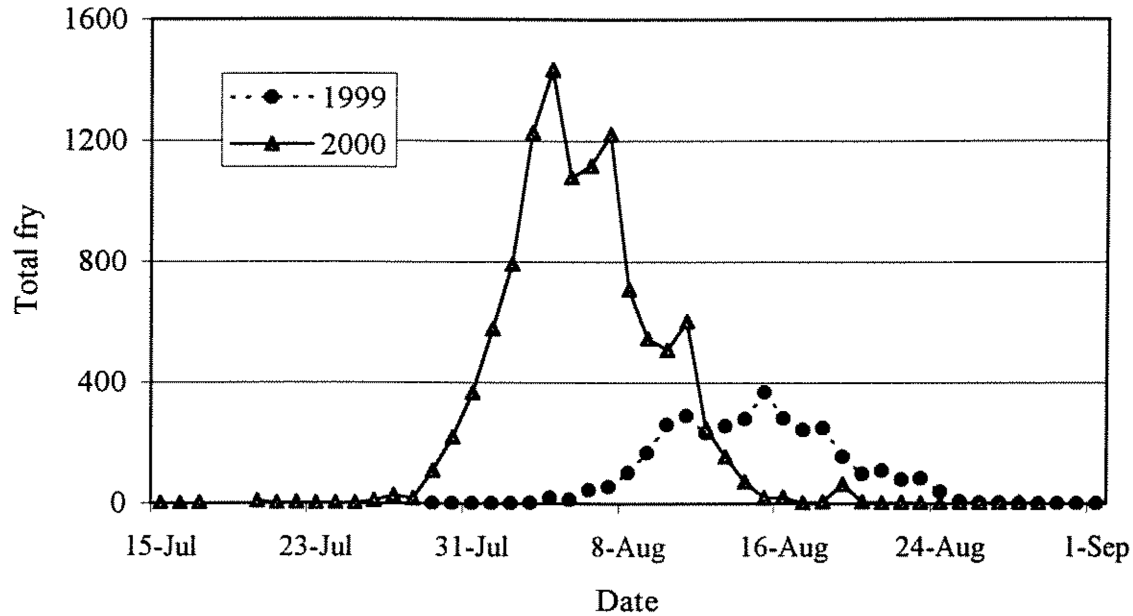

Figure 9. Comparison of total fry captured each day in Big Creek, Montana, from July to September 1999 and 2000.

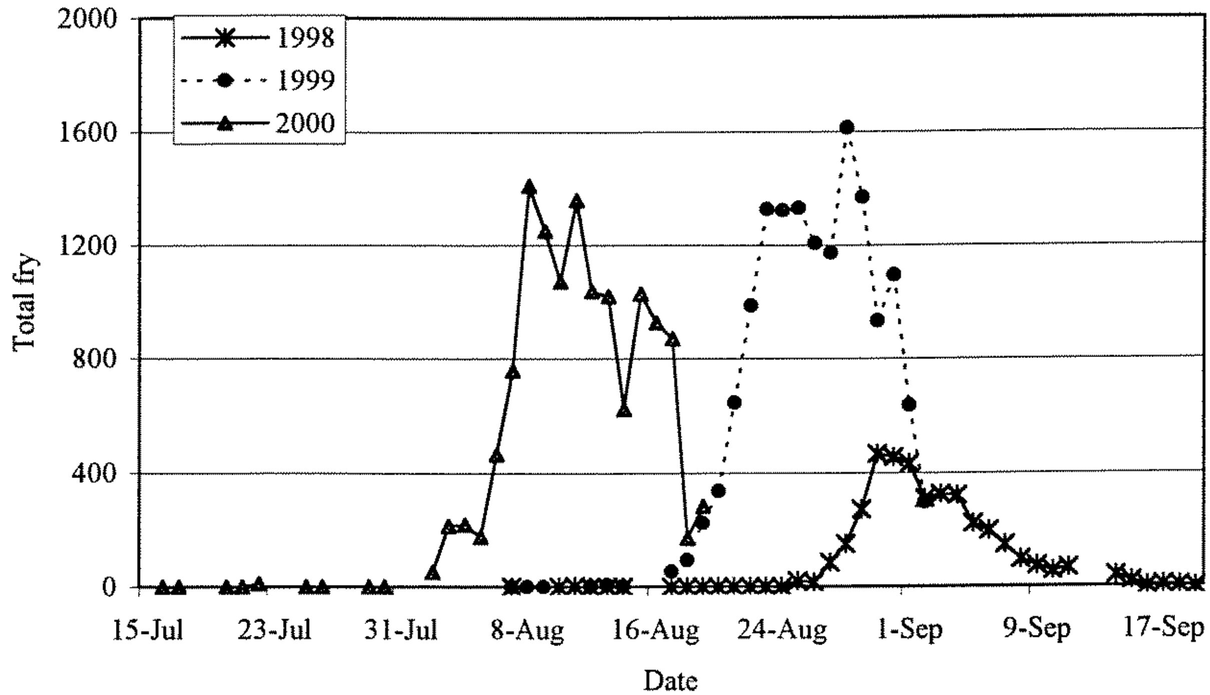

Figure 10. Comparison of total fry captured each day in Cedar Creek, Montana, from July to September 1998, 1999 and 2000.

5.3.4 Mol Heron Creek

Total fry catch returned to levels consistent with earlier surveys in 2000 after a large increase in Mol Heron Creek in 1999 (Table 3). CPUE decreased to 61 fry per day as compared to 166 fry per day in 1999 (Table 3). As in the other three creeks outmigration was detected much earlier in 2000 with the first fry trapped on July 20, at a mean water temperature of 59.4 °F (15.2 °C). Outmigration increased slowly over the next two weeks, and peaked on August 8 with 189 fry captured, and then dropped slowly, plateauing for eight days with trap catches fluctuating near 80 to 90 fry a day, and then dropped sharply on August 19 (Figure 11). A total of 1,586 fry were caught over 26 trapping occasions (Table 3). Incidental mortalities declined from a high of 26.2% in 1999 to 16% in 2000. Although this rate is still much higher than that seen in other creeks, 87% of all mortalities were concentrated on the three days when the levels of fine debris from storm runoff were highest in the trap, suggesting that the mortalities were due to suffocation rather than stress from too high of a velocity because of trap placement. This pattern is consistent with data from 1999 and previous years.

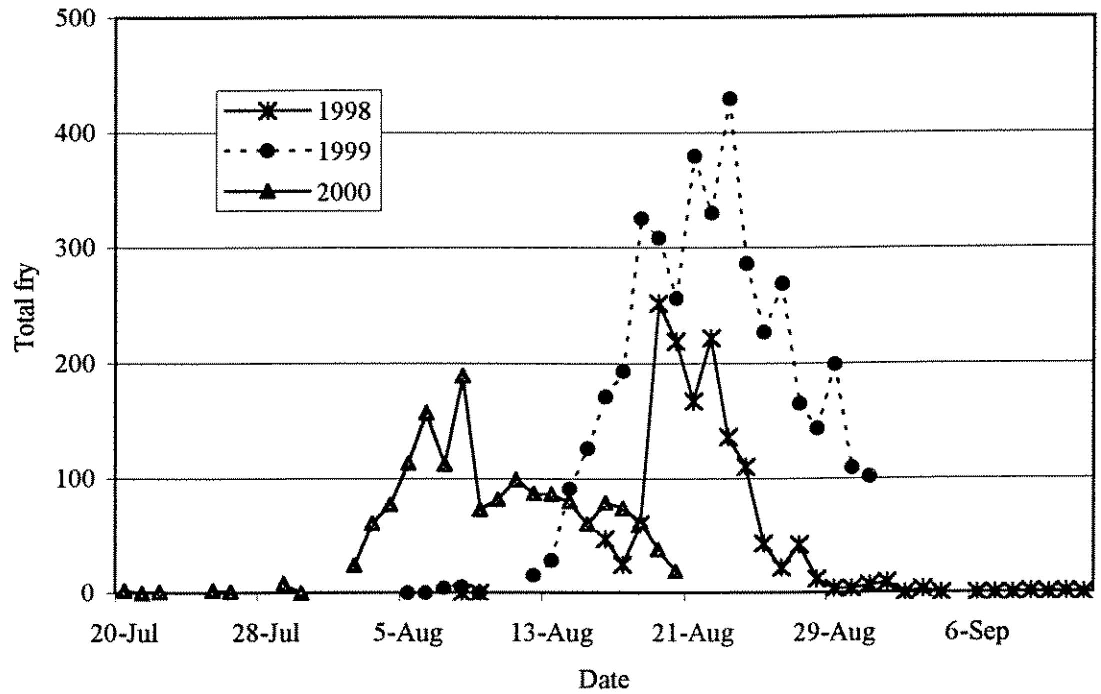

Figure 11. Comparison of total fry captured each day in Mol Heron Creek, Montana, from July to September 1998, 1999 and 2000.

