Nutrient Sources in the Clark Fork River Basin

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Abstract

Under Section 525 of the 1987 amendments to the federal Clean Water Act, Montana initiated an intensive monitoring program to identify and rank the major point and nonpoint sources of nutrients to the Clark Fork River. A 51 station monitoring network was established, including 19 stations on the Clark Fork River, 22 stations on tributary streams, and 10 municipal and industrial wastewater discharges to the river. In the first year of monitoring, samples were collected 15 times and analyzed for total and soluble forms of phosphorus and nitrogen.

Several small tributaries to the upper Clark Fork (Gold, Flint, Lost, Racetrack, and Dempsey creeks and the Mill-Willow Bypass) and all 10 wastewater discharges exhibited elevated nutrient concentrations. The Missoula, Butte, and Deer Lodge municipal wastewater discharges were responsible for the largest nutrient concentrations in the Clark Fork. Inflows from good quality tributaries such as Rock Creek and the Blackfoot, Little Blackfoot, Bitterroot, and Flathead rivers were important in diluting nutrient concentrations in the Clark Fork.

Overall, soluble phosphorus loading to the Clark Fork originated about equally from tributary inflows and wastewater discharges. About two-thirds of the soluble nitrogen loading came from tributaries, with effluents contributing the remaining third. During the summer low flow period, an even greater share of the soluble nutrient loading came from effluents.

Tributary sources of soluble nutrient loading were dominated by the Flathead, Bitterroot, and Blackfoot rivers. Gold and Flint creeks ranked fourth in importance as tributary sources of soluble phosphorus and nitrogen, respectively.

The Missoula, Butte, and Deer Lodge municipal wastewater treatment plants and the Stone Container Corporation kraft mill discharged most of the soluble nutrient loading from effluents. However, the Warm Springs treatment ponds on Silver Bow Creek removed most of the Butte nutrient load prior to reaching the Clark Fork River.

Introduction

In 1987, the Section 525 amendments to the federal Clean Water Act authorized a comprehensive water quality assessment of the Clark Fork/Pend Oreille Basin, which encompasses a three-state area. Funding was appropriated for a three-year study beginning in 1988. Montana, Idaho and Washington were each directed to conduct water quality evaluations in portions of the drainage basin within their states and a steering committee was established to coordinate the interstate project.

Because of a growing concern over nutrient pollution in the basin and limitations in the available data, a plan was developed to identify, monitor and rank the major point and nonpoint sources of nutrients to the Clark Fork River in Montana. The upper and middle reaches of the Clark Fork are some of the most productive stream waters in Montana west of the Continental Divide from the standpoint of nutrient concentrations and the potential to grow algae (Bahls et al., 1979a. 1979b). Elevated concentrations of phosphorus and nitrogen stimulate the growth of nuisance levels of attached algae, which negatively affect the use of well over 100 miles of the river (MDHES. 1990). Dense algal mats reduce dissolved oxygen levels in the Clark Fork, impair aesthetics, and impede irrigation and recreation (MDHES. 1988a. Johnson and Schmidt. 1988; Ingman and Kerf .1989a).

In the lower Clark Fork, concerns have focused on nutrient loading to Idaho’s Lake Pend Oreille, which has exhibited subtle signs of eutrophication in recent years (Watson. 1985; MDHES. 1985; Johnson and Schmidt. 1988; IDOHW .1989). The Clark Fork provides greater than 90 percent of the lake's inflow.

The Section 525 study emphasizes the nutrient problem in the Clark Fork/Pend Oreille Basin because it is the primary interstate issue. Additionally, it was recognized that the 525 study would provide the resources to assess the nutrient problem on a basin-wide scale. Goals of the project include: I) investigating the sources and fates of nutrients in the basin, 2) quantifying the extent and severity of eutrophication problems, and 3) the recommending of appropriate control measures. The objectives of Montana's Clark Fork Basin nutrient source assessment are to:

- Document nutrient concentrations and loads in the Clark Fork from its headwaters to Idaho.
- Document nutrient contributions from tributaries and waste- water discharges.
- Identify the most important sources of nutrients.
- Identify controllable sources of nutrients.

Methods

Water quality data was collected approximately 15 times during the year (monthly from July 1988 through March 1989, excluding February, and twice monthly from April through June 1989) at 51 stations in the Clark Fork Basin. The monitoring network included 19 stations on the Clark Fork River, 22 stations on tributary streams, and 10 municipal and industrial wastewater discharges (Table 1 and Figure 1). Tributaries were selected on the basis of size, the suspected or known and presence of significant nutrient sources within the watershed, and the presence of active U S. Geological Survey stream flow gaging stations (MDHES, 1988b). Collectively, the tributaries accounted for about three-fourths of the stream flow in the Clark Fork at the Idaho border, based on annual mean discharges. Thus, the majority of potential nonpoint source contributions of nutrients from tributary watersheds were inventoried. The wastewater discharges represented the majority of those present in the basin. Four municipal discharges (Towns of Phillipsburg, Lolo Stevensville, Hamilton) were not sampled. However, all four discharge to either Flint Creek or the Bitterroot River -tributaries that were included in the monitoring network.

Grab-samples for nutrient analysis were collected at each monitoring station during each visit. Subsamples for dissolved nutrients were filtered on site. Samples were stored on ice and delivered to the laboratory for analysis within 48 hours of collection. All sample collection, handling, preservation, and storage procedures followed EPA-approved methods (Table 2).

Discharge rates for effluents were measured at the time of sample collection with the primary flow measuring device located at each outfall (weir, flume, or totalizer). Mainstem and tributary streamflows were gaged with standard streamflow gaging equipment at the time of sampling, except for those locations where USGS gaging stations were present.

Nutrient samples were analyzed by the Montana Department of Health Chemistry Laboratory Bureau. Variables analyzed included dissolved orthophosphate (or soluble reactive phosphorus), dissolved nitrate plus nitrite nitrogen, dissolved ammonia nitrogen, total phosphorus, and total Kjeldahl nitrogen. The Stone Container Corporation wastewater proved to be unfilterable and was analyzed for total forms of all the above nutrient variables. Analytical methods and detection limits are summarized in Table 2. Extensive field and laboratory quality assurance measures were employed to insure the integrity of the nutrient data. These included 1) acid-washing of all sample collection and filtration equipment, 2) the use of standardized sample collection procedures, 3) analysis of field-originated filter blanks and blind duplicate samples, and 4) analysis of lab originated duplicates, spikes, known standards, and EPA audit samples (Ingman and Kerr, 1989a; MDHES 1988c).

Analytical results were used to tabulate concentration ranges and means for total and soluble phosphorus (P) and nitrogen (N). Soluble P was measured as soluble reactive phosphorus (SRP). Total N was computed by summing total Kjeldahl nitrogen and dissolved nitrate plus nitrite nitrogen concentrations. Soluble nitrogen (TSIN) was computed by summing dissolved nitrate plus nitrite nitrogen dissolved ammonia nitrogen concentrations. Mean daily nutrient loads were computed for the entire year (July through June) and for the summer period only (July through September).

Results and Discussion

Nutrient Concentrations

Nutrient concentrations were used to evaluate water quality at each mainstem, tributary, and effluent station. They are an important factor controlling the distribution and abundance of attached algae in the Clark Fork River (Watson, 1990).

Nutrient concentrations in the Clark Fork River were highly variable spatially temporally (Table 3 and Figure 2). In general, mean concentrations declined with increasing distance downstream from wastewater discharges. An initial decline in mean concentrations in the upper Clark Fork was attributable to increasing distance from the Butte municipal wastewater treatment plant (WWTP) discharge to Silver Bow Creek and increased dilution from incoming tributaries.

Notable increases in P concentrations and the highest mean concentrations found anywhere in the river occurred immediately downstream of the Deer Lodge and Missoula municipal WWTP discharges, at stations 10 and 18, respectively. Highest mean N concentrations were found in the extreme headwaters, downstream of several tributaries to the upper Clark Fork (station 9), and below the Deer Lodge and Missoula WWTPs (stations 10 and 18, respectively). Smaller increases in mean p and N concentrations were observed at station 22, downstream from the Stone Container Corporation kraft mill discharge. Lowest mean P concentrations were measured in reaches of the Clark Fork immediately above Deer Lodge and Missoula (stations 9 and 16 respectively) and in the lower Clark Fork below the Flathead River confluence (stations 27-30). Lowest N concentrations were found above Missoula (stations 15-16) and below the Flathead River. Tributary inflows from Rock Creek (entering the river between stations 12and

13), and the Little Blackfoot (bracketed by stations 10and 11), Blackfoot (stations 13 to 15), Bitterroot (stations 18 to 20), and Flathead rivers (stations 25 to 27) caused notable decreases in mean Clark Fork nutrient concentrations.

