ARSENIC DATA FOR STREAMS IN THE UPPER MISSOURI RIVER BASIN, MONTANA AND WYOMING

By J.R. Knapton and A.A. Horpestad

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CONVERSION FACTORS

The following factors may be used to convert inch-pound units published herein to the International System (SI) of units.

Multiply inch-pound unit	By	To obtain SI unit
acre-foot	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
pound per day (lb/d)	453.6	gram per day

Temperature can be converted from degrees Celsius (°C) to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ (°C) + 32$$

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By J.R. Knapton and A.A. Horpestad[1]

ABSTRACT

Although large concentrations of arsenic originating from geothermal sources within Yellowstone National Park have been known to be present in the Madison River for many years, systematic monitoring throughout the upper Missouri River basin had not been done. Therefore, a monitoring network consisting of 24 stations was established for the purpose of measuring arsenic concentrations and determining arsenic discharge. Included were 5 sites on mainstems of the Madison and Missouri Rivers and 19 sites on major and some minor tributaries from Yellowstone National Park to Canyon Ferry Lake. Fifteen of the 24 stations were sampled 12 times from November 1985 to October 1986. The remaining stations were sampled twice during the year, at high flow and at low flow. Total recoverable arsenic discharge (loading) in pounds per day was calculated for each sample by multiplying total recoverable arsenic concentration by water discharge (obtained at time of sample collection) and a conversion factor. This report presents data resulting from the monitoring program.

INTRODUCTION

An early study conducted in Yellowstone National Park, which included parts of the upper Madison River drainage, described the presence of large concentrations of arsenic in waters associated with geothermal activities (Hague, 1887). Investigations conducted since 1887 have verified these large concentrations. Arsenic-enriched thermal waters reach tributaries to the Madison River both by surface and subsurface flows. From the Madison River, arsenic is transported downstream into the Missouri River.

Water samples collected and analyzed prior to this investigation indicated that arsenic concentrations of 200-300 μg/L (micrograms per liter) in the upper Madison River (U.S. Environmental Protection Agency, 1972) were diluted by inflow waters to concentrations of 20-40 μg/L in the Missouri River just upstream from Canyon Ferry Lake (U.S. Geological Survey, 1976-85). Because 50 μg/L is the maximum allowable limit for arsenic as established by primary drinking-water standards (U.S. Environmental Protection Agency, 1986), concern exists regarding the potential effects on human health.

Arsenic concentrations previously had been measured in the upper Madison River and in the Missouri River upstream from Canyon Ferry Lake. However, little

[1]Water Quality Bureau, Montana Department of Health and Environmental Sciences.

information was available on reaches of the river and tributaries between these areas. Missing was information needed to determine dilution sources or possible sources of arsenic contribution. In addition, much of the data on arsenic concentrations in the upper Madison River lacked concurrent stream-discharge values that would enable calculation of arsenic discharge (loading) to the stream from the tributaries. Because previous sampling for arsenic generally was not conducted systematically, seasonal variations throughout the hydrologic cycle could not be determined.

As a result of these current data needs, a monitoring network (fig. 1) was established to measure arsenic concentrations and determine arsenic discharge from selected tributary basins of the upper Missouri River. The purpose of this report is to document the data acquired from the monitoring network.

The network consisted of 24 stations--5 sites on the mainstems of the Madison and Missouri Rivers and the remainder on tributary streams in the upper Missouri River system (fig. 1). Where possible, station locations were selected at current Geological Survey streamflow-gaging stations or former stations. Of the 24 stations, 15 were sampled 12 times from November 1985 to October 1986. Sampling was generally on a monthly frequency, but the schedule was modified to sample more frequently during maximum runoff conditions and less frequently during the winter when conditions were more stable. The remaining nine stations were sampled twice during the year, at high flow and at low flow. Sampling of all network stations was generally accomplished within 3-day periods.

In addition to network stations, sampling was conducted at four miscellaneous stations within or near Yellowstone National Park. All four stations were in the upstream reaches of the Madison River or its tributaries.

Arsenic loading determinations, as calculated from arsenic concentrations and stream discharge, allows the quantification of downstream gains or losses of arsenic in the Madison and Missouri Rivers. To supplement the arsenic information, specific conductance of the samples was measured as a surrogate determination of dissolved-solids concentration. Stream discharge, water temperature, and air temperature were determined at the time of sample collection.

The monitoring program was funded jointly by the U.S. Geological Survey and the Montana Department of Health and Environmental Sciences (Water Quality Bureau). Sample collection and onsite measurements were done by the Geological Survey. Samples were analyzed by the Chemistry Laboratory Bureau of the Montana Department of Health and Environmental Sciences.

FIELD PROCEDURES

Because laboratory analysis was to be performed for total recoverable arsenic concentration, a representative stream sample of the water-sediment mixture was required. Samples, therefore, were collected either by the "Equal Width Increment" or the "Equal Discharge Increment" method, using modified suspended-sediment samplers (Guy and Norman, 1970). Where streams were shallow enough to allow wading across the stream section, the Equal Width Increment method was used with a US-DH-48 sampler. Where stream sections were too deep to wade and samples had to be collected from cableways or bridges, the Equal Discharge Increment method was used with a US-D-74 type sampler and appropriate bridge cranes and reels. Both methods