5.3.5 Fry Length and Residence Time

Mean fry length and the range of lengths were more consistent throughout the field season in 2000, a pattern similar to what was seen in 1999 (Roulson 1999). Newly emerged fry (< 25 mm TL) were captured during the last weeks of trapping in each creek, and increases in fry length were much less linear than in previous years (Kelly 1993, Hennessey 1998, Roulson 1998). Trapping began as much as four weeks earlier in 2000 than in any of the previous field seasons, and some of the initial fry trapped in Mill, Big, and Cedar creeks were longer than the standard for newly emerged fry. One possible explanation is that the Yellowstone cutthroat trout fry outmigration may have begun before all of the rainbow trout (*Oncorhynchus mykiss*) fry had emigrated to the mainstem. Cutthroat trout appear to ripen for spawning in response to a combination of increasing water temperature, declining (post-peak) tributary flow levels, and light or day-length (Thurow and King 1994, Brown and Mackay 1995) Unfortunately, it is virtually impossible to distinguish between rainbow trout fry and Yellowstone cutthroat trout fry (10- 44 mm), or their hybrids in the field (Martinez 1984). GANDA biologists propose that some of these early fry probably were rainbow trout based on the life history information from previous work and the fact that rainbow trout generally spawn, and consequently outmigrate, as much as six weeks earlier than Yellowstone cutthroat trout in Yellowstone River tributaries (Behnke 1992, Shepard 1992).

Mill and Big creeks showed an increase in fry length over time, with Big Creek showing two distinct peaks, again suggesting that some of the earlier fry captured may have been rainbow trout (Figures 11-12). Big Creek did show an increase in mean fry length during the last 10 days of sampling, suggesting that majority of these late-moving fry may be holding in the creek to mature before outmigrating. Mean fry length remained below 26 mm in all but Mill and Big creeks, and very few individual fry longer than 30 mm were captured from any of the study streams (Figures 12-13).

5.3.6 Flushing Flows

All Water and Sewer District irrigation diversions on Mill Creek were closed at approximately 0100 hours on August 22 and reopened by 0700 hours on August 24, 1998. Discharge at the

East River Road bridge increased from 3.1 cfs (0.09 m^3/s) to 26.2 cfs (0.74 m^3/s) by 1200 hours on August 22 (Figure 2). Discharge declined rapidly after the flush and had dropped to pre-flush levels by August 26 when flows declined to 3.7 cfs (0.10 m^3/s). A total of 23 fry, over 35% of the entire season's catch, were trapped throughout the 2000 flushing flow. No fry had been captured during the 14 days before the flush, and no more fry were trapped after August 25 (Figure 8).

5.4 Climatic Data

Climatic trends varied considerably between the two climatic data stations. While the Livingston 12S station recorded data consistent with historical means for precipitation, the Gardiner station experienced much lower than average precipitation. From January until August 2000, average daily maximum temperatures were at least 2 to 4° F higher than the historic pattern at Gardiner, with the exception of May 2000 which was consistent with the historical mean (WRCC 2000). Temperatures were slightly higher than historical average for the Livingston 12S station from January through April of 2000, but were well within normal variation as represented by the standard deviation of the data (WRCC 2000)(Figures 14 and 15).

Precipitation varied significantly from the historic pattern at Gardiner with most months receiving only 20 to 40 percent of the average (Figure 15). Total precipitation accumulated at Gardiner by September 1999 was approximately 37% of average for that point in the year (WRCC 2000). This low level of moisture represents more than 3.5 standard deviations from the mean (WRCC 2000).

Precipitation at the Livingston 12S station followed the historic pattern for most of 2000, and was much closer to normal in early summer 2000 than in 1999 (Figure 14) (WRCC 2000). At the end of July, annual precipitation accumulation was 95% of normal for Livingston 12S, compared with 78% in 1999 (WRCC 2000, Roulson 1999).

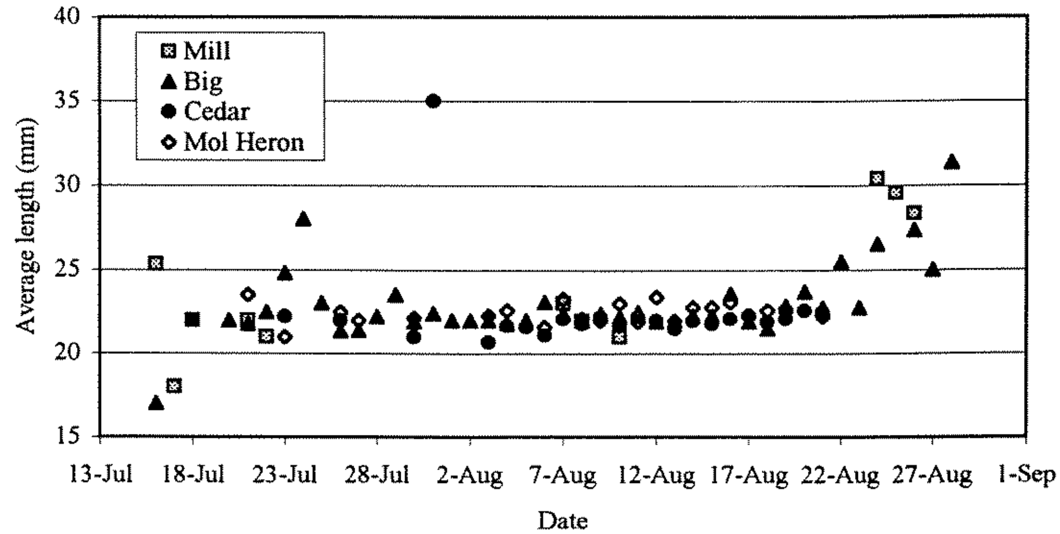

Figure 12. Average total length of a random subsample of Yellowstone cutthroat trout fry by date collected from the four project streams in Park County, Montana, 2000.

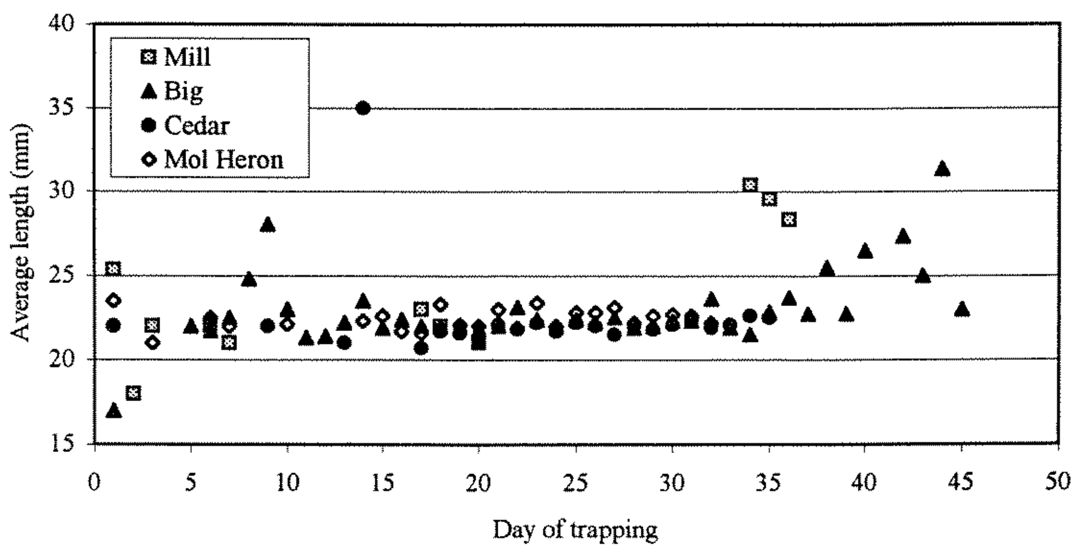

Figure 13. Average total length of a random subsample of Yellowstone cutthroat trout fry by day of sampling period for the four project streams in Park County, Montana, 2000.

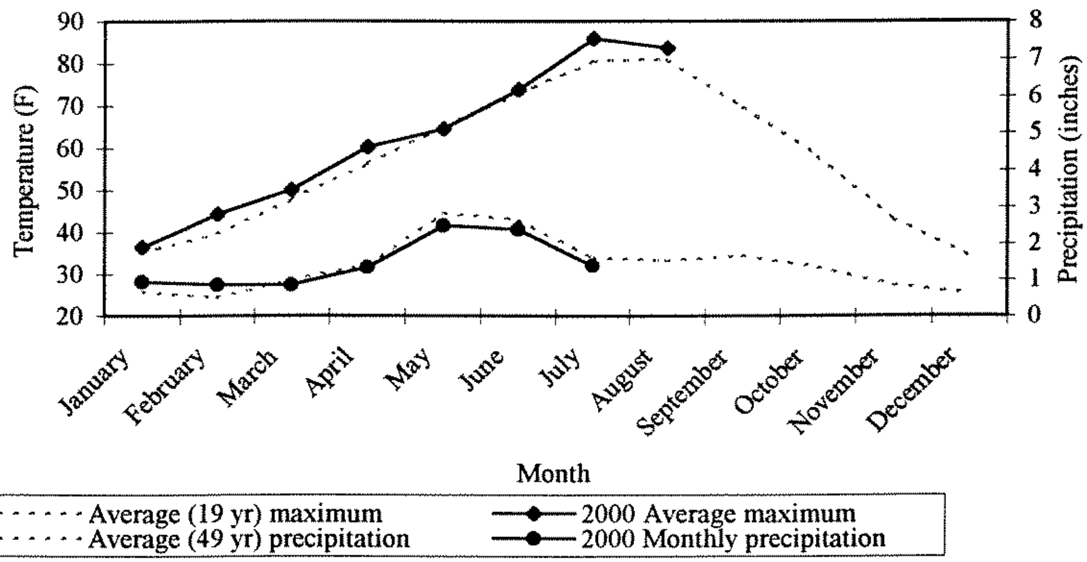

Figure 14. Comparison of the average daily maximum temperature (19 years of record) and monthly precipitation (49 years of record) for the Livingston 12S, Montana climate station with the data collected through July 2000 (WRCC 2000).