The EPA total P criterion of 50 ug/l, which is a general guideline recommended to control excessive developments of attached algae and to prevent accelerated eutrophical of lakes (U.S. EPA, 1986), was commonly exceeded in the Clark Fork from its headwaters downstream to Bonita (station 12) (Table 3 and Figure 2A). The Clark Fork downstream to Bonita harbored dense growths of attached filamentous algae (Cladophora) and is known to suffer from seasonal depressions in dissolved oxygen concentrations (Watson, 1989a). Mean total P concentrations also regularly exceeded the EPA criterion in the river immediately below Missoula. The river here supports dense growths of diatom algae and also experiences reduced dissolved oxygen levels during summer low flows (Kerr, 1988; Watson, 1989b).

The EPA criterion for TSIN of 1000 ug/l (water quality criteria matrix in MDHES 1986), which has been recommended to prevent nuisance instream levels of algae, was never exceeded in the Clark Fork (Table 3 and Figure 2).

Nutrient criteria for the control of Nuisance attached algae in the Clark Fork River have recently been proposed (Watson et al., this volume). Based on artificial stream experiments, the maximum standing crops of certain attached algae communities increases with nutrient additions up to about 30 ug/l SRP and 250 ug/l TSIN. Above these levels more nutrients do not appear to produce higher standing crops. Below these nutrient levels, attached algae levels may be controlled by nutrients. In 1988, from July to September (when algal standing crops generally reach their peaks), mean SRP concentrations exceeded the criterion at only four monitoring locations in the river (Figure 3A). Summer mean TSIN concentrations in the Clark Fork newver exceeded the criterion at any station although it was closely approached at Deer Lodge (Figure 3B). These data suggest that summer algae standing crops might be reduced in many reaches of the Clark Fork through nutrient control measures.

Concentrations of P and N in Clark Fork tributaries provided evidence of additional nutrient sources. Nutrient concentrations in Silver Bow Creek below Butte (stations O1-03) were an order of magnitude larger than at all other monitoring stations in the Clark Fork Basin. The source of those nutrients was the Butte WWTP discharge and the problem was inadequate dilution. On average the Butte WWTP discharge nearly doubled the volume of flow in Silver Bow Creek. Silver Bow Creek does not support nuisance growths of algae because of the presence of toxic levels of heavy metals (Greene et al, 1986; Ingman and Ken, 1990). Nutrient concentrations in lower Silver Bow Creek were greatly reduced as a result of treatment provided by the Warm Springs Ponds before discharging to the Clark Fork headwaters. However, they remained noticeably higher than in other Clark Fork tributaries.

Gold Creek and Flint Creek exhibited elevated soluble P concentrations relative to other Clark Fork tributaries. Gold Creek crosses the geologic Phosphoria and Cabbage Patch formations (Carey) 1989; Ingman and Bahls) 1979) and P sources are at least in part) natural. Flint Creek receives the Phillipsburg WWTP discharge and is a heavily irrigated agricultural subbasin (Johnson and Schmidt) 1988). Tributaries Lo the Clark Fork below Missoula had the lowest P concentrations.

Most tributaries to upper Clark Fork, and especially the Mill- Willow creeks bypass, Lost Creek, Racetrack Creek, and Dempsey Creek contained elevated mean concentrations of soluble N. The Mill-Willow Bypass flows adjacent to an unsewered suburb of Anaconda (Opportunity) with a shallow groundwater

table. The other streams drain heavily irrigated agricultural areas and their quality was seasonally variable as a result of agricultural dewatering and irrigation return flows. Cottonwood Creek, the Little Blackfoot River, Rock Creek, and tributaries to the lower Clark Fork contained the lowest N concentrations.

All of the monitored wastewater discharges to the Clark Fork contained very high concentrations of P and N (Table 3). The Stone kraft mill discharge contained some of the lowest nutrient concentrations relative to the other point source discharges. Its quality reflected extensive efforts by management over the previous five years to reduce nutrient levels in the effluent (Stone Container Corporation, 1990; Ingman and Ken, 1989b). The Missoula WWTP discharge contained some of the highest nutrient concentrations P concentrations in this wastewater have subsequently been reduced by nearly half following the adoption in May 1989 of a county-wide phosphorus detergent ban (Aldegarie, 1990). Most sampling was done prior to this ban.

Nutrient Loads

Nutrient loads define the quality of nutrients discharged by the river, it tributaries, and effluents per unit of time. Nutrient loads were used to identify and rank the most important sources of nutrients in the Clark Fork Basin from the standpoint of controlling nuisance algae. They are also an important consideration in assessing the trophic status, or state of enrichment, of lakes. Because lakes such as Pend Oreille have long hydraulic retention times, the overall rate of nutrient loading has a strong influence on a lake's ability to grow & algae.

On a year-round basis, nutrient loading to the Clark Fork River appeared to be dominated by a handful of tributaries and wastewater discharges (Table 4 and Figure 5). Of the Clark Fork tributaries monitored, the Flathead, Bitterroot, and Blackfoot rivers contributed the bulk of soluble nutrients. Nutrient concentration in these rivers were low, but because they are the largest tributaries to the Clark Fork, their cumulative loadings were sizeable. Gold Creek discharged a substantial SRP load compared to many of the other Clark Fork tributaries, despite its small size (annual mean discharge for this period was 32.5 cubic feet per second). The TSI loads contributed by Flint Creek and by Silver Bow Creek via the Pond Two discharge were also noteworthy.

Nutrient loadings from effluents were clearly dominated by the Missoula and Butte WWTP discharges. The Deer Lodge WWTP and Stone kraft mill discharge contributed smaller loads of soluble nutrients. The remaining six monitored municipal discharges, even collectively, were responsible for only a small fraction of the measured nutrient loading from effluents.

Summer soluble nutrient loading (mean for months July through September) was computed to determine which sources were likely to be most important in supporting the dense summer growths of attached algae in the Clark Fork River (Figure 6). This loading was clearly dominated by effluents. Overall, effluents where contributed 75 and 38 percent of the SRP and TSIN loading. In the upper Clark Fork, where attached algae densities reach peak proportions, wastewater discharges provided 56 and 57 percent of the SRP and TSIN loading, if loading from the Butte WWTP via the Pond Two discharge is considered. The single largest effluent source of nutrient loading to the upper Clark Fork was the Deer Lodge WWTP. Wastewater discharges provided 93 and 42 percent of the SRP and TSIN loading to the middle Clark Fork, with most coming from the Missoula WWTP. In the lower Clark Fork, where attached

algae are not a common problem, most soluble nutrient loading came from the Flathead River, with effluents contributing one percent or less of the total.

Conclusions and Management Implications

Tables 5 and 6 give summary rankings to the Clark Fork tributaries and wastewater discharges on the basis of quality (nutrient concentrations) and quantity (loads) of nutrients discharged to the Clark Fork River. All of the wastewater discharges, Silver Bow Creek, and several other tributaries to the upper Clark Fork contained elevated concentrations of nutrients. While nutrient loading from some of the smaller, upper Clark Fork tributaries are relatively small, their nutrient-rich inflows probably supported localized developments of nuisance algae in their mixing zones. These tributaries included Gold, Flint, Lost, Dempsey, and Racetrack creeks and possibly the Mill-Willow Bypass.

The Missoula, Deer Lodge and Butte WWTP discharges were the sources most responsible for elevated soluble nutrient concentrations in the Clark Fork River. They also provided the largest share of soluble nutrient loading to the reaches where, and during the times of year when, algae problems are most prevalent. As such, efforts to reduce instream nutrient concentrations to control nuisance algae should initially focus on these sources. The Missoula County phosphorus detergent ban is a large step in this direction.

Inflows from tributaries with low nutrient concentrations were important in diluting soluble nutrient concentrations in the river. Thus, preserving adequate stream flows in tributaries should be an integral part of efforts to reduce instream concentrations.

Overall, SRP loading from tributaries nearly equalled that contributed by effluents (Figure 8). About two-thirds of the TSIN loading came from the tributaries, with the remaining third originating from wastewater discharges. During the low flow summer period, point source discharges were responsible for most of the SRP and nearly half of the TSIN loading.

Tributary sources of soluble nutrient loading were dominated by the Flathead, Bitterroot and Blackfoot rivers (Figure 9). Gold Creek appeared to be the fourth most important tributary source of soluble phosphorus loading. Flint Creek was a significant source of soluble nitrogen loading.

The Missoula, Butte and Deer Lodge WWTPs and the Stone Container Corporation kraft mill discharged the majority of the soluble nutrient loading from effluents (Figure 10). Most of the nutrient load from Butte was removed in the Warm Springs treatment ponds on Silver Bow Creek prior to reaching the Clark Fork River. Nutrient loading from the Missoula WWTP has declined since this study was undertaken, as a result of the countywide phosphorus ban.

It is reasonable to assume that a sizeable percentage of the nutrient loading to Lake Pend Oreille from the Clark Fork River originated from wastewater discharges, considering the relative importance of wastewater nutrient loading throughout the Clark Fork watershed. Our data indicate that, prior to the Missoula County phosphorus ban, the Missoula WWTP was the single largest effluent source of soluble nutrient loading to the Clark Fork. Consequently, we are convinced that the phosphorus detergent ban, put into effect in 1989, was the single most effective measure that could have been taken to reduce soluble nutrient loads from the Clark Fork to Lake Pend Oreille.