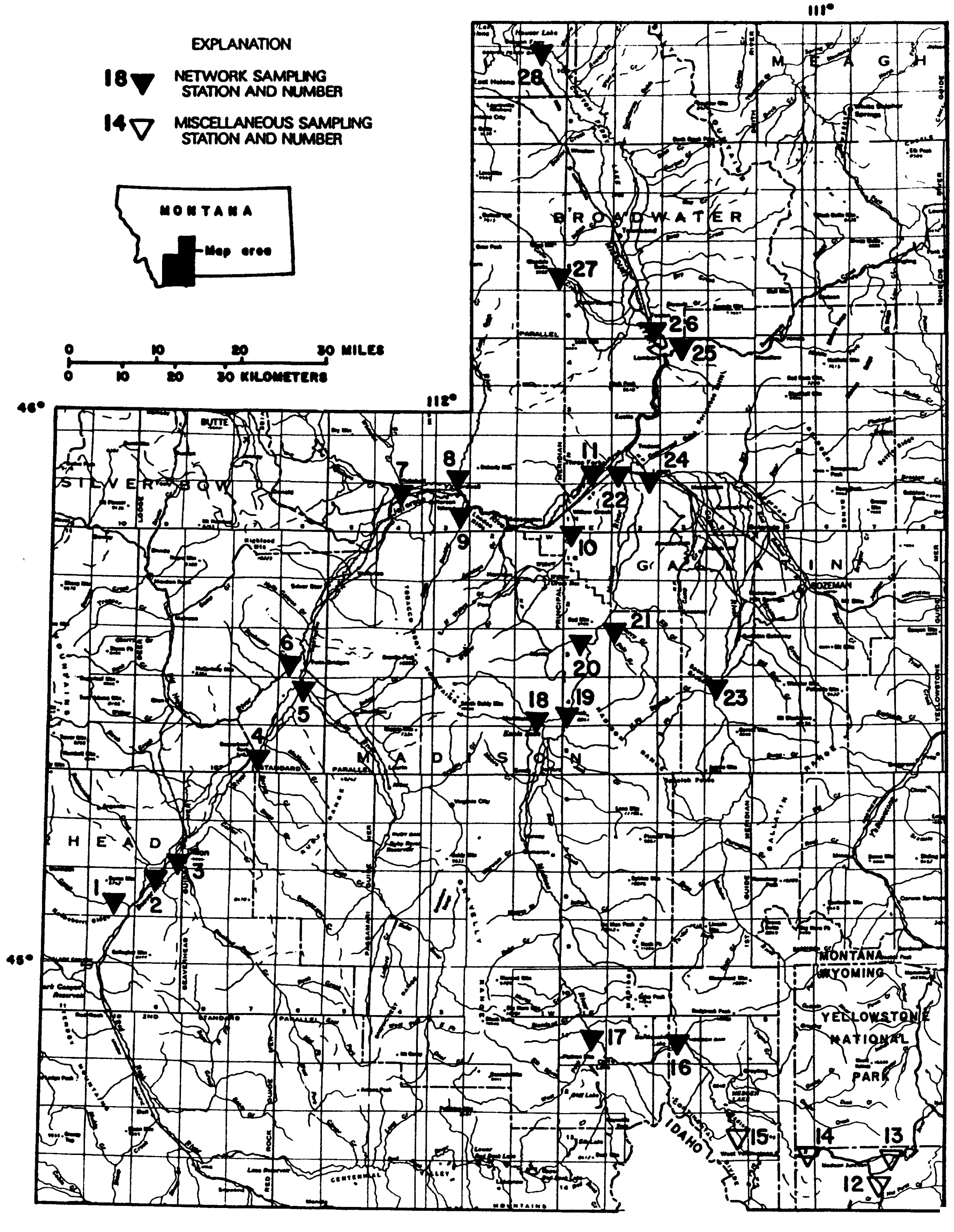

Figure 1.--Location of study area and sampling stations.

of sampling allowed for depth integration through a series of vertical sections across the stream channel.

The subset samples from the vertical sections were composited (mixed) onsite in a Geological Survey churn sample splitter, followed by withdrawing a representative sample of the water-sediment mixture for arsenic analysis. The arsenic sample then was preserved by acidification with nitric acid prior to transmittal to the laboratory. A second sample for measurement of specific conductance was withdrawn from the sample splitter in the same manner, but not acidified.

Stream discharge was obtained either by direct measurement or, where stream gages were present, indirectly from observed stream stage and stage-discharge rating tables. All methods conformed to documented procedures of the U.S. Geological Survey (Rantz and others, 1982).

Stream temperatures were measured at mid-stream using field grade thermometers. Air temperatures were measured at the time of sampling.

LABORATORY PROCEDURES

The samples from individual stations consisted of two bottles each of representative water-sediment mixtures--one acidified and the other untreated. (No additional pretreatment of samples was done either in the field or in the laboratory.) The acidified sample was analyzed for arsenic and reported as total recoverable arsenic. The untreated sample was analyzed for specific conductance.

Arsenic was analyzed by the atomic absorption, spectrophotometric, gaseous hydride method. In a series of steps, all arsenic is reduced to As^{+3}, then combined wih sodium borohydride to form gaseous arsine. The arsine is swept by a flow of nitrogen into a quartz cell heated to 900 °C, where concentration is determined by atomic absorption. Detection level for this procedure is 1 µg/L. Analytical precision is given in table 1.

Specific conductance was determined by the electrometry method using a cathode ray tube with wheatstone bridge circuitry in which a variable resistance is adjusted so that it is equal to the resistance of the unknown solution present in a standardized conductivity cell. The reciprocal of the measured resistance is reported as specific conductance, in microsiemens per centimeter (µS/cm). All measurements were made on samples and standards at a temperature of 25 °C. Specific conductance was reported to the nearest whole number. Analytical precision is given in table 1.

As part of the quality assurance plan, duplicate samples were collected periodically at selected sampling locations. The sampling locations chosen were generally those where arsenic concentrations were known to be larger than background levels. The duplicates were submitted to the laboratory with false station numbers, dates, and times. Results of the arsenic duplicates indicated that the largest difference between paired samples was 4 µg/L, the smallest difference was 0, and the median difference was 1 µg/L. Paired samples for specific conductance indicated that the largest difference was 106 µS/cm, the smallest difference was 0, and the median difference was 1 µS/cm.

The Chemistry Laboratory Bureau is certified by the U.S. Environmental Protection Agency for water, wastewater, air, and hazardous-waste analyses. Internal laboratory quality-control procedures include duplicate analyses for measurement of precision, spiked analyses for checking accuracy, and reference sample analyses used as an external check on standards. Acceptability criteria are given in table 1.

DATA RESULTS

The map of the study area (fig. 1) shows the location of sampling stations. The numbers on the map correspond to the numbers preceding station names in tables 2-4.

Variations with time of arsenic concentration and arsenic discharge (figs. 2 and 3) are shown for two stations, one on the Madison and one on the Missouri River. During months of more than one sample collection, the concentration plotted represents the average concentration of the samples.

Arsenic concentrations and arsenic discharges (figs. 4 and 5) are shown for five mainstem stations during specific periods. The November sampling period (fig. 4) represents low streamflow conditions when most water-quality constituents are considered to be stable. The June sampling period (fig. 5) represents spring runoff conditions with generally more variable constituent concentrations and stream discharges.

Descriptions of the sampling stations, in downstream order, are given in table 2. The number preceding the station name is the station number shown in figure 1. The number following the station name is the formal downstream-order station number assigned by the Geological Survey.

The results of onsite and laboratory measurements are given in table 3. Arsenic concentrations are reported in micrograms per liter and are equivalent to parts per billion. Arsenic discharge was determined by multiplying the water discharge by the concentration of arsenic and a units conversion constant:

$$Q_a = Q_w \times C_a \times k \tag{1}$$

where

Q_a is arsenic discharge, in pounds per day;
Q_w is the water discharge, in cubic feet per second;
C_a is arsenic concentration, in micrograms per liter; and
k is 0.0054, a constant used to convert arsenic discharge to pounds per day.

In addition to the scheduled sampling program, miscellaneous samples were collected and analyzed from the Madison River upstream from Hebgen Lake and from the Firehole and Gibbon Rivers and the South Fork Madison River. This miscellaneous information is listed in table 4.