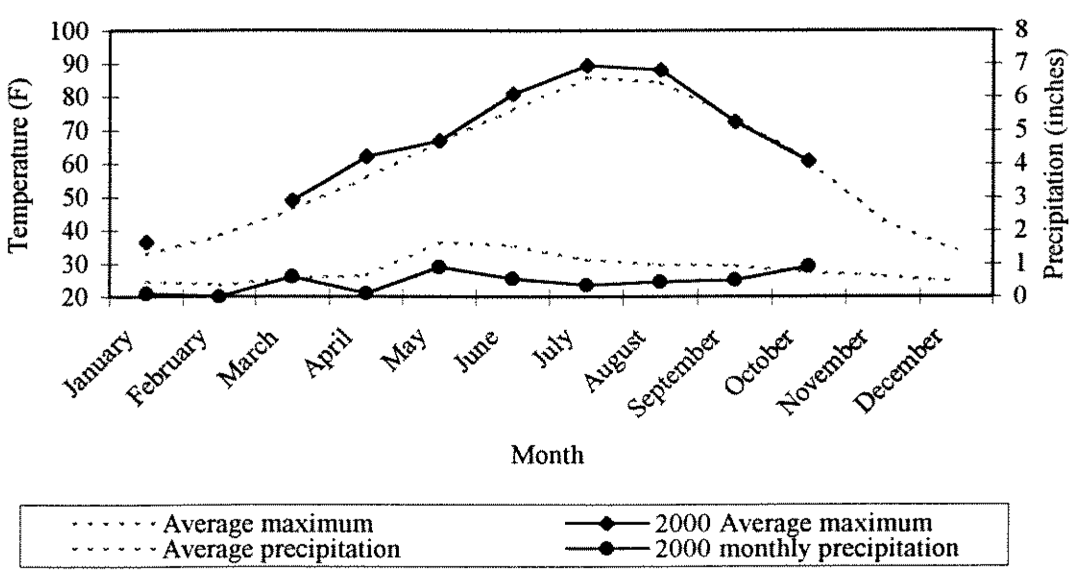

Figure 15. Comparison of the average daily maximum temperature and monthly precipitation for the Gardiner, Montana, climate station with the data collected through November 2000 (WRCC 2000). No temperature data were provided by WRCC for February 2000.

6.0 Discussion of Findings

Although lower than average precipitation in the early summer of 1999 put a strain on available water in the upper Yellowstone River, in 2000, the combination of earlier, warmer temperatures and continued low precipitation substantially impaired flows on all tributaries and reduced the water available for all uses, impacting the water leases. Accumulated precipitation in Park County was 33% of normal at the Gardiner station by August 2000, and average temperatures were significantly higher than the historic averages in April, July, and August (WRCC 2000). However, as in 1999, conditions were not as extreme in the northern portion of the valley. While the Livingston 12S weather station recorded only 78% of the normal precipitation by July in 1999, by the same time in the calendar year 2000 they had accumulated almost 95% of normal precipitation (WRCC 2000). Why then was water in such short supply throughout the Yellowstone valley in 2000 ?

One answer may come from the preceding winter's precipitation data. In the winter of 1998 both the Gardiner and Livingston 12S had average precipitation from October to March, but in the winter of 1999, when watersheds began storing water for the summer of 2000, both stations received significantly less than average precipitation, creating dry soil conditions and a potential water deficit coming into spring. By looking at the data in the context of the water year, which begins in October and ends in September of the following year, instead of the calendar year, it becomes apparent that watersheds probably held much less water at the beginning of the summer 2000.

Table 4. Summary of precipitation in inches by water year (October to September) for the Gardiner and Livingston 12S climate data stations for 1999 and 2000 (WRCC 2000).

Water year	Gardiner			Livingston 12 S		
	October to March	April to September	Total	October to March	April to September	Total
1999	4.63	6.39	11.02	4.76	9.46	14.22
2000	2.22[a]	2.82	5.04	2.58	8.75	11.33
Historical average	4.12	5.91	10.03	4.98	11.7	16.68

[a] No data were available from WRCC for February 2000

With less water stored either in the form of soil moisture or snowpack, the watershed was not capable of keeping up with irrigation needs in the Mill Creek valley. Flows declined rapidly in early July, two weeks earlier than in 1999 (Figure 3). All four project streams saw similar early declines in flows and stabilized at lower levels than in 1999, and both Big and Mol Heron creeks, which maintained higher flows in 1999, dropped to within a few cfs of their lease levels in 2000 (Figures 3 to 7).

Spawning was observed at least one week earlier in all four project streams, and the subsequent outmigrations were documented even earlier than would be expected given the spawning dates. Higher air temperatures and lower flows probably resulted in a faster accumulation of thermal degree days, which would account for the earlier emergence of Yellowstone cutthroat trout fry from the gravels (Benson 1960, Kelly 1993). In any other year, this earlier movement on the part of the Yellowstone cutthroat trout fry would have worked in their favor, since heavy irrigation withdrawals do not usually begin until mid-July. However, poor soil moisture conditions and lower peak flows seem to have contributed to earlier and more intensive withdrawals in Mill and Cedar creeks in particular. As a result, Mill Creek reached lease level flows in early August and Cedar Creek required its first lease intervention in mid-July (Figures 3 and 5).

As in 1999, irrigation withdrawals dewatered much of the spawning gravels in Mill Creek during the first two weeks of August, coinciding with the end of the probable Yellowstone cutthroat trout egg incubation and emergence period for 2000. Recent natural restructuring of the Mill Creek channel has created a high gravel bar near the mouth that is submerged during spring runoff, but is quickly dewatered as flows recede. Even with flows above the lease quantification level of 4.4 cfs (0.11 m^3/s), much of these spawning-quality gravels in the section nearest the creek mouth are exposed throughout late July and August. Since salmonid eggs and newly emerged fry require a moist environment and flowing water to maintain their development, it is highly likely that redds in the dewatered portions of Mill Creek did not produce fry in 1999 or 2000 (Benson 1960, Clancy 1988, Kelly 1993).

Recruitment from Mill Creek has been falling since a high point in 1997, and in the past two years, there have been fewer than 100 fry trapped throughout the entire field seasons (Table 3). The lower channel of Mill Creek near the mouth was completely dry for at least eight consecutive days despite several efforts to maintain lease level flows at the East River Road bridge. GANDA mounted a fish salvage effort on August 16, when insufficient flows had reduced the creek to isolated pools. GANDA caught and successfully transported 1,263 fish, 1,153 of which were fry and fingerling (0-4 inches)Yellowstone cutthroat trout, rainbow trout, and brown trout (*Salmo trutta*). These fish were carried to the mainstem of the Yellowstone River in coolers and released. An additional 213 fish were observed dead either in the shallower pools or on dry creekbed. Given the warm daytime temperatures and the dwindling interstitial flow near the mouth it can be assumed that the majority of the stranded fish would have died during the next six days before the flush on August 22 reconnected Mill Creek with the mainstem.

Fry trapping results of 1998, 1999, and 2000 demonstrate that the enforceable lease level alone is not adequate to prevent large Yellowstone cutthroat trout fry losses in low to average water years (Roulson 1998, Roulson 1999). The water lease was designed to protect Yellowstone cutthroat trout eggs and fry in "8 out of 10 years", by augmenting the flows that should normally exist in the creek above all withdrawals (Spence 1995, K. Williams pers. comm. 2001). It is also important to note that public expenditures on the Mill Creek pipeline project, at least in part, were justified by the projected generation of salvage water to benefit the downstream fishery (Hunter 1993, EQC 1998). These facts coupled with the definitive seniority of the FWP-leased water right for maintaining in-stream flow from May to October should ensure that there is always a minimum of 4.4 cfs (0.11 m^3/s) of water in Mill Creek (Hunter 1993, Spence 1995).

Despite these facts, in 2000, arguably a drought year, the water lease enforcement contact was unable to maintain flows at the lease quantification point in Mill Creek despite almost daily efforts. Mill Creek is a wide, flat, cobble and gravel-bottomed creek, and the amount of water necessary to ensure a specific level of streambed coverage or redd success has not been quantified. If the lease is to meet its prescribed intent to "maintain and enhance streamflows for the benefit of fisheries", an evaluation of the minimum amount of water required to cover a prescribed wetted perimeter should be undertaken to determine what amount of water is truly needed to meet this goal (Spence 1995, EQC 1998). If the water commissioner cannot maintain an adequate amount of water to fulfill the lease, it may be necessary to evaluate whether the Mill Creek lease requires more stringent enforcement. There is no doubt that Mill Creek is capable of recruiting substantial numbers of Yellowstone cutthroat trout fry when flows are adequate throughout the incubation and emergence period. However, continuing the lease may not be cost-effective unless reliable and sufficient flows can be maintained (Hennessey 1998). Given the average life cycle of a Yellowstone cutthroat trout, 2000 should have been the first year that the large recruitment from 1997 would have shown up in the spawning runs. The extremely low fry trapping results from 2000 are evidence that either the 1997 fish have not yet returned, or that their return was thwarted by insufficient in-stream flow for successful reproduction.

Cedar Creek experienced similar flow reductions early on in the field season, but coordination with the water lease enforcement contact was better this year resulting in no prolonged low-flow periods. Flows did drop below lease level a full two weeks earlier in 2000 than in 1999, but timely adjustments to the necessary ditches restored lease level flows in less than 12 hours (Figure 5). Most stages of fry incubation can withstand short-term dewatering since gravels hold some water in the interstitial spaces (Becker et al. 1983). The rapid response time seen at Cedar Creek this year probably prevented greater fry losses. Recruitment as measured by trap results in Cedar Creek was down slightly from 1999, but was well within the range from the previous four years (Table 3).