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Table 1: Fiscal year 1989 Clark Fork Basin Nutrient Monitoring Stations

Station Number/ Abbreviation *		Station Name
I. Mainstem Stations		
07		Clark Fork below Warm Springs Creek
08		Clark Fork near Dempsey
09		Clark Fork at Deer Lodge
10		Clark Fork above Little Blackfoot River
11		Clark Fork at Gold Creek Bridge
12		Clark Fork at Bonita
13		Clark Fork at Turah
15		Clark Fork below Milltown Dam
16		Clark Fork above Missoula WWTP
18		Clark Fork at Shuffield's
20		Clark Fork at Harper Bridge
22		Clark Fork at Huson
23		Clark Fork near Alberton
24		Clark Fork at Superior
25		Clark Fork above Flathead River
27		Clark Fork above Thompson Falls Reservoir
28		Clark Fork below Thompson Falls Dam
29		Clark Fork at Noxon Bridge
30		Clark Fork below Cabinet Gorge Dam
II. Tributaries		
00		Silver Bow Creek above Butte WWTP
01		Silver Bow Creek below Colorado Tailings
02		Silver Bow Creek at Miles Crossing near Ramsay
03		Silver Bow Creek above Warm Springs Ponds
04	PD2	Discharge from AMC Pond 2 (Silver Bow Creek)
05	MW	Mill-Willow Bypass at mouth
06	WS	Warm Springs Creek near mouth
07.3	LC	Lost Creek near mouth
08.3	RT	Racetrack Creek near mouth
08.7	DC	Dempsey Creek near mouth
09.3	CC	Cottonwood Creek near mouth
10.2	LB	Little Blackfoot River at USGS station near mouth
10.5	WS	Warm Springs Creek (near Phosphate) near mouth
10.7	GC	Gold Creek near mouth
11.5	FC	Flint Creek near mouth
12.5	RC	Rock Creek at USGS station near mouth
14	BL	Blackfoot River at USGS Station near mouth
18.5	BI1	Bitterroot River at HW93 crossing
19	BI2	Bitterroot River near mouth
26	FH	Flathead River near mouth
27.5	TH	Thompson River at USGS station near mouth
27.7	PC	Prospect Creek at USGS station near mouth
III. Point Source Discharges		
00.5	BUT	Butte Metro WWTP discharge
06.5	WMSP	Warm Springs lagoon discharge
07.7	GAL	Galen WWTP discharge
09.5	DLG	Deer Lodge lagoon discharge
11.6	DRUM	Drummond lagoon discharge
17	MSLA	Missoula WWTP discharge
21	STONE	Stone Container Corporation wastewater discharge
23.5	ALB	Alberton lagoon discharge
24.5	SUP	Superior lagoon discharge
27.6	TFLS	Thompson Falls lagoon discharge

* Station abbreviations are used to identify tributary and point source discharge monitoring stations in the data plots included in this report. Station numbers are used to identify mainstem Clark Fork monitoring stations.

Figure 1

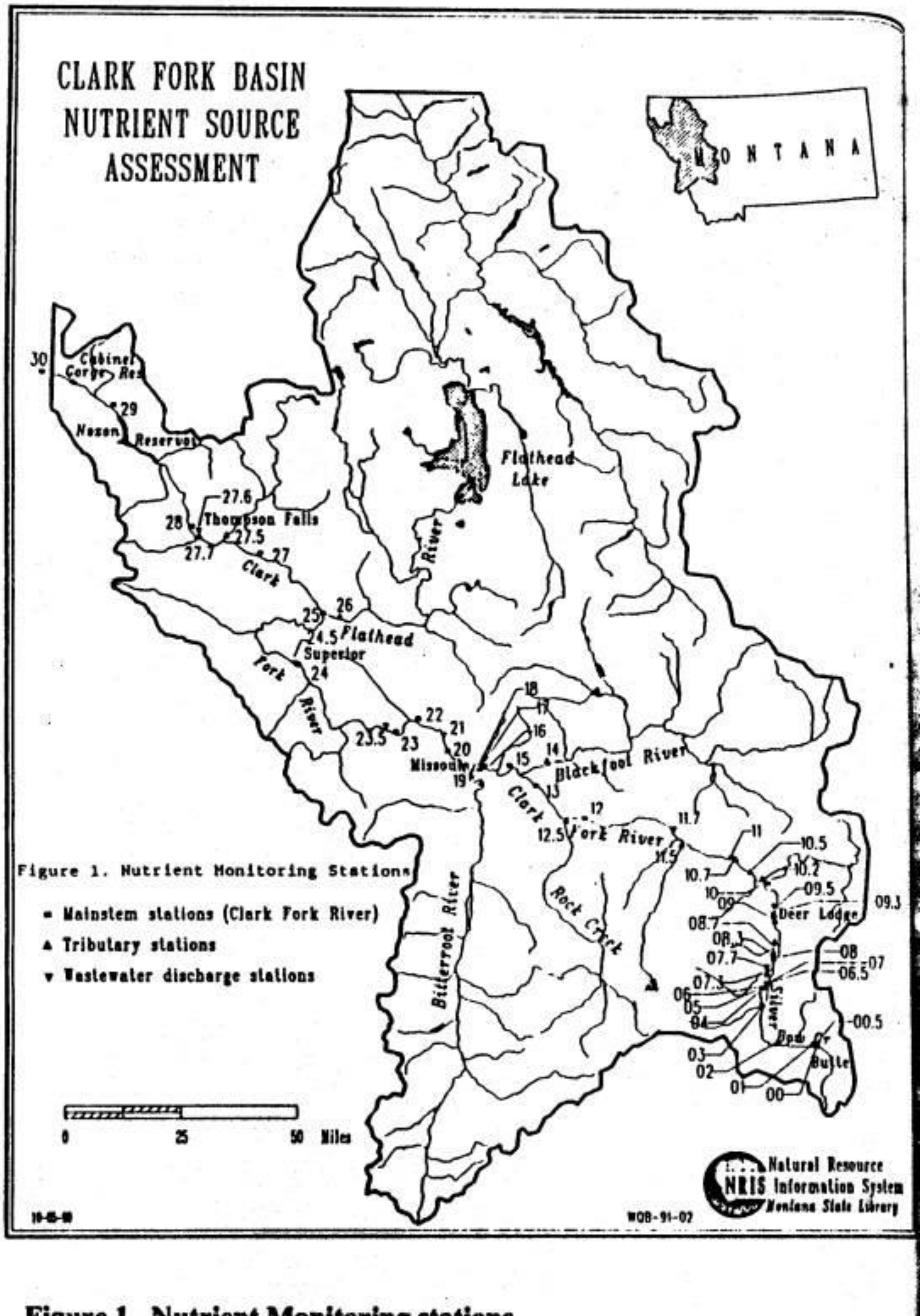


Figure 1. Nutrient Monitoring stations.

Table 2

Table 2. Nutrient Sampling and Analysis Methods and Quality Assurance Limits

Variable	Collection	Preservation	Holding Time	Analytical Method*	Detection Limit	Precision Range (ug/L)	Precision Limit (+or-)	Accuracy Warning Limits (% recovery)	Accuracy Acceptance Limits (% recovery)
Soluble Reactive Phosphorus	Grab sample, field filtration through 0.45 um membrane filter	Cool, 4° C	48 hours	EPA 365.1	1 ug/l	1- 10 10- 20 20- 100 100- 1000	2 3 4 10	86-109	81-115
Total Phosphorus	Grab sample	H_2SO_4 to pH <2, Cool, 4° C	28 days	EPA 365.1	1 ug/l	1- 20 20- 100 100- 1000	5 11 36	79-121	68-131
Dissolved Nitrate + Nitrite Nitrogen	Grab sample, field filtration through 0.45 um membrane filter	H_2SO_4 to pH <2, Cool, 4° C	28 days	EPA 353.2	10 ug/l	10- 100 100- 500 500- 2000 1000- 4000	10 30 40 80	93-113	88-118
Dissolved Ammonia Nitrogen	Grab sample, field filtration through 0.45 um membrane filter	H_2SO_4 to pH <2, Cool, 4° C	28 days	EPA 350.1	10 ug/l	10- 100 100- 1000	10 20	85-120	77-128
Total Kjeldahl Nitrogen	Grab sample	H_2SO_4 to pH <2, Cool, 4° C	28 days	EPA 351.2	100 ug/l	100- 1500 1500- 5000 5000-10000	200 600 1400	74-128	61-141