If data in this report are used for interpretation, the reader is cautioned to consider the effects of impoundments on the results. Three reservoirs are present on the mainstems of the Madison River and the upper Missouri River: Hebgen Lake (capacity of 385,000 acre-feet), Ennis Lake (capacity of 42,000 acre-feet),

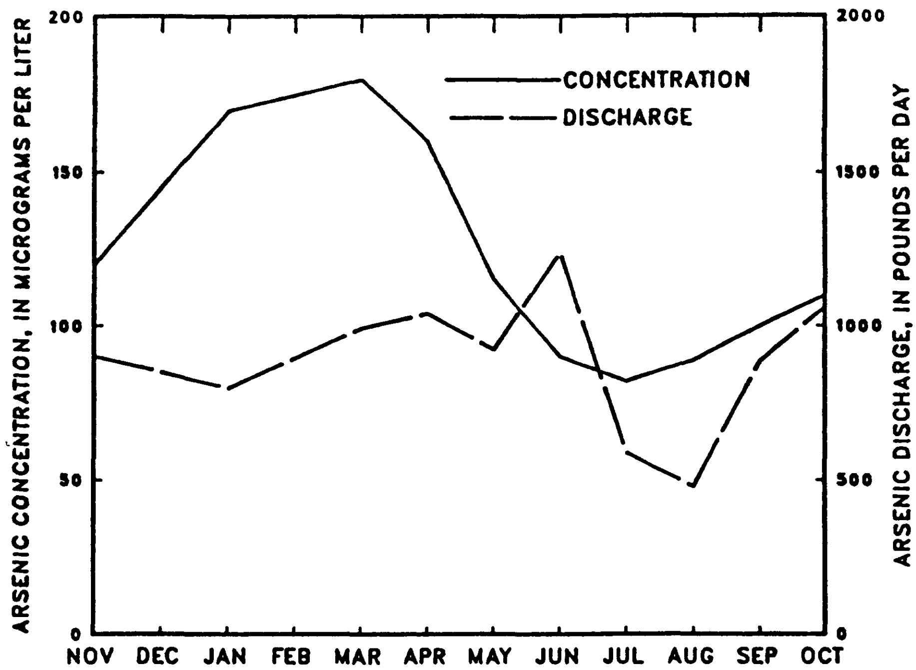

Figure 2.--Total recoverable arsenic concentration and total recoverable arsenic discharge for the Madison River below Hebgen Lake, near Grayling (station 16), November 1985 through October 1986.

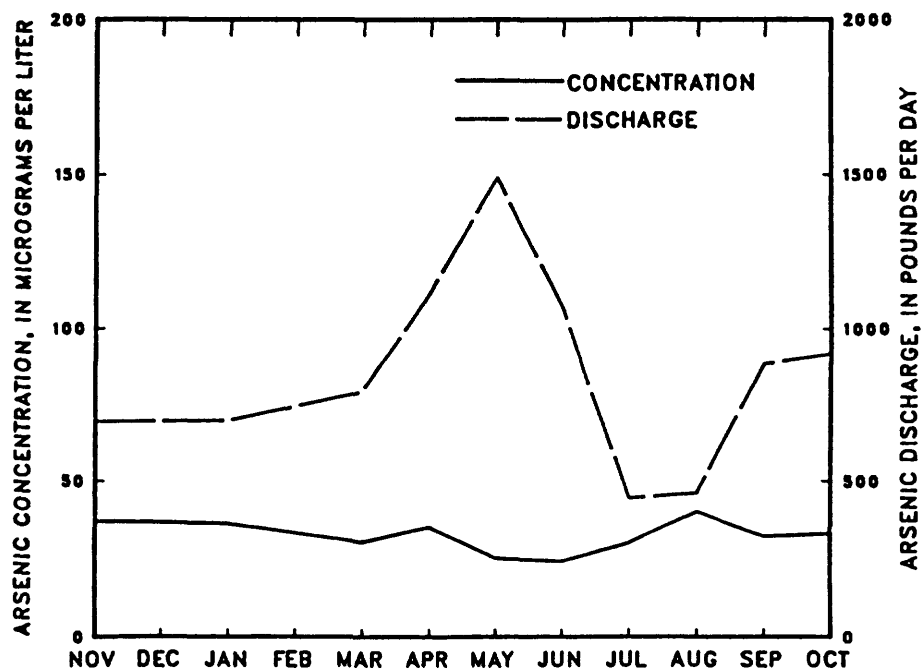

Figure 3.--Total recoverable arsenic concentration and total recoverable arsenic discharge for the Missouri River at Toston (station 26), November 1985 through October 1986.

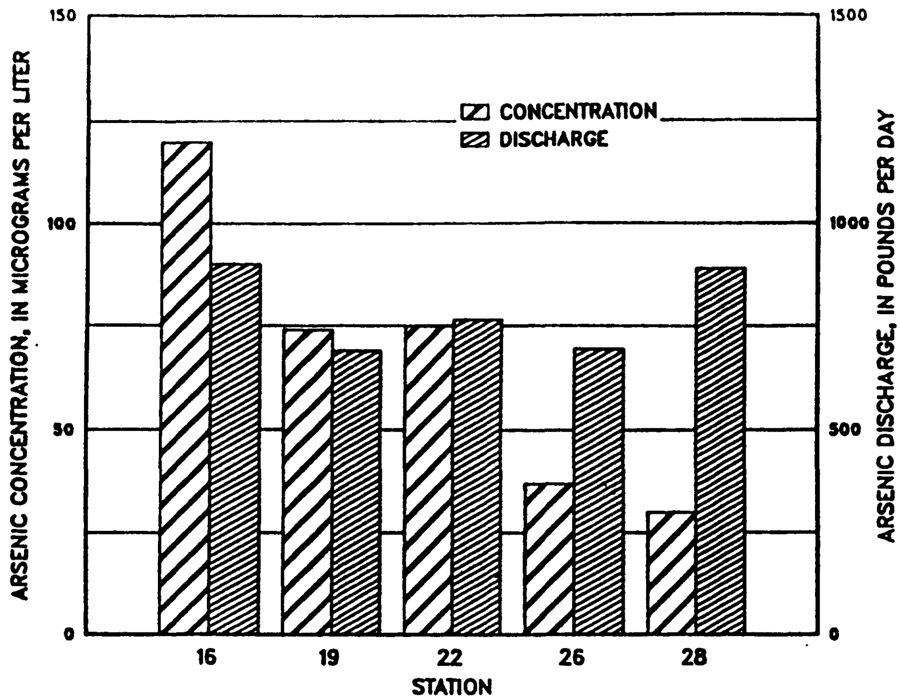

Figure 4.--Total recoverable arsenic concentration and total recoverable arsenic discharge at five stations on the Madison and Missouri Rivers for samples collected November 13-15, 1985.