Water levels on Big Creek were met the water lease agreement in 2000, but Big Creek was not immune to the valley-wide water shortage, and discharge dropped earlier and stabilized at a much lower level in 2000 than in 1999. If 2001 appears to be another low flow or drought year, it would be good to establish a more explicit protocol for adjusting flows on Big Creek before the 2001 field season begins. As a positive indicator of the spirit of the water lease program, one of the landowners/ lessors on Big Creek was very interested in the fry monitoring and GANDA established a good rapport with him regarding his ditch withdrawals which we hope to build on in 2001. Fry recruitment increased substantially in 2000. Hopefully continued maintenance of in-stream flows in Big Creek will generate even higher recruitment in the future.

The discharge situation on Mol Heron Creek was very similar to that on Big Creek in 2000, and an effort should be made to clarify the lease enforcement protocol on that creek as well. GANDA does not anticipate any problems with coordinating lease-level flow adjustments, but it would be good to establish communications before any flow adjustment requests have to be made.

GANDA used Hennessey's protocol on Mill, Cedar, and Mol Heron creeks for the second year in 2000. Despite much earlier spawning and onset of outmigration, the protocol was able to detect the ascending limb in Cedar and Mol Heron creeks. Mill Creek was again sampled more frequently because of a lack of a distinct ascending limb, but sampling was suspended when flows became insufficient to connect the mouth of the creek with the Yellowstone mainstem. GANDA tested Hennessey's protocol on the Big Creek data from 2000 and found that it would have sampled 94.3% of the total fry caught and reduced trapping effort by 53%, from 44 days to 21 days. This reinforces the data from 1999 that showed that 95.7% of the total fry would have been sampled with a trapping effort reduction of 37%, from 35 days to 22 days (Roulson 1999). These two years of data demonstrate the potential suitability of Hennessey's protocol to other tributary streams with Yellowstone cutthroat trout populations. Given the results from Cedar, Mol Heron, and Big creeks, GANDA recommends that FWP adopt Hennessey's protocol for use in future monitoring on Big Creek beginning in 2001. The protocol may be continued on Mill Creek as well, but more frequent monitoring may be required if outmigration appears inconsistent.

The 2000 sampling season was considerably shorter than in 1997 or 1998 because of the use of Hennessey's protocol. This translated into savings for FWP in terms of labor and monitoring costs, but also changed some of the data gathered. Because the descending limbs of fry outmigrations were not monitored, data on fry lengths may have been truncated. If FWP wants to collect information on the life history of Yellowstone cutthroat trout fry concerning their residence time in natal tributaries, then this late-season data may be valuable. Should further research on fry residence time become a priority, it would be important to sample the latter end of outmigration and perhaps sample well into late September or October to ensure that late moving fry are documented.

Based on the results from this survey and a review of results from 1996-1999, GANDA recommends the following management actions to secure continued protection of Yellowstone cutthroat trout populations in the four project streams:

1. Maintain the water leases on all four project streams and pursue renewal of leases shown to be effective for the maximum time allowed when available;

2. FWP staff should continue to resolve issues that may be allowing junior water users to receive water out of priority to FWP's leases.

3. Re-evaluate the current level of leases on Mill Creek and determine the flows necessary to effectively, and consistently increase the wetted streambed perimeter in the section up to ½ mile from the mouth of the creek. If sufficient flows cannot be maintained either by more stringent enforcement/ administration of the current leases or by obtaining additional flows in an economical manner, FWP should seriously consider whether the Mill Creek lease should be continued;

4. Continue annual monitoring of fry outmigration using Hennessey's protocol on all four project streams;

5. Clearly define the protocol for contacting appropriate water lease enforcement contacts on Mol Heron and Big creeks; and

6. Pursue additional water leases on other Yellowstone cutthroat trout spawning streams to further protect the species.

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Appendices

Appendix A:
Staff Gauge Rating Tables Used to Quantify Flows in 2000

The following are reproductions of staff gauge rating tables that were verified by GANDA at the beginning of the 2000 field season. It should be noted that each gauge may require a correction factor or "shift" when converting the gauge reading as seen in the field to a flow measurement on the rating table. For example, the Cedar Creek gauge required a +0.04 shift to make the 1998 rating curve read 2000 flows accurately. This requires that a gauge reading of 1.00 be translated to 1.04 as read off the 1998 rating table to quantify the flow on the creek.

BIG CREEK

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE
DATE PROCESSED: 09-20-1999 @ 13:01 BY slynn

TYPE: LOG

?1820
CREEK AT KENDALL BRIDGE NR EMIGRANT MT
?RT: .00

DD: 1 TYPE: 001 RATING NO: 1.0
START DATE/TIME: 07-01-1999 (0015)

?D ON ______ DISCHARGE MEASUREMENTS, NOS ______, AND ______, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS
COMP BY ______ DATE ______ CHK. BY ______ DATE ______

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
.20	.620*	.684	.751	.821	.894	.971	1.050	1.133	1.219	1.308	.780
.30	1.400*	1.496	1.594	1.697	1.802	1.910	2.022	2.136	2.254	2.376	1.100
.40	2.500*	2.630	2.763	2.900	3.039	3.183	3.329	3.479	3.633	3.790	1.450
.50	3.950*	4.126	4.306	4.490	4.679	4.872	5.069	5.270	5.476	5.686	1.950
.60	5.900*	6.136	6.376	6.623	6.874	7.132	7.394	7.662	7.936	8.215	2.600
.70	8.500*	8.817	9.141	9.473	9.812	10.16	10.51	10.87	11.24	11.62	3.500
.80	12.00*	12.47	12.96	13.45	13.96	14.49	15.02	15.57	16.13	16.71	5.300
.90	17.30	17.91	18.52	19.16	19.80	20.47	21.14	21.83	22.54	23.26	6.700
?.00	24.00*	24.74	25.50	26.28	27.07	27.88	28.70	29.54	30.39	31.27	8.160
?.10	32.16	33.06	33.98	34.92	35.88	36.86	37.85	38.86	39.89	40.93	9.840*
?.20	42.00*										

2000 - no change

Effective 8/26/99

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE
DATE PROCESSED: 10-01-1999 @ 10:43 BY slynn

TYPE: LOG

6192050
ILL CREEK NEAR MOUTH, NEAR PRAY, MT
FFSET: .40

DD: 1 TYPE: 001 RATING NO: 5.0
START DATE/TIME: 04-01-1999 (0015)

ASED ON ________ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS
COMP BY _____ DATE ________ CHK. BY _____ DATE ________

STAFF GAGE WITH 1999 REVISED DATUM.

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
	DISCHARGE IN CUBIC FEET PER SECOND					(STANDARD PRECISION)					
.70	3.8*	4.1	4.3	4.6	4.9	5.1	5.4	5.7	6.1	6.4	2.9
.80	6.7	7.0	7.4	7.7	8.1	8.4	8.8	9.2	9.6	10.0	3.7
.90	10.4	10.8	11.2	11.6	12.1	12.5	13.0	13.4	13.9	14.4	4.5
1.00	14.9	15.4	15.9	16.4	16.9	17.4	17.9	18.5	19.0	19.6	5.2
1.10	20.1	20.7	21.3	21.9	22.5	23.1	23.7	24.3	24.9	25.5	6.1
1.20	26.2	26.8	27.5	28.1	28.8	29.5	30.2	30.9	31.6	32.3	6.8
1.30	33.0*	33.7	34.5	35.2	36.0	36.7	37.5	38.3	39.1	39.9	7.7
1.40	40.7	41.5	42.3	43.1	43.9	44.8	45.6	46.5	47.4	48.2	8.4
1.50	49.1	50.0	50.9	51.8	52.7	53.6	54.6	55.5	56.4	57.4	9.3
1.60	58.4	59.3	60.3	61.3	62.3	63.3	64.3	65.3	66.3	67.3	10.0
1.70	68.4	69.4	70.5	71.5	72.6	73.7	74.8	75.9	77.0	78.1	10.8
1.80	79.2	80.3	81.5	82.6	83.7	84.9	86.1	87.2	88.4	89.6	11.6
1.90	90.8	92.0	93.2	94.4	95.7	96.9	98.1	99.4	101	102	12.2
2.00	103	104	106	107	108	110	111	112	114	115	13.0
2.10	116	118	119	120	122	123	125	126	127	129	14.0
2.20	130	132	133	135	136	138	139	141	142	144	15.0
2.30	145	147	148	150	151	153	154	156	157	159	16.0
2.40	161	162	164	165	167	169	170	172	174	175	16.0
2.50	177	179	180	182	184	185	187	189	190	192	17.0
2.60	194	196	197	199	201	203	205	206	208	210	18.0
2.70	212	214	215	217	219	221	223	225	227	229	18.0
2.80	230	232	234	236	238	240	242	244	246	248	20.0
2.90	250	252	254	256	258	260	262	264	266	268	20.0*
3.00	270*										

2000 - NO change

Mill Creek at Mouth

'118

...est

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE
DATE PROCESSED: 08-28-1998 @ 14:21 BY slynn

TYPE: LOG

.191620
..DAR CR AT MOUTH NR CORWIN SPRINGS, MT
..FSET: .00

DD: 1 TYPE: 001 RATING NO: 4.0
START DATE/TIME: 04-01-98 (0015)

..SED ON ______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS
COMP BY _____ DATE ________ CHK. BY _____ DATE ________