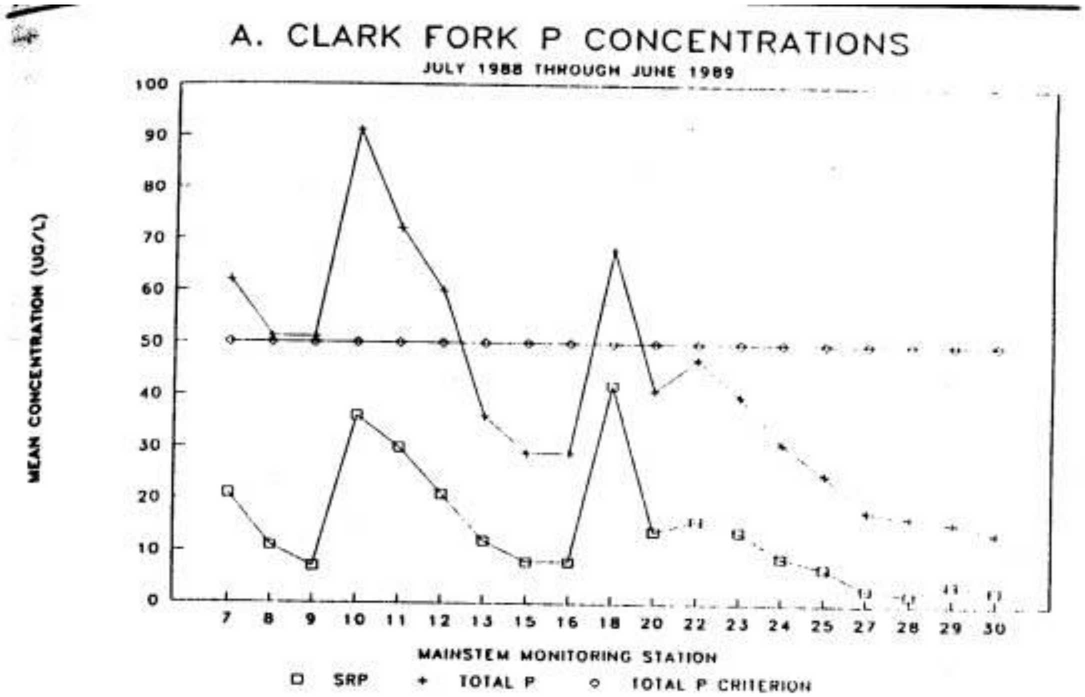
* From U.S. EPA, 1983.

Table 3: Fiscal Year 1989 Clark Fork Basin Nutrient Concentration Data

Station		Measured Concentration (ug/l) July 1988 Through June 1989							
		SRP		Total P		TSIN		Total N	
Number	N=	Conc. Range	Mean	Conc. Range	Mean	Conc. Range	Mean	Conc. Range	Mean
I. Mainstem Stations									
07	15	<1- 70	21	21- 112	62	30- 840	284	230-1340	659
08	15	2- 18	11	24- 135	51	<10- 690	215	250-1340	607
09	15	2- 15	7	12- 133	51	40- 660	306	270-1390	671
10	15	8- 92	36	53- 165	91	<10- 740	255	210-1410	693
11	15	10- 84	30	38- 133	72	<10- 590	187	220-1170	546
12	15	6- 53	21	18- 180	60	<10- 450	99	220-1120	496
13	15	3- 34	12	15- 104	36	10- 340	76	120-1020	359
15	15	3- 21	8	13- 59	29	<10- 190	47	<100-1130	325
16	15	2- 20	8	15- 57	29	<10- 210	49	<100-1130	264
18	15	8- 96	42	30- 106	68	30- 280	148	110- 660	396
20	15	7- 23	14	20- 60	41	30- 230	103	<100- 550	294
22	15	8- 29	16	23- 108	47	<10- 240	83	100- 440	323
23	15	8- 20	14	23- 70	40	<10- 220	62	<100- 580	297
24	15	6- 21	9	15- 79	31	<10- 190	62	<100- 320	218
25	15	2- 18	7	12- 70	25	<10- 120	38	<100- 320	240
27	15	<1- 13	3	7- 59	18	<10- 110	23	<100- 260	108
28	15	<1- 8	2	7- 46	17	<10- 100	19	<100- 200	101
29	15	<1- 14	4	8- 45	16	<10- 180	51	<100- 250	191
30	15	<1- 5	3	7- 31	14	<10- 150	43	<100- 490	161
II. Tributaries									
00	15	9- 55	19	58- 129	94	760-2110	1717	1320-2500	2055
01	15	526-1180	893	1040-1890	1440	2850-5670	4632	3750-6240	5315
02	15	76- 645	344	610-1230	836	1870-5390	3437	2540-5600	3894
03	15	36- 284	146	259- 998	523	820-3230	2085	1290-3460	2612
04	15	1- 137	40	40- 320	123	<10-1220	396	320-2140	904
05	15	<1- 21	9	19- 69	37	30- 380	186	230-1050	517
06	15	<1- 16	6	8- 28	14	20- 330	98	<100-1050	326
07.3	15	2- 17	6	7- 68	29	<10- 670	292	220-1600	607
08.3	15	<1- 42	8	11- 66	19	120- 360	210	140- 108	412
08.7	15	18- 36	29	30- 64	44	180- 780	460	180-1050	649
09.3	15	9- 120	30	19- 156	49	<10- 190	32	<100- 600	261
10.2	15	10- 93	20	25- 750	68	<10- 100	22	200-1370	336
10.5	15	5- 161	21	17-5940	303	<10- 220	90	110-5920	561
10.7	15	30- 402	122	57-4330	336	10- 550	122	<100-9500	844
11.5	15	20- 86	44	46- 343	97	<10- 350	100	200-1600	520
12.5	15	1- 11	6	9- 38	18	<10- 40	16	<100-1020	209
14	15	1- 16	4	5- 53	20	<10- 440	54	<100- 940	230
18.5	15	<1- 14	5	12- 44	21	30- 120	65	<100- 870	277
19	.15	2- 8	5	11- 44	22	40- 130	69	<100-1260	311
26	15	<1- 19	3	4- 78	16	<10- 120	24	<100- 220	111
27.5	15	<1- 5	3	5- 33	14	<10- 40	16	<100- 310	107
27.7	15	<1- 10	4	4- 30	11	<10- 60	22	<100- 420	113
III. Wastewater Discharges									
00.5	15	2200-3990	3099	3190-4470	3667	6810-11970	10160	8680-13960	11761
06.5	14	34- 468	195	93- 886	376	140- 2250	987	110- 4330	2628
07.7	15	1290-4280	2712	1470-4500	3012	2580-11500	7414	4080-13000	9421
09.5	15	954-2530	1828	1320-5250	2396	1330- 8200	4856	4260-11420	7411
11.6	15	67-1110	613	298-7870	1412	10- 4420	1837	910- 4610	3153
17	15	2680-5300	4454	3250-6150	4789	10110-22850	15120	11460-41620	17201
21[a]	10	92- 566	287	368- 829	567	790- 1990	1388	2400- 8100	4522
23.5	15	2310-6210	4420	2730-6850	5118	5040-19540	13612	10430-23820	18046
24.5	15	864-6880	5350	4940-9620	6471	12610-19780	16791	18270-27640	22160
27.6	15	313-4220	2207	1710-4650	3140	10-17560	3737	5410-10550	7675

[a] Concentration data given are all totals. Stone wastewater is not filterable.

Figure 2: Mean nutrient concentrations in the Clark Fork River for the period July 1988 through June 1989. A-Phosphorus variables. B-Nitrogen variables. Criteria are for the prevention of nuisance levels of attached algae in flowing waters (U.S. EPA, 1986; U.S. EPA in MDHES, 1986).