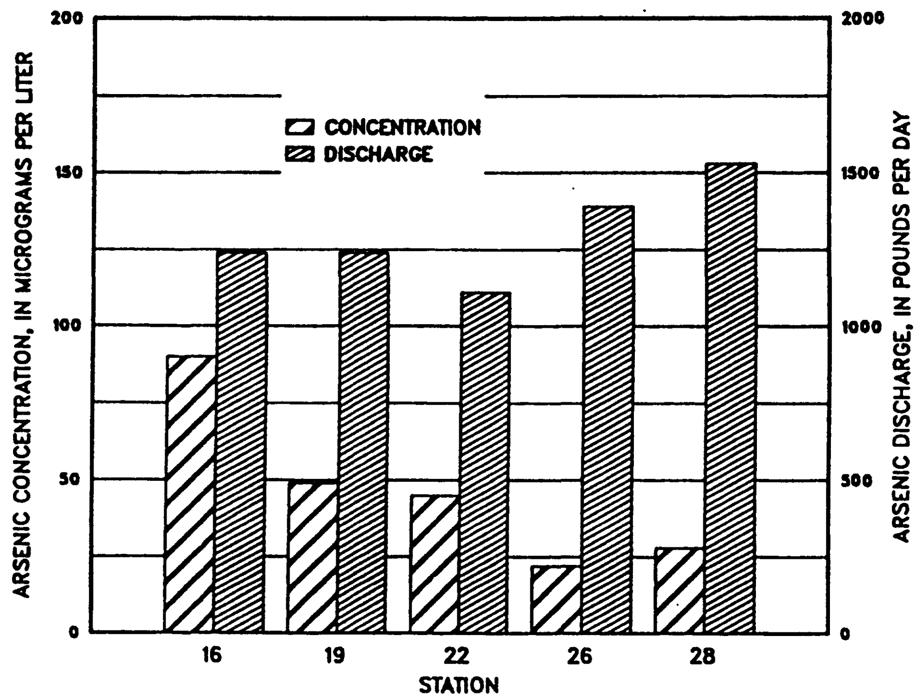

Figure 5.--Total recoverable arsenic concentration and total recoverable arsenic discharge at five stations on the Madison and Missouri Rivers for samples collected June 16-18, 1986.

and Canyon Ferry Lake (capacity of 2,050,000 acre-feet). Processes within these reservoirs and the manner of water releases from the dams are responsible for some modifications in the natural transport of dissolved and suspended constituents, including arsenic. Important modifications for the reader to consider are: (1) dampening of short- and intermediate-term fluctuations in arsenic concentrations resulting from mixing of water within the reservoirs, (2) deposition of arsenic-associated sediments on reservoir bottoms as a result of decreased water velocities, and (3) changes in downstream arsenic discharge resulting from controlled water discharge at the dams.

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______ 1983, Methods for chemical analysis of water and wastes: Office of Water Supply, EPA 600/4-79-0020, report unnumbered.

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Table 1.--*Laboratory precision, accuracy, and detection limit for arsenic and specific conductance*

[μg/L, micrograms per liter; μS/cm, microsiemens per centimeter; --, no data or insufficient data]

Parameter	Precision		Accuracy		Detection limit
	Range	Limit	Warning limits (percent recovery)	Acceptance limits (percent recovery)	
Arsenic (Automated gaseous hydride method)	1-5 μg/L	2 μg/L	--	--	1 μg/L
	5-20 μg/L	3 μg/L	93-125	85-133	--
	20-100 μg/L	5 μg/L	--	--	--
Specific conductance (EPA 120.1 method[1]	0.10-75 μS/cm	11.7 μS/cm	--	--	0.10 μS/cm
	75-560 μS/cm	13.8 μS/cm	--	--	--
	560-870 μS/cm	35.7 μS/cm	--	--	--
	870-1500 μS/cm	64.2 μS/cm	--	--	--

[1]U.S. Environmental Protection Agency, 1983.

Table 2.--*Descriptions of network stations*

[mi, miles; ft, feet]

Station 1--GRASSHOPPER CREEK NEAR DILLON, MONT. (06015500)

LOCATION.--Lat 45°06'40", long 112°48'00", in E1/2 SW1/4 NW1/4 sec. 26, T. 8 S., R. 10 W., Beaverhead County, 1.75 mi upstream from Beaverhead River, and 11 mi southwest of Dillon.

Station 2--BEAVERHEAD RIVER AT BARRETTS, MONT. (06016000)

LOCATION.--Lat 45°06'59", long 112°44'59", in SE1/4 SW1/4 SE1/4 sec. 19, T. 8 S., R. 9 W., Beaverhead County, 1.4 mi upstream from Barretts, 2.2 mi downstream from Grasshopper Creek, and 8.9 mi southwest of Dillon.

Station 3--BLACKTAIL DEER CREEK AT DILLON, MONT. (06017600)

LOCATION.--Lat 45°11'32", long 112°39'08", in SE1/4 NE1/4 SW1/4 sec. 25, T. 7 S, R. 9 W, Beaverhead County, 50 ft downstream from U.S. Highway 91, and 1.0 mi southwest of Dillon.

Station 4--BEAVERHEAD RIVER NEAR TWIN BRIDGES, MONT. (06018500)

LOCATION.--Lat 45°23'01", long 112°27'07", in SW1/4 NW1/4 SE1/4 sec. 22, T. 5 S., R. 7 W., Madison County, at bridge on State Highway 41, 11.5 mi upstream from Ruby River, 12.7 mi southwest of Twin Bridges, and 14.5 mi northeast of Dillon.

Station 5--RUBY RIVER NEAR TWIN BRIDGES, MONT. (06023000)

LOCATION.--Lat 45°30'28", long 112°19'48", in SE1/4 NE1/4 NW1/4 sec. 10, T. 4 S., R. 6 W., Madison County, 300 ft upstream from county bridge, 1.2 mi upstream from mouth, and 2.5 mi south of Twin Bridges.

Station 6--BIG HOLE RIVER NEAR TWIN BRIDGES, MONT. (06026400)

LOCATION.--Lat 45°32'50", long 112°21'59", in SW1/4 NW1/4 SE1/4 sec. 29, T. 3 S., R. 6 W., Madison County, 0.4 mi upstream from bridge on secondary highway 361, 0.4 mi upstream from Rochester Creek, and 1.8 mi west of Twin Bridges.

Station 7--BIG PIPESTONE CREEK AT WHITEHALL, MONT. (06028700)

LOCATION.--Lat 45°51'49", long 112°05'48", in SE1/4 NE1/4 SE1/4 sec. 4, T. 1 N., R. 4 W., Jefferson County, at culvert on county road, and 0.1 mi south of Whitehall.