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)					DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
.30	.400*	.436	.474	.515	.557	.601	.648	.696	.747	.800	.456
.40	.856	.914	.974	1.036	1.101	1.168	1.238	1.311	1.386	1.464	.688
.50	1.544	1.627	1.712	1.801	1.892	1.986	2.083	2.183	2.286	2.391	.956
.60	2.500*	2.615	2.733	2.854	2.979	3.107	3.239	3.374	3.512	3.654	1.300
.70	3.800*	3.960	4.124	4.292	4.465	4.643	4.825	5.012	5.203	5.399	1.800
.80	5.600*	5.815	6.035	6.260	6.492	6.729	6.971	7.219	7.474	7.734	2.400
.90	8.000*	8.295	8.597	8.907	9.224	9.550	9.883	10.22	10.57	10.93	3.300
1.00	11.30	11.67	12.05	12.44	12.84	13.25	13.67	14.10	14.53	14.98	4.130
1.10	15.43	15.90	16.37	16.86	17.35	17.85	18.37	18.89	19.42	19.97	5.090
1.20	20.52	21.09	21.66	22.25	22.85	23.46	24.08	24.71	25.35	26.01	6.150
1.30	26.67	27.35	28.04	28.74	29.46	30.18	30.92	31.67	32.44	33.21	7.330*
1.40	34.00*										

1999 use + 0.04 shift

2000 use + 0.04 shift

FED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

EXPANDED RATING TABLE

DATE PROCESSED: 07-22-1999 @ 10:03 BY slynn

PAGE 1

TYPE: LOG

06191610

CEDAR CR AB DIVERSION ERWIN SPRINGS, MT

OFFSET: -.20

DD: 1 TYPE: 001 RATING NO: 2.0

START DATE/TIME: 07-01-1997 (0015)

BASED ON ______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS

COMP BY _____ DATE ______ CHK. BY _____ DATE ________

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
.70	8.000*	17	8.580	8.881	9.188	9.503	9.826	10.16	10.49	10.84	3.190
.80	11.19	11	11.92	12.29	12.68	13.07	13.47	13.88	14.30	14.72	3.970
.90	15.16	11	16.05	16.52	16.99	17.46	17.95	18.45	18.96	19.47	4.840
1.00	20.00*	21	21.24	21.88	22.53	23.20	23.88	24.58	25.29	26.01	6.750
1.10	26.75	21	28.28	29.06	29.87	30.68	31.52	32.37	33.24	34.12	8.270
1.20	35.02	31	36.87	37.83	38.80	39.78	40.79	41.81	42.86	43.92	9.980*
1.30	45.00*										

2000 - 0.03 shift (S. Lynn 8/9/00)

Middle Gauge : Cedar Creek [illegible]

per gage

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

EXPANDED RATING TABLE

TYPE: LOG

DATE PROCESSED: 10-30-1997 @ 10:03 BY slynn

191600

DAR CR AT OTO RANCH NEAR CORWIN SPRINGS, MT

DD: 1 TYPE: 001 RATING NO: 2.0

FSET: .30

START DATE/TIME: 04-01-97 (0015)

SED ON _______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN ______ AND ______ CFS

COMP BY _____ DATE ________ CHK. BY _____ DATE ________

DISCHARGE IN CUBIC FEET PER SECOND (STANDARD PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
.80	4.0*	4.3	4.6	4.9	5.2	5.5	5.8	6.2	6.5	6.9	3.3
.90	7.3	7.7	8.2	8.6	9.1	9.5	10.0	10.6	11.1	11.6	4.9
1.00	12.2	12.8	13.4	14.0	14.7	15.3	16.0	16.7	17.5	18.2	6.8
1.10	19.0*	19.8	20.6	21.5	22.4	23.3*	24.4	25.5	26.6	27.8	10.0
1.20	29.0*	30.4	31.9	33.4	35.0	36.6	38.3	40.0	41.8	43.7	16.6
1.30	45.6	47.6	49.7	51.8	54.0	56.3	58.6	61.1	63.5	66.1	23.2
1.40	68.8	71.5	74.3	77.2	80.2	83.3	86.4	89.7	93.0	96.5	31.2*
1.50	100*										

1999

+0.03 shift

2000 - + 0.03 again

Mol Heron Rating Table 1999

gauge height	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	^/0.1 ft
0.90	4.021	4.251	4.492	4.743	5.005	5.279	5.565	5.863	6.174	6.497	
1.00	6.834	7.185	7.551	7.931	8.326	8.737	9.164	9.607	10.068	10.546	2.813
1.10	11.042	11.557	12.090	12.644	13.217	13.811	14.426	15.063	15.723	16.405	4.208
1.20	17.111	17.841	18.595	19.375	20.181	21.014	21.874	22.762	23.678	24.624	6.068
1.30	25.600	26.607	27.645	28.716	29.819	30.956	32.128	33.335	34.578	35.857	8.490
1.40	37.175	38.531	39.926	41.362	42.838	44.357	45.918	47.524	49.173	50.869	11.575
1.50	52.611	54.400	56.238	58.125	60.063	62.052	64.093	66.188	68.338	70.543	15.436
1.60	72.805	75.124	77.502	79.941	82.440	85.002	87.627	90.316	93.072	95.894	20.194
1.70	98.784	101.744	104.775	107.877	111.053	114.303	117.629	121.031	124.513	128.074	25.980
1.80	131.716	135.441	139.250	143.144	147.125	151.194	155.353	159.603	163.946	168.383	32.932
1.90	172.916	177.545	182.274	187.103	192.034	197.069	202.209	207.456	212.811	218.276	41.199
2.00	223.854	229.545	235.351	241.275	247.317	253.480	259.766	266.176	272.712	279.376	50.938

*1.56 is the highest actual measured discharge

**for 2000 use a -0.25 shift

Appendix B:
Graphs of daily discharge and temperature readings for the four project streams in Park County, Montana from June to September 2000.

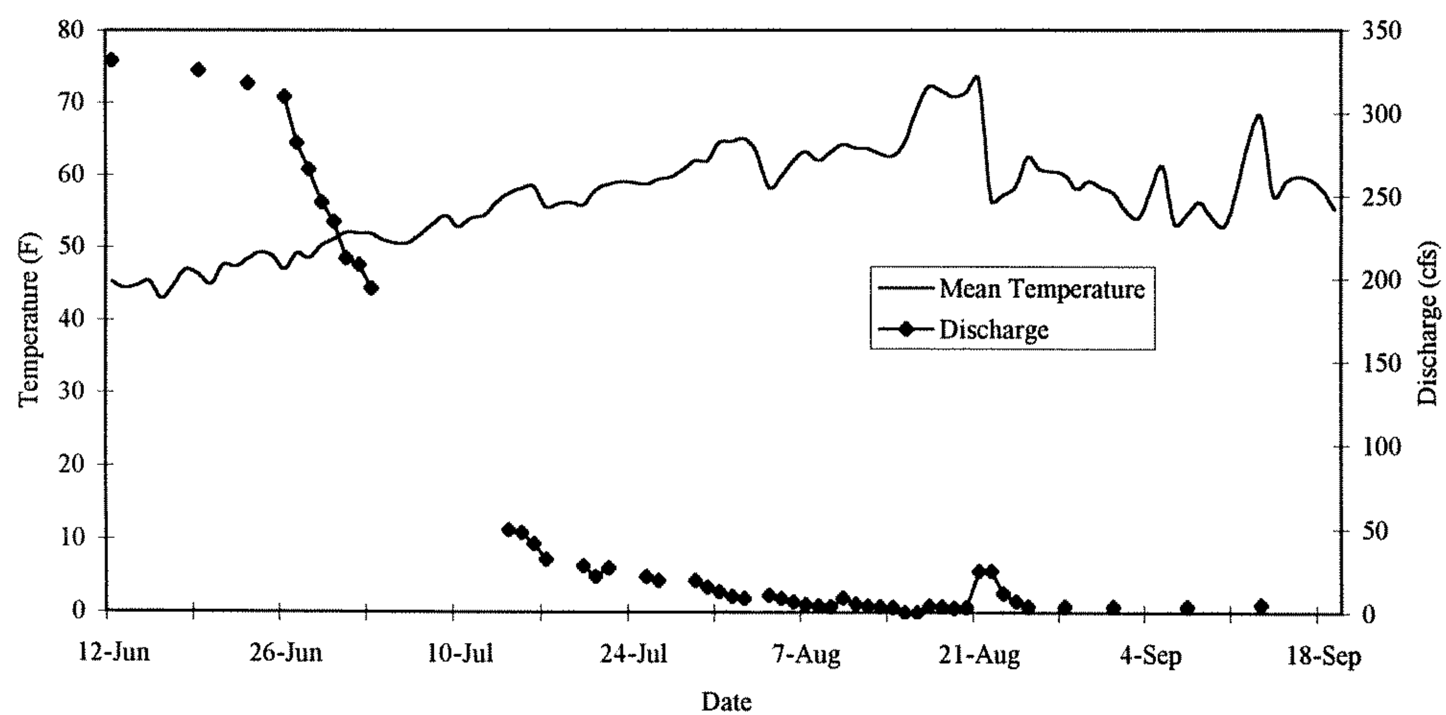

Figure B1. Daily discharge and mean daily temperature for Mill Creek, Montana from June to September 2000.