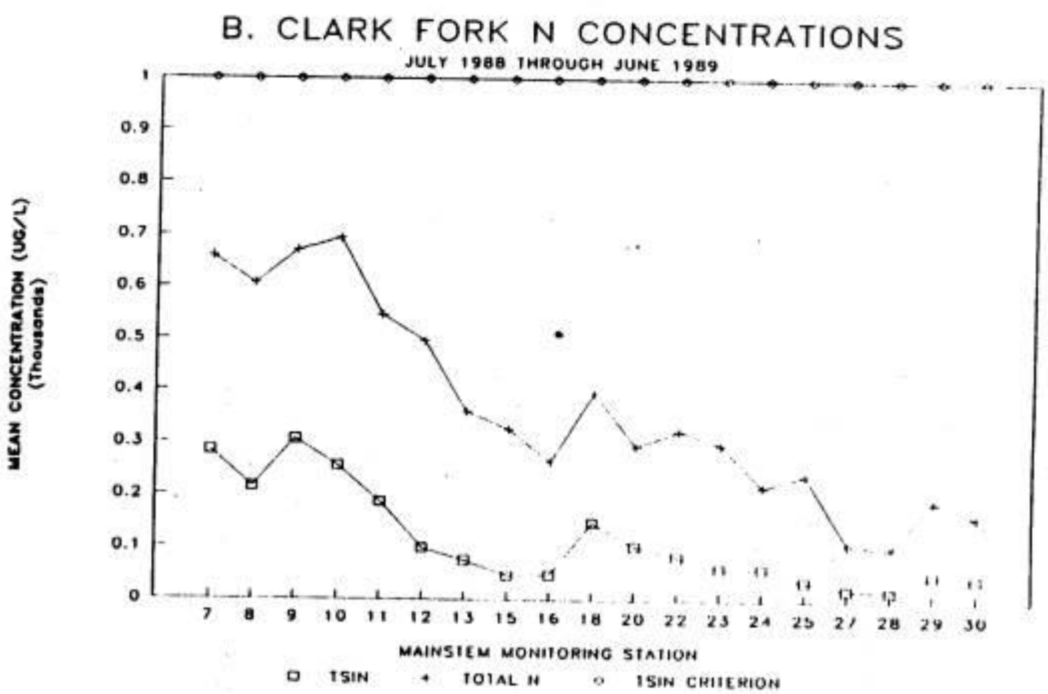
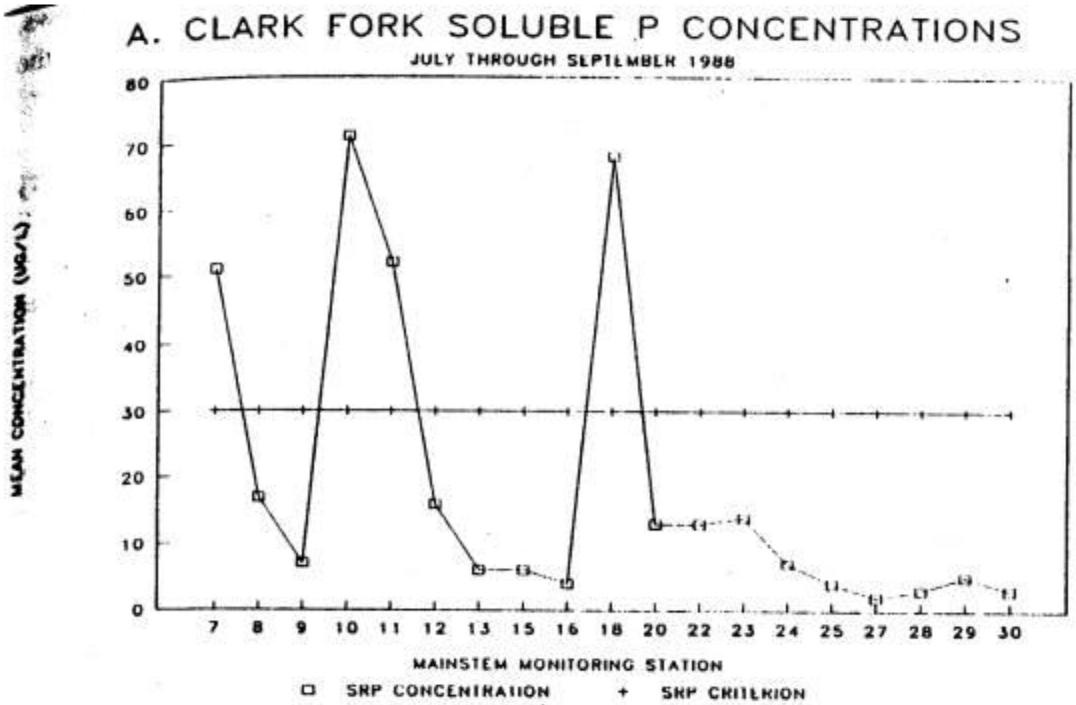


Figure 3: Mean soluble nutrient concentrations in the Clark Fork River for the period July through September 1988. A-Phosphorus. B-Nitrogen. Criteria are for the control of diatom algae in the Clark Fork River (Watson, 1990).



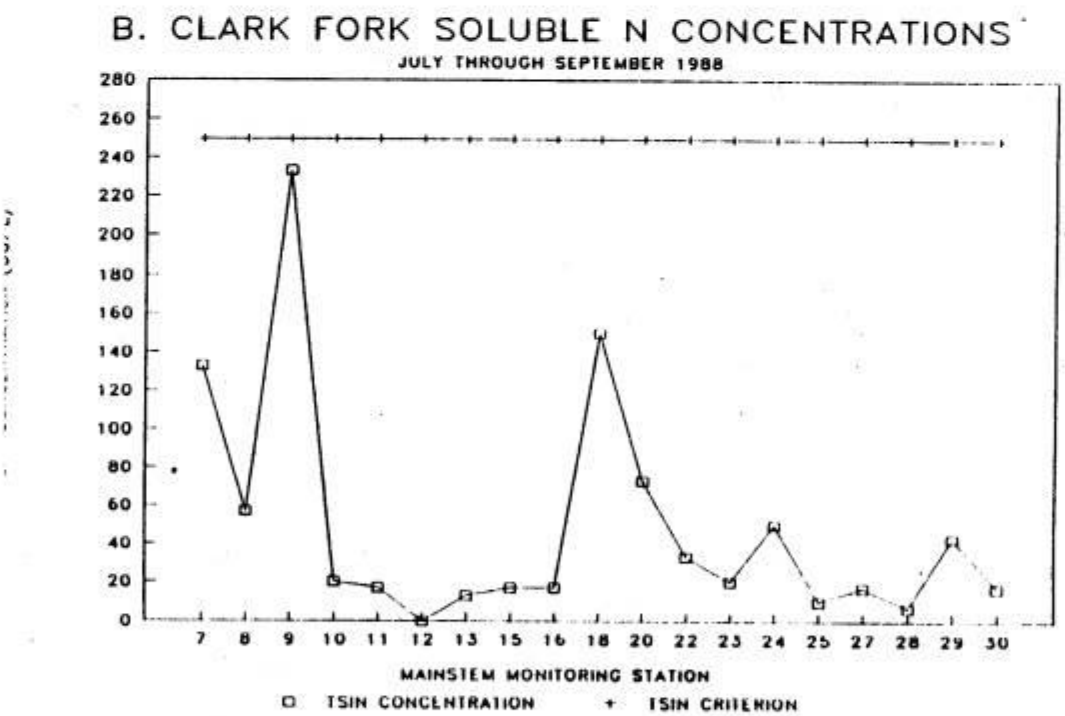
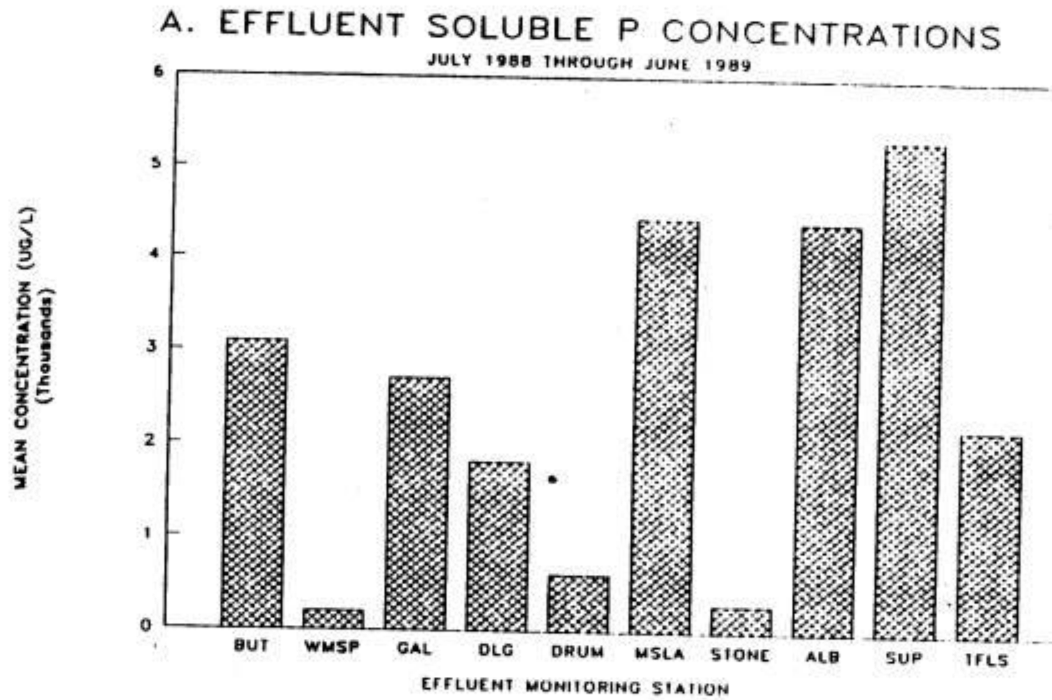


Figure 4: Mean soluble nutrient concentrations in selected wastewater discharges to Silver Bow Creek and the Clark Fork River for the period July 1988 through June 1989. A-Phosphorus. B-Nitrogen.