Station 8--BOULDER RIVER NEAR CARDWELL, MONT. (06033900)

LOCATION.--Lat 45°52'14", long 111°56'30", in NW1/4 SE1/4 NW1/4 sec. 2, T. 1 N., R. 3 W., Jefferson County, at bridge on Interstate Highway 15, and 0.8 mi northeast of Cardwell.

Station 9--SOUTH BOULDER RIVER NEAR CARDWELL, MONT. (06034300)

LOCATION.--Lat 45°48'10", long 111°55'26", in SE1/4 SW1/4 NW1/4 sec. 25, T. 1 N., R. 3 W., Madison County, 100 ft upstream from bridge on State Highway 359, and 3.5 mi south of Cardwell.

Station 10--WILLOW CREEK NEAR WILLOW CREEK, MONT. (06036500)

LOCATION.--Lat 45°45'00", long 111°39'00", in SW1/4 sec. 18, T. 1 S., R. 1 E., Gallatin County, at bridge, 3 mi downstream from Willow Creek Reservoir, 5.5 mi south of Willow Creek, and 6 mi upstream from mouth.

Station 11--JEFFERSON RIVER NEAR THREE FORKS, MONT. (06036650)

LOCATION.--Lat 45°53'52", long 111°35'45", in SW1/4 SW1/4 NW1/4 sec. 27, T. 2 N., R. 1 E., Broadwater County, 50 ft downstream from bridge on U.S. Highway 10, and 2.5 mi northwest of Three Forks.

Station 16--MADISON RIVER BELOW HEBGEN LAKE, NEAR GRAYLING, MONT. (06038500)

LOCATION.--Lat 44°52'00", long 111°20'15", in NE1/2 NE1/4 NE1/4 sec. 22, T. 11 S., R. 3 E., Gallatin County, Gallatin National Forest, 1,500 ft downstream from Hebgen Dam, 8 mi northwest of Grayling, and 17 mi upstream from West Fork.

Station 17--WEST FORK MADISON RIVER NEAR CAMERON, MONT. (06039200)

LOCATION.--Lat 44°53'15", long 111°34'55", in SE1/4 sec. 10, T. 11 S., R. 1 E., Madison County, on bridge 0.25 mi upstream from mouth, and 22 mi southeast of Cameron.

Station 18--MEADOW CREEK NEAR MCALLISTER, MONT. (06040400)

LOCATION.--Lat 45°26'30", long 111°42'38", in SE1/4 NE1/4 SW1/4 sec. 34, T. 4 N., R. 1 E., Madison County, just upstream from mouth, 0.2 mi south of Meadow Lake Camp, and 1.0 mi east of McAllister.

Station 19--MADISON RIVER BELOW ENNIS LAKE, NEAR MCALLISTER, MONT. (06041000)

LOCATION.--Lat 45°29'25", long 111°38'00", in SW1/4 SE1/4 NW1/4 sec. 17, T. 4 S., R. 1 E., Madison County, 500 ft downstream from Madison powerplant, 1.5 mi downstream from Ennis Lake, and 5.7 mi northeast of McAllister.

Station 20--HOT SPRINGS CREEK NEAR NORRIS, MONT. (06041300)

LOCATION.--Lat 45°35'07", long 111°35'38", in NE1/4 SW1/4 SW1/4 sec. 10, T. 3 S., R. 1 E., Madison County, just upstream from mouth, 0.1 mi south of State Highway 84, and 4.8 mi northeast of Norris.

Station 21--CHERRY CREEK NEAR NORRIS, MONT. (06041700)

LOCATION.--Lat 45°37'20", long 111°32'50", in NE1/4 SE1/4 NW1/4 sec. 36, T. 2 S., R. 1 E., Madison County, at bridge on State Highway 84, and 7.8 mi northeast of Norris.

Station 22--MADISON RIVER AT THREE FORKS, MONT. (06042600)

LOCATION.--Lat 45°54'05", long 111°31'29", in SE1/4 NE1/4 NW1/4 sec. 30, T. 2 N., R. 2 E., Gallatin County, at bridge on old U.S. Highway 10, 1.5 mi east of Three Forks, and 3.0 mi upstream from mouth.

Station 23--GALLATIN RIVER NEAR GALLATIN GATEWAY, MONT. (06043500)

LOCATION.--Lat 45°29'51", long 111°25'12", in SE1/4 SE1/4 SE1/4 sec. 7, T. 4 S., R. 4 E., Gallatin County, 0.3 mi downstream from Spanish Creek, and 7.3 mi south of Gallatin Gateway.

STATION 24--GALLATIN RIVER AT LOGAN, MONT. (06052500)

LOCATION.--Lat 45°53'07", long 111°26'15", in SE1/4 NW1/4 NE1/4 sec. 35, T. 2 N., R. 2 E., Gallatin County, at former county road bridge site, 0.5 mi west of Logan, and 6.0 mi upstream from mouth.

Station 25--SIXTEENMILE CREEK NEAR TOSTON, MONT. (06053400)

LOCATION.--Lat 46°07'02", long 111°21'41", in NE1/4 SE1/4 NW1/4 sec. 9, T. 4 N., R. 3 E., Broadwater County, at bridge on county road, 5.3 mi southeast of Toston.

Station 26--MISSOURI RIVER AT TOSTON, MONT. (06054500)

LOCATION.--Lat 46°08'46", long 111°25'11", in SE1/4 NW1/4 sec. 36, T. 5 N., R 2 E., Broadwater County, 2.2 mi southeast of Toston, 4.8 mi upstream from Crow Creek, and 7.8 mi downstream from Sixteenmile Creek.

Station 27--CROW CREEK NEAR RADERSBURG, MONT. (06055500)

LOCATION.--Lat 46°16'05", long 111°41'30", in SE1/4 sec. 14, T. 6 N., R. 1 W., Broadwater County, 1.5 mi upstream from Slim Sam Creek, and 6 mi northwest of Radersburg.

Station 28--MISSOURI RIVER BELOW CANYON FERRY DAM, NEAR HELENA, MONT. (06058502)

LOCATION.--Lat 46°38'58", long 111°43'39", in NW1/4 SE1/4 SE1/4 sec. 4, T. 10 N., R. 1 W., Lewis and Clark County, at penstock of No. 1 generator at Canyon Ferry Dam, and 15 mi east of Helena.