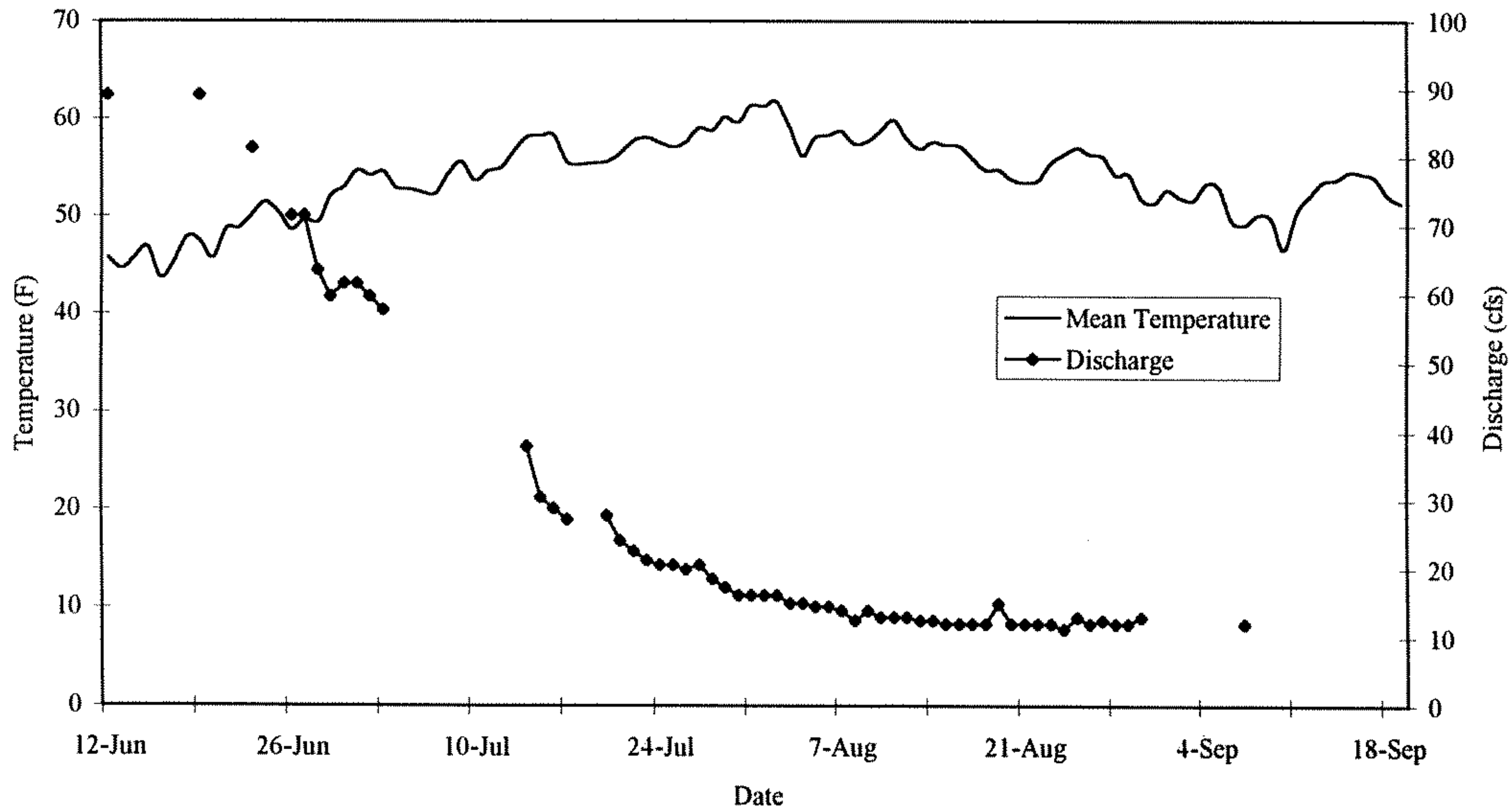

Figure B2. Daily discharge and mean daily temperature for Big Creek, Montana from June to September 2000.

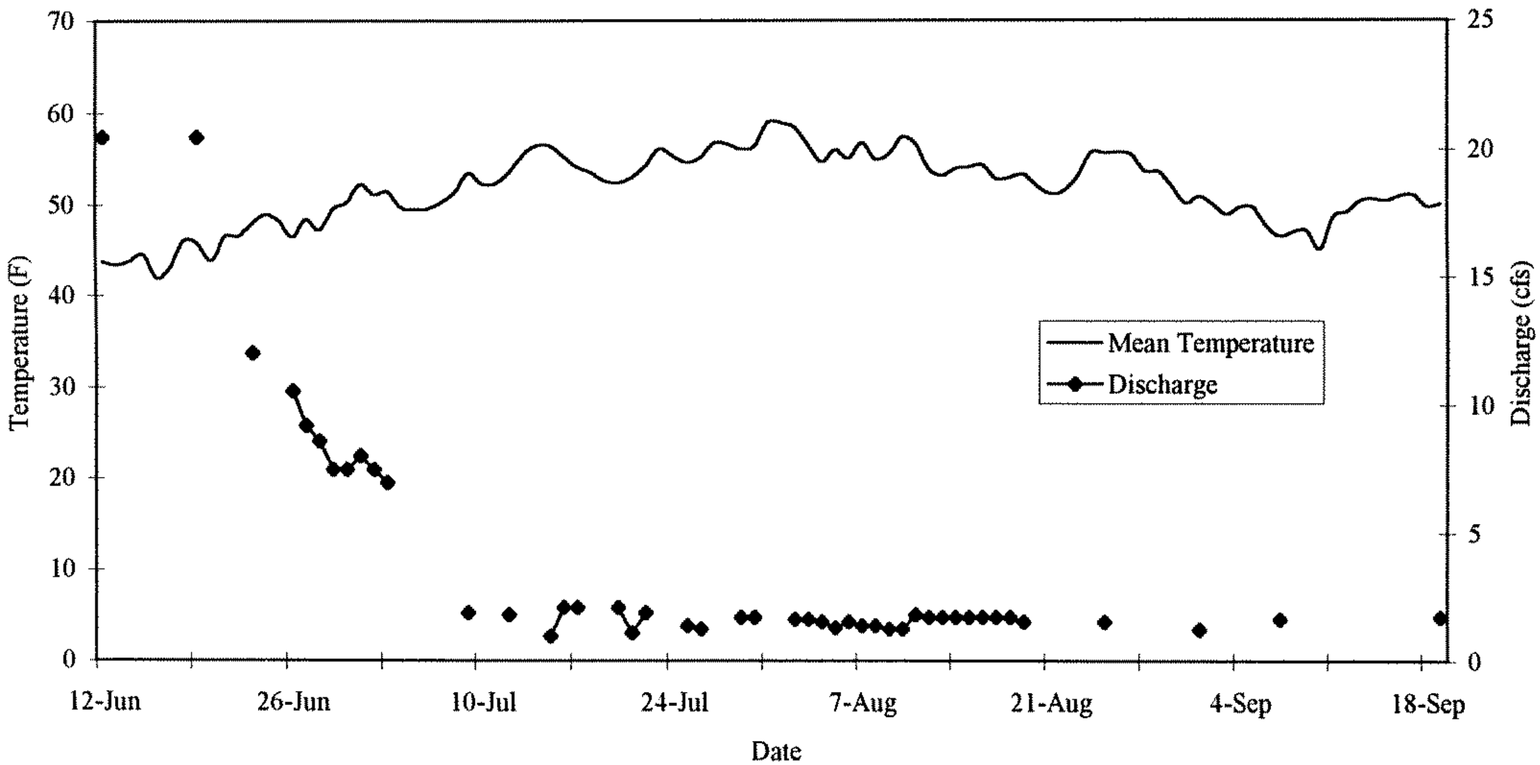

Figure B3. Daily discharge and mean daily temperature for Cedar Creek, Montana from June to September 2000.

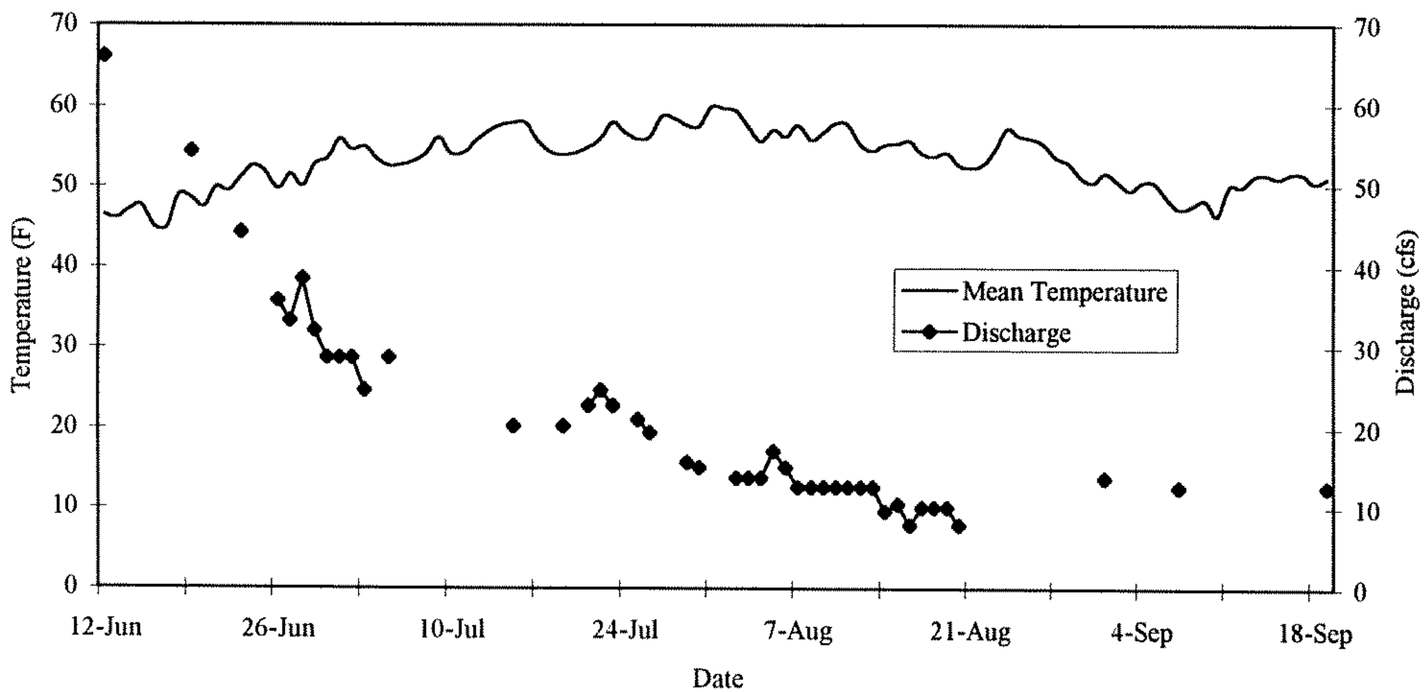

Figure B4. Daily discharge and mean daily temperature for Mol Heron Creek, Montana from June to September 2000.