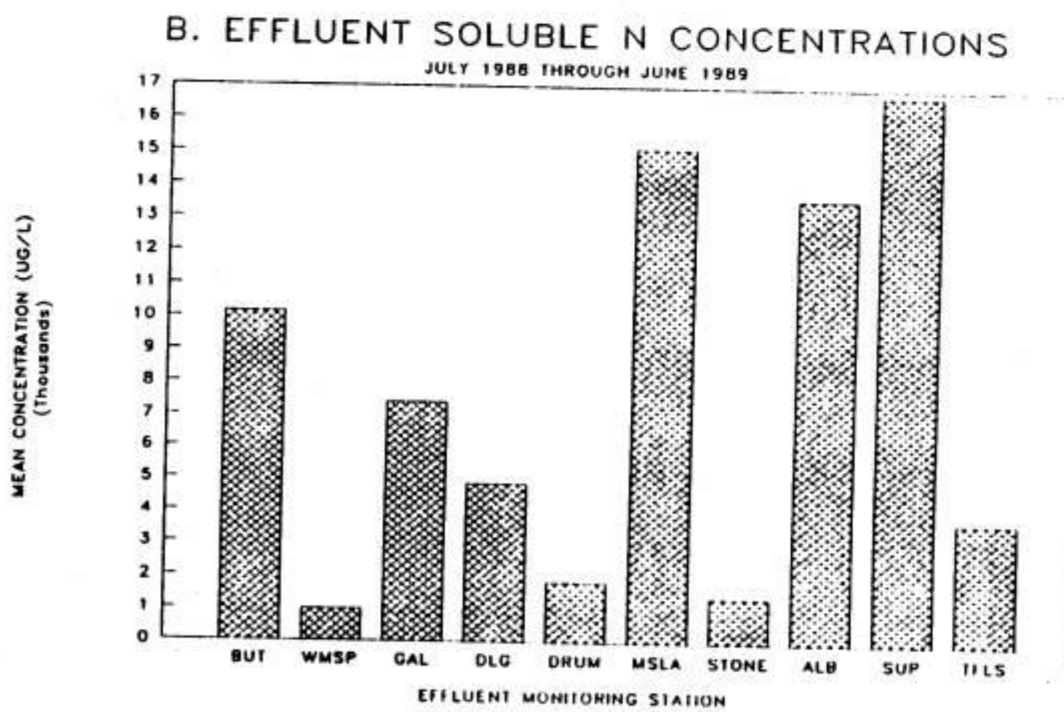


Table 4

Table 4. Fiscal Year 1989 Clark Fork Basin Nutrient Load Data Summary

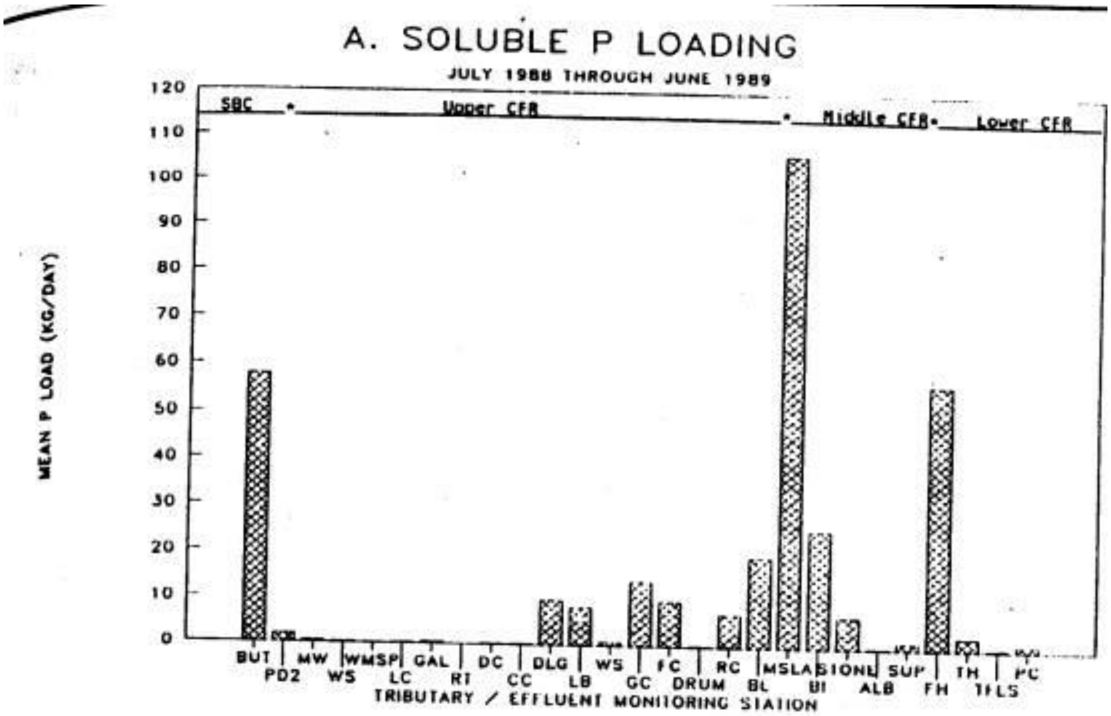
Station Number	Mean Load (kg/day) July 1988 Through June 1989 * SRP	Total P	TSIN	Total N
I. Mainstem Stations				
07	2.70	11.79	56.61	120.14
08	2.11	15.78	66.11	156.38
09	3.01	27.01	135.64	273.27
10	10.67	38.95	137.28	291.03
11	22.63	69.27	206.98	494.88
12	37.06	106.79	204.36	786.05
13	37.57	108.88	223.83	913.04
15	58.02	224.41	291.84	2288.36
16	57.26	227.25	317.73	2024.38
18	159.03	343.62	763.31	2043.62
20	129.91	441.27	915.95	3075.07
22	142.86	491.70	826.63	3428.74
23	129.62	458.24	674.11	3008.18
24	108.13	417.70	683.40	2546.22
25	112.81	466.83	687.97	3412.28
27	96.89	779.85	1001.62	3833.65
28	87.08	832.46	848.15	4865.71
29	150.08	679.33	2056.64	6590.21
30	126.18	738.88	2365.31	6313.67
II. Tributaries				
00	0.54	2.30	39.20	47.29
01	41.74	69.22	224.86	251.84
02[a]	16.39	47.82	194.19	217.23
03	11.42	46.19	180.79	223.90
04	1.89	12.26	45.23	83.46
05	0.60	2.33	8.80	28.03
06	0.24	1.10	5.33	18.26
07.3	0.27	1.90	23.87	36.22
08.3	0.08	0.22	2.06	3.30
08.7	0.25	0.41	3.27	4.91
09.3	0.23	0.35	0.09	1.65
10.2	8.27	45.15	13.72	139.60
10.5	0.99	29.96	2.81	33.22
10.7	14.16	110.60	27.57	248.08
11.5	9.85	31.41	42.98	157.98
12.5	7.25	21.41	16.36	284.64
14	19.59	102.15	117.88	1078.83
18.5	25.24	115.13	267.98	1496.18
19	25.62	126.71	283.59	1773.05
26	56.88	366.23	594.78	2197.71
27.5	2.83	18.15	12.83	90.18
27.7	1.21	8.17	13.33	41.92
III. Wastewater Discharges				
00.5	57.78	67.62	186.16	216.32
06.5	0.16	0.36	0.85	2.26
07.7	0.51	0.56	1.36	1.72
09.5	9.85	12.67	25.38	39.71
11.6	0.30	0.76	0.96	1.58
17	106.27	114.68	370.27	423.04
21[b]	7.01	18.39	38.10	132.60
23.5	0.32	0.38	1.09	1.42
24.5	1.55	1.88	4.90	6.50
27.6	0.45	0.64	0.69	1.57

* No concentration or streamflow data were collected in February. Nutrient load data are means for an 11 month period.

a Nutrient loads for station 02 can be presumed to be under-estimated. Gaged streamflows did not include a side channel to the creek.

b Load data given are for total nutrients. Stone wastewater is not filterable.

Figure 5: Mean soluble nutrient loading to Silver Bow Creek and the Clark Fork River from selected tributaries and wastewater discharges for the period July 1988 through June 1989. A-Phosphorus. B-Nitrogen.