Table 3.--*Water-quality data for network stations*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; µg/L, micrograms per liter; lb/d, pounds per day; <, less than detection limit]

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temperature, air (°C)	Temperature, water (°C)	Arsenic, total recoverable (µg/L as As)	Arsenic discharge (lb/d)
		Station 1--GRASSHOPPER CREEK NEAR DILLON, MONT. (06015500)					
Nov 1985							
13...	1200	29	323	-6.5	0.0	3	0.47
May 1986							
28...	1630	140	259	27.0	21.0	6	4.5
		Station 2--BEAVERHEAD RIVER AT BARRETTS, MONT. (06016000)					
Nov 1985							
12...	1300	173	592	-10.0	1.5	6	5.6
Jan 1986							
16...	0740	178	605	-3.0	2.0	6	5.8
Mar							
13...	1025	214	560	3.0	5.0	6	6.9
Apr							
15...	1700	227	520	12.0	10.0	5	6.1
May							
14...	1215	227	540	7.0	8.0	6	7.4
28...	1545	863	529	27.5	16.0	3	14
Jun							
17...	1345	922	559	27.0	14.0	3	15
Jul							
02...	0830	760	590	16.5	12.0	4	16
23...	1245	993	562	24.0	17.0	3	16
Aug							
13...	0910	752	568	23.5	16.0	4	16
Sep							
16...	1615	286	526	18.0	13.0	6	9.3
Oct							
20...	1515	370	538	19.0	10.0	5	10
		Station 3--BLACKTAIL DEER CREEK AT DILLON, MONT. (06017600)					
Nov 1985							
13...	0930	22	635	-10.0	.5	3	.36
May 1986							
28...	1430	49	494	26.5	20.0	5	1.3

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Stream-flow, instan-taneous (ft³/s)	Specific conductance, laboratory (µS/cm)	Temper-ature, air (°C)	Temper-ature, water (°C)	Arsenic, total recov-erable (µg/L as As)	Arsenic discharge (lb/d)
Station 4--BEAVERHEAD RIVER NEAR TWIN BRIDGES, MONT. (06018500)							
Nov 1985							
13...	1300	430	688	-6.5	.0	4	9.3
Jan 1986							
16...	0900	338	664	-2.5	.0	5	9.1
Mar							
13...	0930	434	650	4.0	5.0	5	12
Apr							
15...	1545	352	667	16.0	9.0	5	9.5
May							
14...	1600	226	660	10.0	10.5	5	6.1
28...	1315	64	797	27.5	19.0	8	2.8
Jun							
17...	1450	192	758	28.5	20.0	6	6.2
Jul							
02...	0930	200	746	19.5	16.0	5	5.4
23...	1045	95	747	22.0	17.0	5	2.6
Aug							
13...	1005	174	728	18.5	15.5	6	5.6
Sep							
16...	1500	526	680	18.0	13.0	4	11
Oct							
20...	1415	530	619	19.0	8.5	4	11
Station 5--RUBY RIVER NEAR TWIN BRIDGES, MONT. (06023000)							
Nov 1985							
14...	1030	163	631	-6.0	.0	1	.88
Jan 1986							
15...	1650	165	724	.5	1.5	1	.89
Mar							
13...	0820	193	617	1.5	4.5	1	1.0
Apr							
15...	1215	169	613	15.0	8.0	2	1.8
May							
13...	1345	208	632	18.5	8.5	2	2.2
27...	1830	163	538	26.0	21.0	2	1.8
Jun							
17...	0900	313	553	20.0	15.0	2	3.4
Jul							
02...	1100	180	679	25.0	17.0	2	1.9

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Streamflow, instantaneous (ft³/s)	Specific conductance, laboratory (µS/cm)	Temperature, air (°C)	Temperature, water (°C)	Arsenic, total recoverable (µg/L as As)	Arsenic discharge (lb/d)
Station 5--RUBY RIVER NEAR TWIN BRIDGES, MONT. (06023000)--Continued							
July 1986							
23...	1115	111	648	30.0	17.0	2	1.2
Aug							
13...	1230	120	653	28.5	18.5	2	1.3
Sep							
16...	1215	322	662	18.0	10.0	2	3.5
Oct							
20...	1200	215	639	12.5	7.0	2	2.3
Station 6--BIG HOLE RIVER NEAR TWIN BRIDGES, MONT. (06026400)							
Nov 1985							
13...	1530	380	270	-3.0	.0	1	2.1
Jan 1986							
16...	1120	321	222	-2.0	.0	<1	<1.7
Mar							
13...	1240	922	160	8.0	5.5	1	5.0
Apr							
15...	1500	1,920	127	16.0	7.0	2	21
May							
13...	1250	2,510	114	15.5	8.0	1	14
28...	0800	4,330	83	15.0	12.0	<1	<23
Jun							
17...	1130	2,310	129	26.0	17.0	2	25
Jul							
01...	1715	839	193	26.0	21.0	2	9.1
23...	1230	564	198	28.0	22.0	1	3.0
Aug							
13...	1100	128	245	29.0	18.5	1	.69
Sep							
16...	1345	514	237	23.0	13.0	2	5.6
Oct							
20...	1330	550	198	15.0	7.5	2	5.9
Station 7--BIG PIPESTONE CREEK AT WHITEHALL, MONT. (06028700)							
Nov 1985							
14...	1230	8.4	673	-1.0	.0	5	.23
May 1986							
27...	1600	10	334	25.0	26.0	5	.27

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Stream-flow, instan-taneous (ft³/s)	Specific conductance, laboratory (μS/cm)	Temper-ature, air (°C)	Temper-ature, water (°C)	Arsenic, total recov-erable (μg/L as As)	Arsenic discharge (lb/d)
Station 8--BOULDER RIVER NEAR CARDWELL, MONT. (06033900)							
Nov 1985							
14...	1400	79	337	-1.0	.5	7	3.0
Jan 1986							
16...	1510	73	327	6.0	3.0	6	2.4
Mar							
13...	1430	167	251	9.5	5.0	9	8.1
Apr							
15...	0830	238	194	4.0	4.0	13	17
May							
13...	0710	285	209	8.0	8.0	12	18
27...	1336	646	140	23.5	18.0	38	133
Jun							
17...	1845	190	246	29.0	23.0	22	23
Jul							
02...	1300	77	368	27.0	20.0	15	6.2
23...	1430	65	396	22.5	21.0	9	3.2
Aug							
14...	1200	28	382	27.0	18.0	8	1.2
Sep							
16...	0845	85	363	10.0	11.0	10	4.6
Oct							
20...	0945	116	304	2.0	6.0	8	5.0
Station 9--SOUTH BOULDER RIVER NEAR CARDWELL, MONT. (06034300)							
Nov 1985							
14...	1515	26	266	-2.0	.0	<1	<.14
Jan 1986							
16...	1400	16	247	6.0	.0	<1	<.09
Mar							
13...	1525	23	253	5.5	7.0	<1	<.12
Apr							
15...	0930	24	231	8.0	4.0	1	.13
May							
13...	0830	47	200	9.0	4.5	<1	<.25
27...	1500	120	131	26.0	14.5	<1	<.65
Jun							
17...	1730	116	140	29.5	13.5	<1	<.63
Jul							
02...	1400	43	239	29.5	15.0	<1	<.23