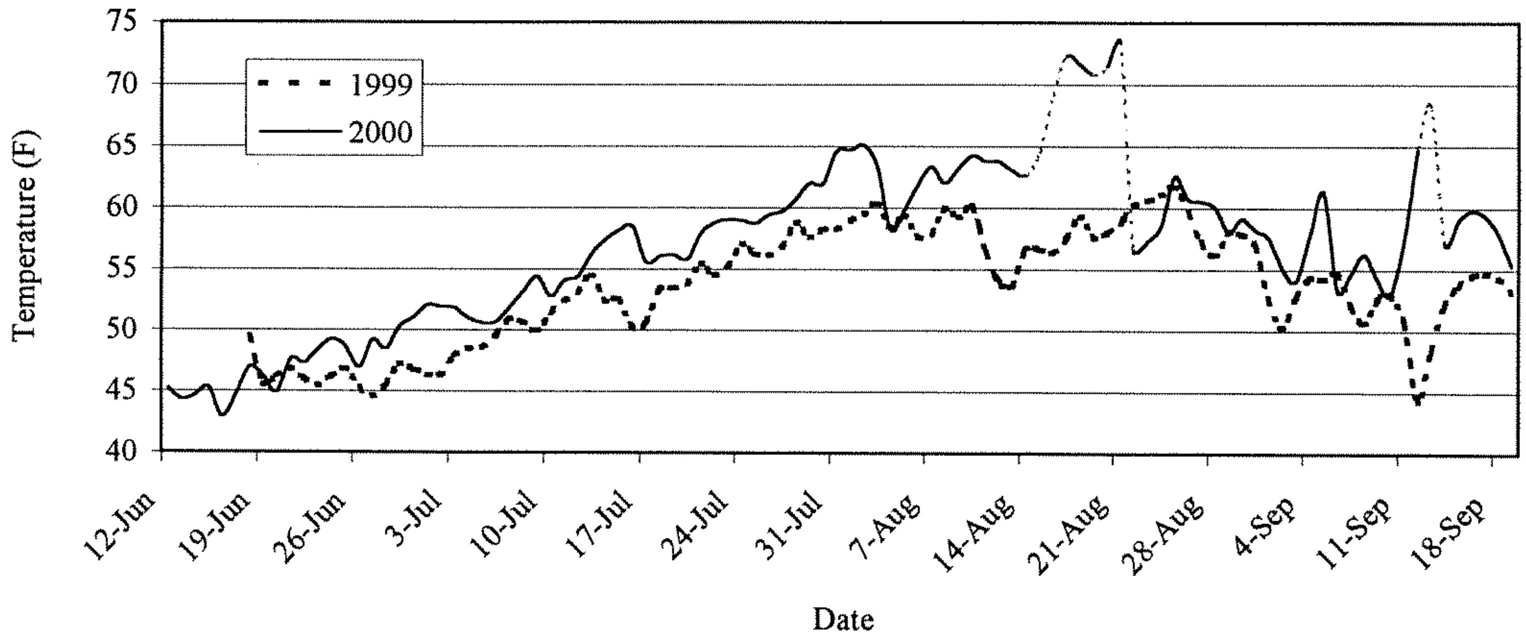

Figure B5. Comparison of daily mean stream temperatures for Mill Creek, Montana from June through September 1999 and 2000. The dashed portions of the 2000 data represent times when the thermograph was likely out of the water due to the creek being dry

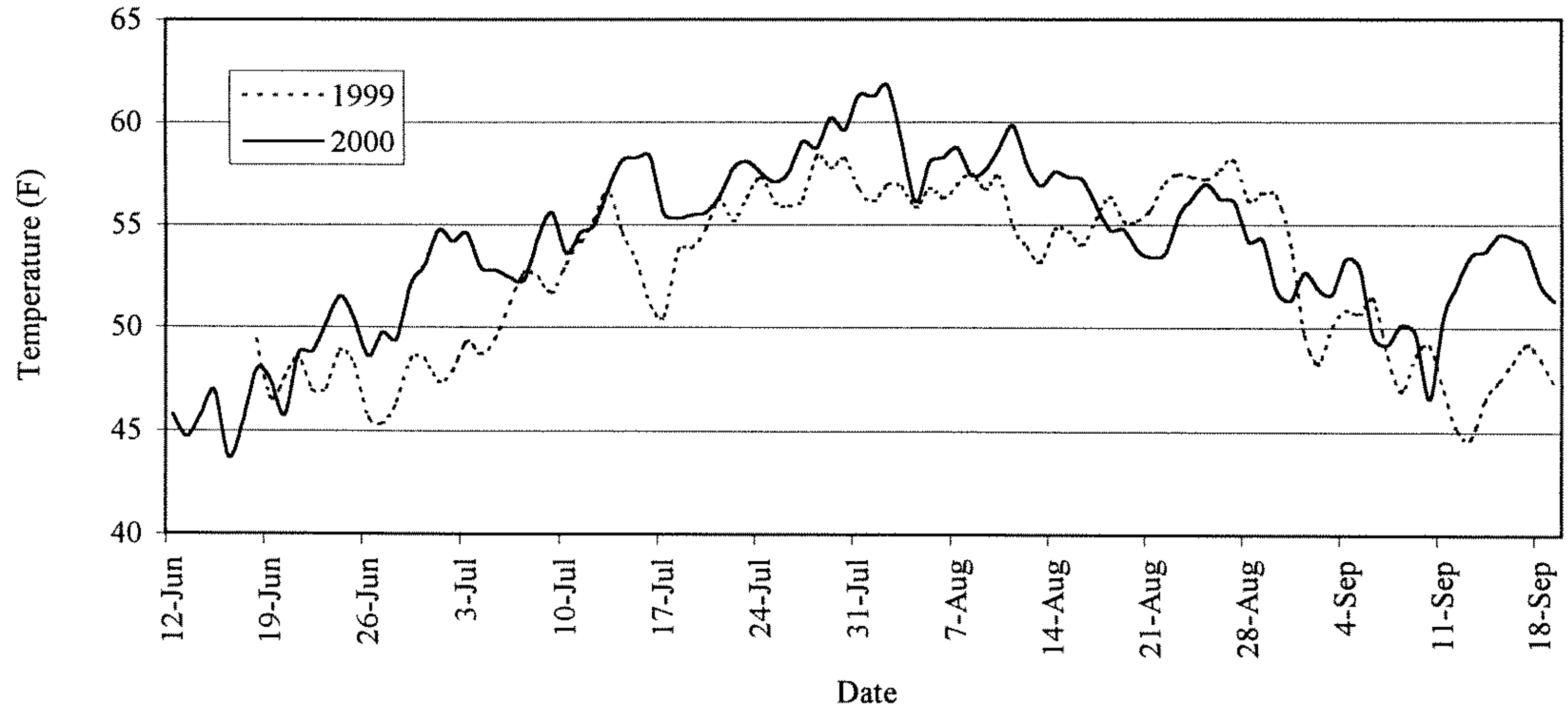

Figure B6. Comparison of daily mean stream temperatures for Big Creek, Montana from June through September 1999 and 2000.