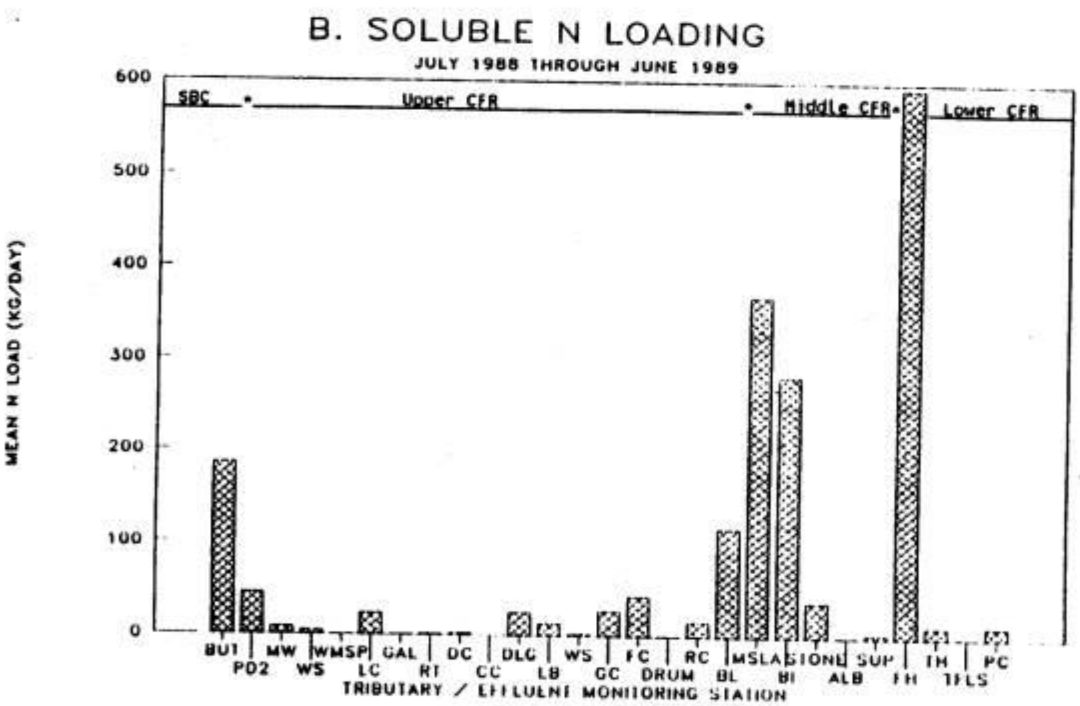
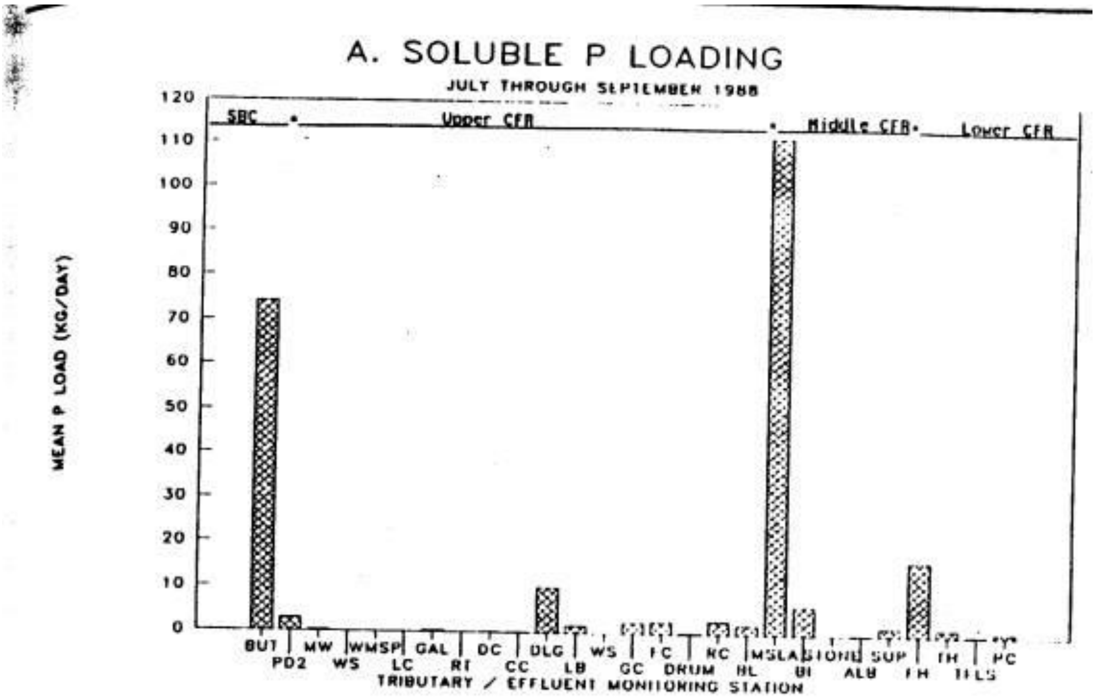


Figure 6: Mean soluble nutrient loading to Silver Bow Creek and the Clark Fork River from selected tributaries and wastewater discharges for the period July through September 1988. A-Phosphorus. B-Nitrogen.



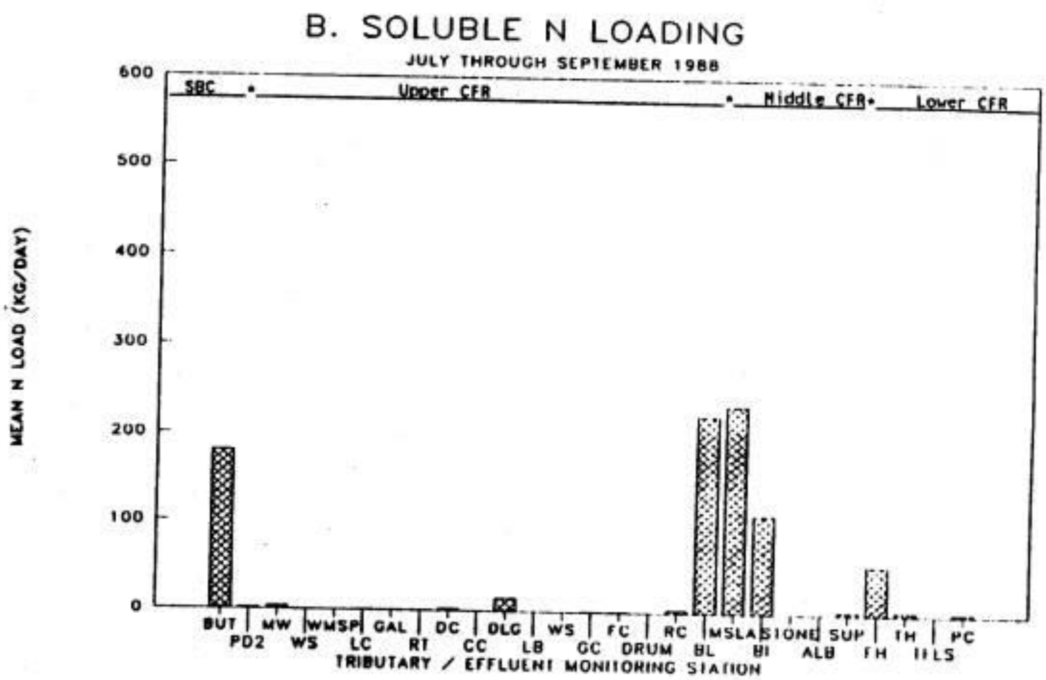
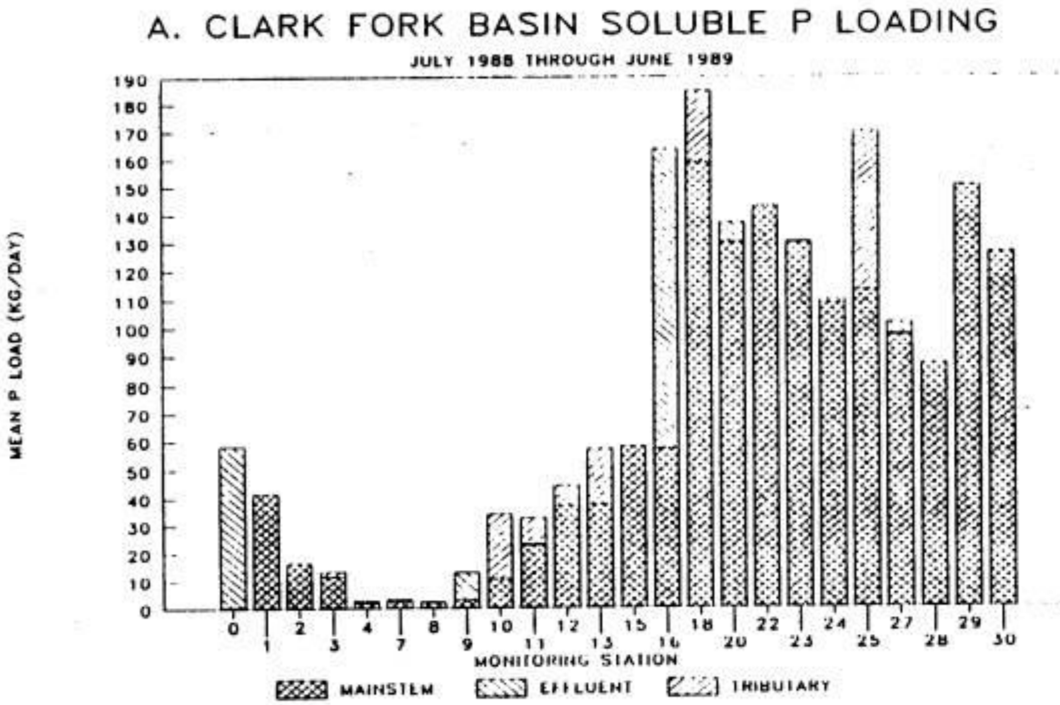


Figure 7: Mean soluble nutrient loading in the Clark Fork River and selected tributaries and wastewater discharges for the period July 1988 through June 1989. A-Phosphorus. B-Nitrogen.