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temper-ature, air (°C)	Temper-ature, water (°C)	Arsenic, total recov-erable (µg/L as As)	Arsenic discharge (lb/d)
Station 9--SOUTH BOULDER RIVER NEAR CARDWELL, MONT. (06034300)--Continued							
Jul 1986							
23...	1510	13	355	22.5	19.5	<1	<.07
Aug							
12...	1155	5.2	455	19.0	15.5	<1	<.03
Sep							
16...	0945	6.2	454	13.0	8.0	<1	<.03
Oct							
20...	1045	29	257	4.0	5.0	<1	<.16
Station 10--WILLOW CREEK NEAR WILLOW CREEK, MONT. (06036500)							
Nov 1985							
14...	1645	8.7	419	-8.0	.0	1	.05
May 1986							
29...	1135	153	224	22.0	18.0	<1	<.83
Station 11--JEFFERSON RIVER NEAR THREE FORKS, MONT. (06036650)							
Nov 1985							
14...	1645	1,700	563	-4.0	.0	3	28
Jan 1986							
14...	1130	1,240	504	-10.0	.0	3	20
Mar							
11...	1250	2,140	406	14.0	7.5	4	46
Apr							
15...	1230	2,780	289	15.0	7.5	4	60
May							
15...	0720	2,780	282	4.0	8.0	4	60
29...	1600	6,820	183	35.0	19.0	10	368
Jun							
17...	1150	3,780	273	30.0	19.0	4	82
30...	1230	1,540	416	21.5	20.0	4	33
Jul							
23...	1610	1,130	403	30.5	24.5	2	12
Aug							
14...	1110	665	487	24.0	15.0	3	11
Sep							
17...	1730	1,960	498	20.0	14.0	3	32
Oct							
22...	1215	1,970	461	13.0	7.0	3	32

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temperature, air (°C)	Temperature, water (°C)	Arsenic, total recoverable (µg/L as As)	Arsenic discharge (lb/d)
Station 16--MADISON RIVER BELOW HEBGEN LAKE, NEAR GRAYLING, MONT. (06038500)							
Nov 1985							
13...	1110	1,390	270	-6.0	3.0	120	901
Jan 1986							
15...	1200	868	357	-11.0	2.0	170	797
Mar							
12...	1200	1,020	360	4.5	2.0	180	991
Apr							
16...	1300	1,200	334	2.0	3.0	160	1,040
May							
14...	0820	1,520	267	-1.5	3.5	120	985
28...	1530	1,440	263	37.0	9.5	110	855
Jun							
16...	1400	2,550	243	25.0	11.0	90	1,240
Jul							
01...	0845	1,500	225	12.0	13.0	78	632
22...	1530	1,170	217	28.5	19.0	86	543
Aug							
12...	0820	993	223	11.0	15.0	89	477
Sep							
17...	1000	1,640	229	9.0	13.0	100	886
Oct							
21...	1100	1,780	252	5.0	9.0	110	1,060
Station 17--WEST FORK MADISON RIVER NEAR CAMERON, MONT. (06039200)							
Nov 1985							
13...	1320	61	239	1.5	.0	<1	<.33
Jan 1986							
15...	1400	57	183	1.0	.5	<1	<.31
Mar							
12...	1330	61	239	6.0	4.5	1	.33
Apr							
16...	0900	78	240	3.5	3.0	1	.42
May							
14...	0700	123	224	-1.5	3.5	1	.66
28...	1430	818	150	27.0	8.5	2	8.8
Jun							
16...	1600	257	192	27.0	14.5	<1	<1.4
Jul							
01...	1030	121	232	19.0	11.0	<1	<.65

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temper-ature, air (°C)	Temper-ature, water (°C)	Arsenic, total recov-erable (µg/L as As)	Arsenic discharge (lb/d)
Station 17--WEST FORK MADISON RIVER NEAR CAMERON, MONT. (06039200)--Continued							
Jul 1986							
22...	1645	84	228	30.0	20.5	<1	<.45
Aug							
12...	0715	68	241	8.5	12.0	1	.37
Sep							
17...	0915	68	242	8.0	7.0	<1	<.37
Oct							
21...	1015	62	244	12.5	6.0	<1	<.33
Station 18--MEADOW CREEK NEAR MCALLISTER, MONT. (06040400)							
Nov 1985							
13...	1650	48	252	-5.0	1.0	<1	<.26
May 1986							
28...	1000	33	248	15.0	12.0	<1	<.18
Station 19--MADISON RIVER BELOW ENNIS LAKE, NEAR MCALLISTER, MONT (06041000)							
Nov 1985							
13...	1525	1,730	296	-2.0	1.0	74	691
Jan 1986							
15...	0910	1,490	338	4.0	1.0	77	620
Mar							
12...	1630	1,520	312	10.0	4.5	94	772
Apr							
16...	1000	1,800	348	7.5	6.0	100	972
May							
13...	1630	2,270	308	15.5	7.5	78	956
28...	1145	3,750	272	18.0	12.0	73	1,480
Jun							
16...	1840	4,700	225	26.0	14.0	49	1,240
Jul							
01...	1315	2,540	247	23.0	19.5	50	686
23...	0900	1,800	259	15.5	19.5	52	505
Aug							
12...	1010	1,460	265	22.0	18.5	74	583
Sep							
18...	1145	142	268	7.5	12.0	64	49
Oct							
21...	0830	2,340	279	1.0	7.5	68	859

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temper-ature, air (°C)	Temper-ature, water (°C)	Arsenic, total recov-erable (µg/L as As)	Arsenic discharge (lb/d)
Station 20--HOT SPRINGS CREEK NEAR NORRIS, MONT. (06041300)							
Nov 1985							
14...	0835	6.0	429	-7.0	.0	1	.03
May 1986							
29...	1000	21	226	20.5	9.5	22	2.5
Station 21--CHERRY CREEK NEAR NORRIS, MONT. (06041700)							
Nov 1985							
14...	0950	20	264	-5.0	.0	1	.11
May 1986							
29...	0915	237	72	18.0	9.0	2	2.6
Station 22--MADISON RIVER AT THREE FORKS, MONT. (06042600)							
Nov 1985							
15...	1045	1,890	322	-10.0	.0	75	765
Jan 1986							
14...	1330	1,600	346	-7.0	.0	69	596
Mar							
11...	1520	1,670	306	16.0	9.0	69	622
Apr							
17...	1230	2,020	342	10.0	8.0	87	949
May							
14...	1400	2,370	297	11.0	8.0	76	973
29...	1440	4,720	249	33.0	19.0	61	1,550
Jun							
17...	0830	4,580	230	30.0	16.0	45	1,110
30...	1445	2,550	244	23.0	21.5	50	689
Jul							
22...	1100	1,730	265	24.5	19.5	54	504
Aug							
14...	0900	1,370	272	22.0	18.5	69	510
Sep							
17...	1615	2,400	265	13.0	23.0	67	868
Oct							
22...	1115	2,360	278	12.5	6.5	64	816