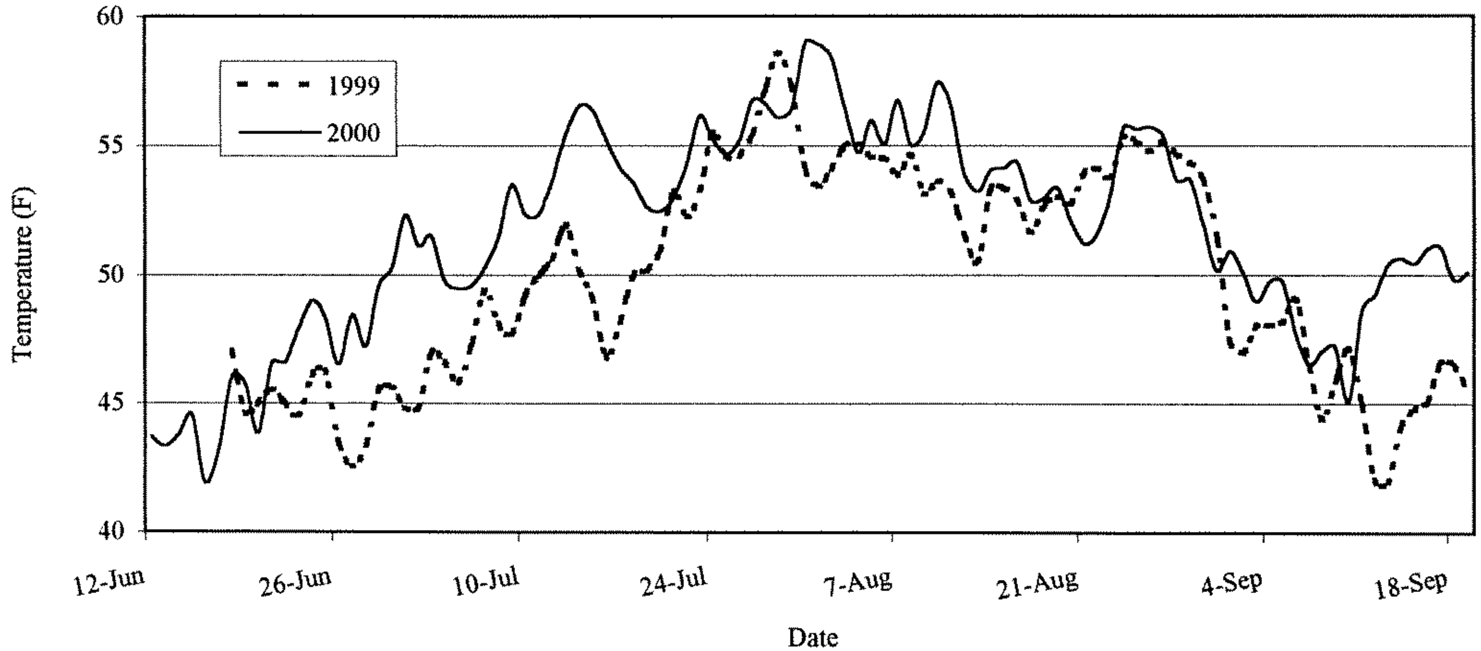

Figure B7. Comparison of daily mean stream temperatures for Cedar Creek, Montana from June through September 1999 and 2000.

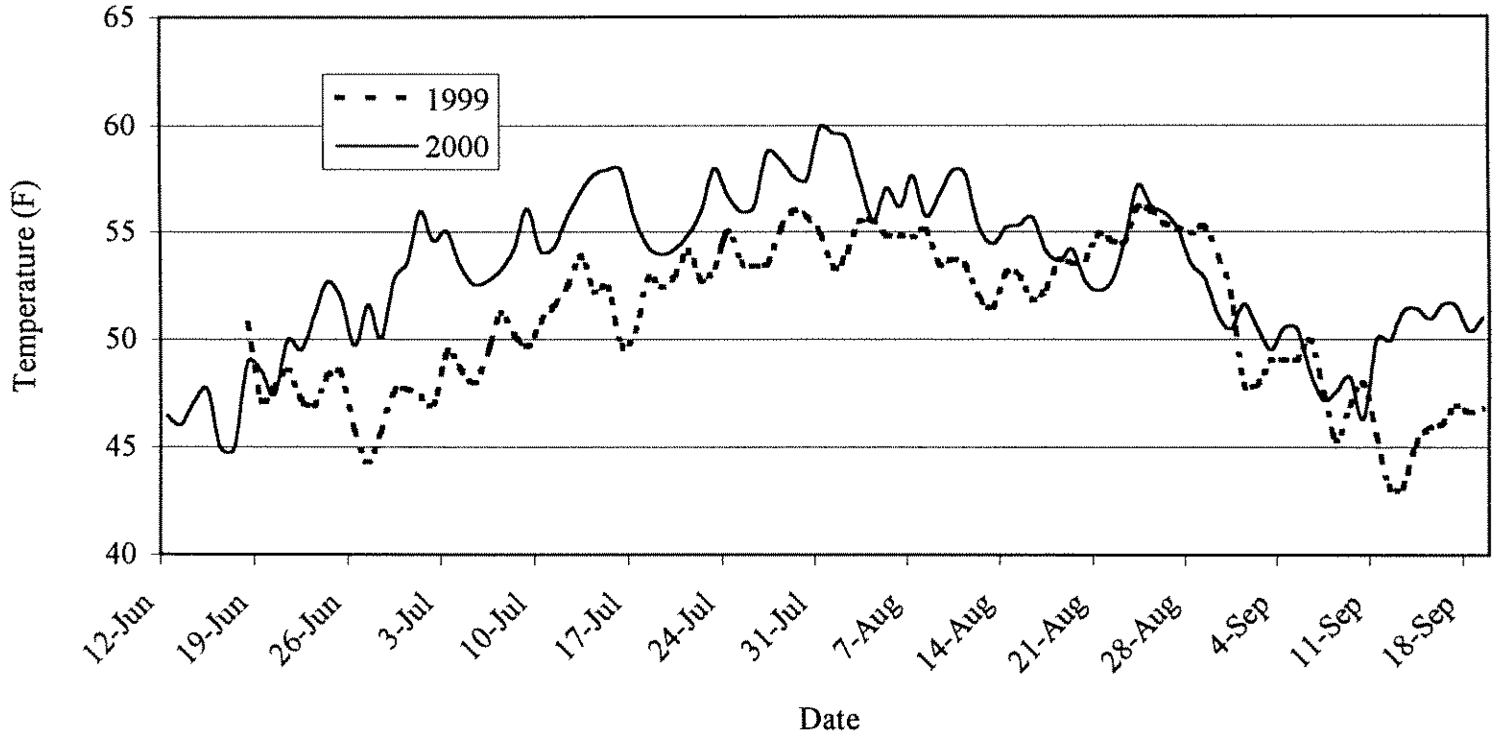

Figure B8. Comparison of daily mean stream temperatures for Mol Heron Creek, Montana from June through September 1999 and 2000.

Appendix C.
Stream discharge readings for the three gauges on Cedar Creek, Montana from June to September 2000.

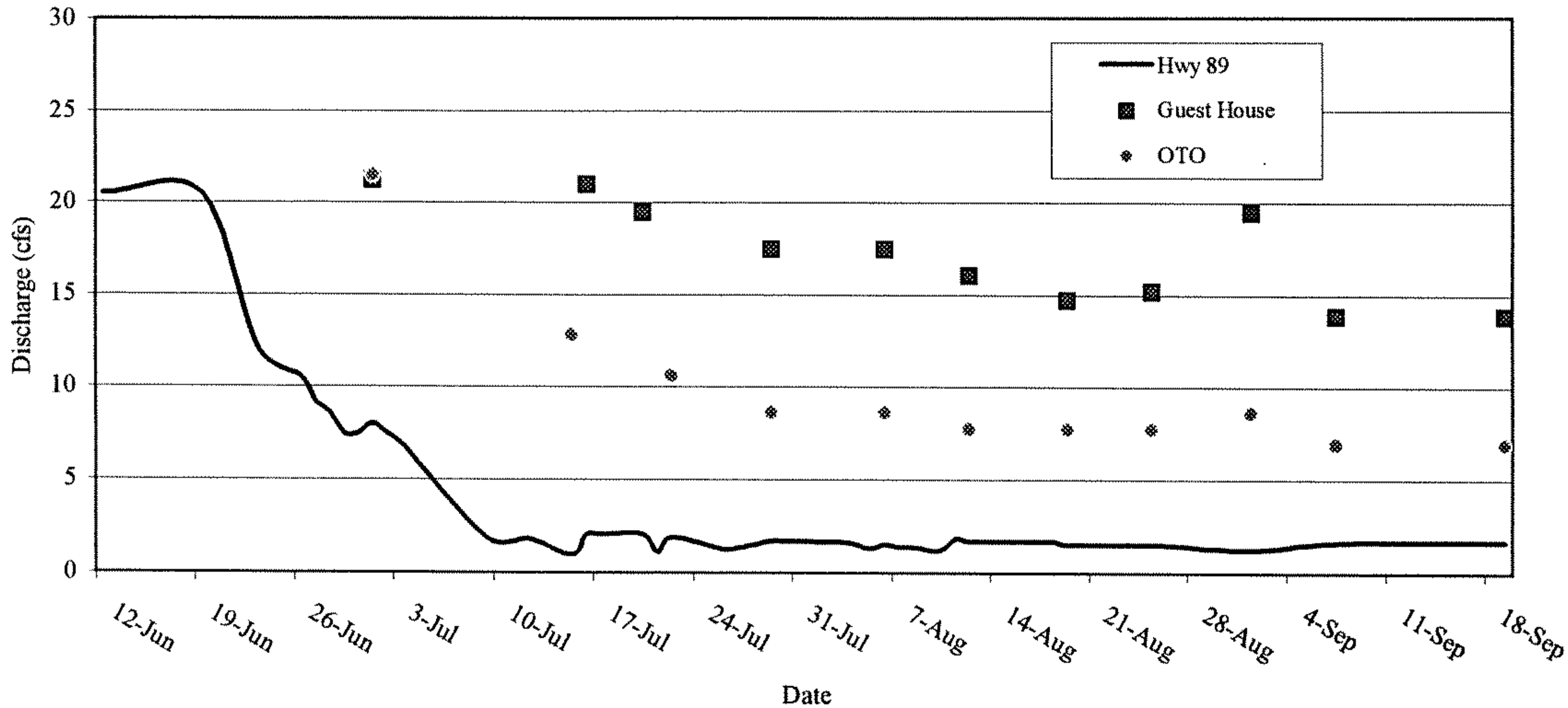

Figure C.1 Stream discharge readings for the three gauges on Cedar Creek, Montana. The Hwy 89 gauge is used for measuring the lease flow level, and is the furthest downstream. The guest house gauge is approximately ½ mile from the mouth, and the OTO gauge is upstream from the OTO Ranch, and is above all working diversions on Cedar Creek.