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Streamflow, instantaneous (ft³/s)	Specific conductance, laboratory (µS/cm)	Temperature, air (°C)	Temperature, water (°C)	Arsenic, total recoverable (µg/L as As)	Arsenic discharge (lb/d)
Station 23--GALLATIN RIVER NEAR GALLATIN GATEWAY, MONT. (06043500)							
Nov 1985							
14...	1245	394	318	-2.0	.0	<1	<2.1
Jan 1986							
14...	1130	358	338	3.0	.0	<1	<1.9
Mar							
12...	0800	342	328	3.0	5.0	<1	<1.8
Apr							
16...	1700	535	288	6.0	7.0	<1	<2.9
May							
14...	1000	905	251	7.0	4.0	<1	<4.9
28...	1750	4,210	112	30.0	10.0	<1	<23
Jun							
16...	1115	3,600	145	21.0	8.0	<1	<19
30...	1730	1,600	198	21.5	13.5	<1	<8.6
Jul							
22...	1320	798	218	28.5	14.0	<1	<4.3
Aug							
14...	1340	555	286	27.0	18.5	<1	<3.0
Sep							
17...	1245	470	291	13.0	8.0	<1	<2.5
Oct							
22...	0800	472	311	-1.0	4.0	1	2.5
Station 24--GALLATIN RIVER AT LOGAN, MONT. (06052500)							
Nov 1985							
14...	1600	785	393	-2.0	1.0	1	4.2
Jan 1986							
14...	1520	689	403	-10.0	.0	<1	<3.7
Mar							
11...	1645	893	401	16.0	9.5	1	4.8
Apr							
17...	0930	946	382	8.0	7.0	1	5.1
May							
14...	1310	1,240	333	10.0	8.0	1	6.7
29...	1245	4,880	204	33.0	12.5	2	53
Jun							
16...	0900	3,980	204	18.0	12.0	<1	<21
30...	1545	1,400	308	25.5	18.5	<1	<7.6

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temper-ature, air (°C)	Temper-ature, water (°C)	Arsenic, total recov-erable (µg/L as As)	Arsenic discharge (lb/d)
Station 24--GALLATIN RIVER AT LOGAN, MONT. (06052500)--Continued							
Jul 1986							
22...	1145	696	365	22.5	20.5	<1	<3.8
Aug							
14...	1500	531	404	29.0	19.0	1	2.9
Sep							
17...	1415	1,010	393	20.0	13.0	<1	<5.5
Oct							
22...	0915	918	389	-0.5	6.0	<1	<5.0
Station 25--SIXTEENMILE CREEK NEAR TOSTON, MONT. (06053400)							
Nov 1985							
15...	1115	30	587	-5.0	.0	1	.16
May 1986							
30...	1130	144	403	27.5	17.0	1	.78
Station 26--MISSOURI RIVER AT TOSTON, MONT. (06054500)							
Nov 1985							
15...	1220	3,410	418	-1.0	.0	37	681
Jan 1986							
14...	1315	3,450	414	2.0	1.0	36	671
Mar							
13...	1710	4,730	374	10.5	7.0	30	766
Apr							
17...	1400	5,650	343	14.0	9.0	35	1,070
May							
15...	0930	6,260	304	10.0	8.5	26	879
30...	0850	15,800	216	20.0	17.0	24	2,050
Jun							
17...	1000	11,400	242	26.0	18.0	22	1,350
30...	1015	4,900	309	20.0	20.0	27	714
Jul							
24...	1100	2,740	336	25.0	23.0	30	444
Aug							
13...	1600	2,040	353	24.0	20.0	40	441
Sep							
18...	1115	5,130	382	8.0	13.0	32	886
Oct							
22...	1330	5,160	371	20.0	8.0	33	920

Table 3.--*Water-quality data for network stations*--Continued

Date	Time	Stream-flow, instantaneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temperature, air (°C)	Temperature, water (°C)	Arsenic, total recoverable (µg/L as As)	Arsenic discharge (lb/d)
Station 27--CROW CREEK NEAR RADERSBURG, MONT. (06055500)							
Nov 1985							
15...	1415	20	98	1.0	.0	<1	<.11
May 1986							
30...	1005	364	50	25.0	7.0	1	2.0
Station 28--MISSOURI RIVER BELOW CANYON FERRY DAM, NEAR HELENA, MONT. (06058502)							
Nov 1985							
15...	1330	5,500	368	1.5	7.5	30	891
Jan 1986							
14...	1530	5,260	385	-2.5	4.0	30	852
Mar							
11...	1030	5,450	402	19.0	3.0	34	1,000
Apr							
17...	1545	4,040	422	14.0	6.0	31	676
May							
15...	1100	6,640	394	15.0	6.5	27	968
Jun							
02...	0922	6,690	383	25.0	9.0	27	975
18...	0750	10,100	373	19.0	9.0	28	1,530
30...	0845	6,080	371	14.0	9.5	26	854
Jul							
24...	0905	5,580	352	22.0	11.0	22	663
Aug							
14...	0930	5,400	320	15.5	14.5	32	933
Sep							
18...	1330	5,060	329	12.5	15.5	26	710
Oct							
22...	1445	5,490	341	16.0	11.0	25	741

Table 4.--*Water-quality data for miscellaneous stations*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; µg/L, micrograms per liter; lb/d, pounds per day]

Date	Time	Stream-flow, instantaneous (ft^3/s)	Specific conductance, laboratory (µS/cm)	Temperature, air (°C)	Temperature, water (°C)	Arsenic, total recoverable (µg/L as As)	Arsenic discharge (lb/d)
Station 12--Firehole River near West Yellowstone, Mont. (06036905; lat 44°37'13" N, long 110°51'45" W)							
Oct 1986							
21...	1415	335	439	19.5	16.5	270	488
Station 13--Gibbon River near West Yellowstone, Mont. (06037000; lat 44°39'00" N, long 110°47'40" W)							
Oct 1986							
21...	1345	92	344	12.0	12.0	130	65
Station 14--Madison River near West Yellowstone, Mont. (06037500; lat 44°39'25" N, long 111°04'03" W)							
Mar 1986							
12...	1030	566	464	5.0	9.0	300	917
Oct							
21...	1515	525	416	19.5	14.0	220	624
Station 15--South Fork Madison River above Denny Creek, near West Yellowstone, Mont. (06037700; lat 44°40'50" N, long 111°11'35" W)							
Oct 1986							
21...	1230	134	81	23.0	7.5	<1	<.72