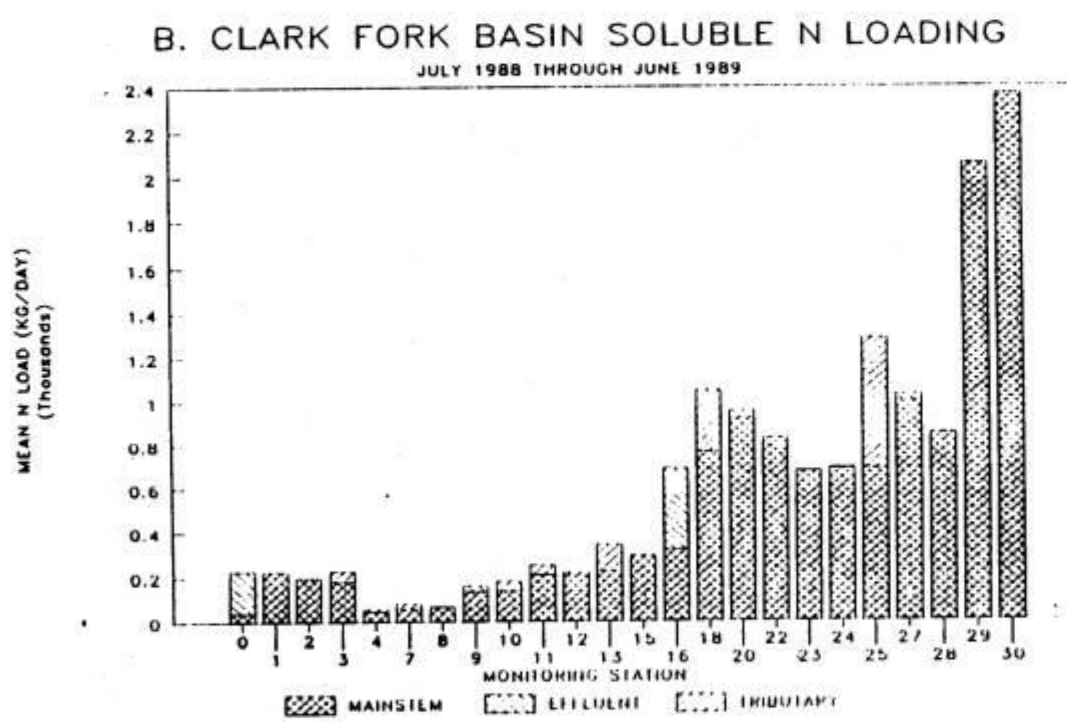


Table 5: Ranking of Clark Fork Basin Nutrient Sources by Mean Concentrations of Phosphorus and Nitrogen.

Source		Rank and Mean Concentration (ug/l)							
		SRP		Total P		TSIN		Total N	
I. Tributaries									
10.7	Gold Creek	1	(122)	1	(336)	6	(122)	2	(844)
11.5	Flint Creek	2	(44)	4	(97)	7	(100)	6	(520)
04	Discharge from AMC Pond 2 (Silver Bow Creek)	3	(40)	3	(97)	2	(396)	1	(904)
09.3	Cottonwood Creek	4	(30)	6	(49)	13	(32)	13	(261)
08.7	Dempsey Creek	5	(29)	7	(44)	1	(460)	3	(649)
10.5	Warm Springs Creek (near Phosphate)	6	(21)	2	(303)	9	(90)	5	(561)
10.2	Little Blackfoot River	7	(20)	5	(68)	15	(22)	9	(336)
05	Mill-Willow Bypass	8	(9)	8	(37)	5	(186)	7	(517)
08.3	Racetrack Creek	9	(8)	13	(19)	4	(210)	8	(412)
06	Warm Springs Creek (near Warm Springs)	10	(6)	16	(14)	8	(98)	10	(326)
07.3	Lost Creek	10	(6)	9	(29)	3	(292)	4	(607)
12.5	Rock Creek	10	(6)	14	(18)	16	(16)	15	(209)
18.5	Bitterroot River (at HWY 93)	11	(5)	11	(21)	11	(65)	12	(277)
19	Bitterroot River (near mouth)	12	(5)	10	(22)	10	(69)	11	(311)
14	Blackfoot River	13	(4)	12	(20)	12	(54)	14	(230)
27.7	Prospect Creek	14	(4)	17	(11)	15	(22)	17	(113)
26	Flathead River	15	(3)	15	(16)	14	(24)	16	(111)
27.5	Thompson River	16	(3)	16	(14)	16	(16)	18	(107)
II. Wastewater Discharges									
24.5	Superior lagoon	1	(5350)	1	(6471)	1	(16791)	1	(22160)
17	Missoula WWTP	2	(4454)	3	(4789)	2	(15120)	3	(17201)
23.5	Alberton lagoon	3	(4420)	2	(5118)	3	(13612)	2	(18046)
00.5	Butte Metro WWTP	4	(3099)	4	(3667)	4	(10160)	4	(11761)
07.7	Galen WWTP	5	(2712)	6	(3012)	5	(7414)	5	(9421)
27.6	Thompson Falls lagoon	6	(2207)	5	(3140)	7	(3737)	6	(7675)
09.5	Deer Lodge lagoon	7	(1828)	7	(2396)	6	(4856)	7	(7411)
11.6	Drummond lagoon	8	(613)	8	(1412)	8	(1837)	9	(3153)
21	Stone Container Corporation	9	(287)	9	(567)	9	(1388)	8	(4522)
06.5	Warm Springs lagoon	10	(195)	10	(376)	10	(987)	10	(2628)

* Based on an average of 15 measurements made from July 1988 through June 1989.

Table 6: Ranking of Clark Fork Basin Nutrient Sources by Mean Load of Phosphorus and Nitrogen.

	Source	Rank and Mean Load (kg/day) SRP		Total P		TSIN		Total N	
I.	**Tributaries**								
26	Flathead River	1	(56.88)	1	(366.23)	1	(594.78)	1	(2197.71)
19	Bitterroot River (near mouth)	2	(25.62)	2	(126.71)	2	(283.59)	2	(1773.05)
18.5	Bitterroot River (at HWY 93)	3	(25.24)	3	(115.13)	3	(267.98)	3	(1496.18)
14	Blackfoot River	4	(19.59)	5	(102.15)	4	(117.88)	4	(1078.83)
10.7	Gold Creek	5	(14.16)	4	(110.60)	7	(27.57)	6	(248.08)
11.5	Flint Creek	6	(9.85)	7	(31.41)	6	(42.98)	7	(157.98)
10.2	Little Blackfoot River	7	(8.27)	6	(45.15)	10	(13.72)	8	(139.60)
12.5	Rock Creek	8	(7.25)	9	(21.41)	9	(16.36)	5	(284.64)
27.5	Thompson River	9	(2.83)	10	(18.15)	12	(12.83)	9	(90.18)
04	Discharge from AMC Pond 2 (Silver Bow Creek)	10	(1.89)	11	(12.26)	5	(45.23)	10	(83.46)
27.7	Prospect Creek	11	(1.21)	12	(8.17)	11	(13.33)	11	(41.92)
10.5	Warm Springs Creek (near Phosphate)	12	(0.99)	8	(29.96)	16	(2.81)	13	(33.22)
05	Mill-Willow Bypass	13	(0.60)	13	(2.33)	13	(8.80)	14	(28.03)
07.3	Lost Creek	14	(0.27)	14	(1.90)	8	(23.87)	12	(36.22)
06	Warm Springs Creek (near Warm Springs)	16	(0.24)	15	(1.10)	14	(5.33)	15	(18.26)
08.7	Dempsey Creek	15	(0.25)	16	(0.41)	15	(3.27)	16	(4.91)
09.3	Cottonwood Creek	17	(0.23)	17	(0.35)	18	(0.09)	18	(1.65)
08.3	Racetrack Creek	18	(0.08)	18	(0.22)	17	(2.06)	17	(3.30)
II.	**Wastewater Discharges**								
17	Missoula WWTP	1	(106.27)	1	(114.68)	1	(370.27)	1	(423.04)
00.5	Butte Metro WWTP	2	(57.78)	2	(67.62)	2	(186.16)	2	(216.32)
09.5	Deer Lodge lagoon	3	(9.85)	4	(12.67)	4	(25.38)	4	(39.71)
21	Stone Container Cooperation	4	(7.01)	3	(18.39)	3	(38.10)	3	(132.60)
24.5	Superior lagoon	5	(1.55)	5	(1.88)	5	(4.90)	5	(6.50)
07.7	Galen WWTP	6	(0.51)	8	(0.56)	6	(1.36)	7	(1.72)
27.6	Thompson Falls lagoon	7	(0.45)	7	(0.64)	10	(0.69)	9	(1.57)
23.5	Alberton lagoon	8	(0.3)	9	(0.38)	7	(1.09)	10	(1.42)
11.6	Drummond lagoon	9	(0.30)	6	(0.76)	8	(0.96)	8	(1.58)
06.5	Warm Springs lagoon	10	(0.16)	10	(0.36)	9	(0.85)	6	(2.26)

* Based on an average of 15 measurements made from July 1988 through June 1989.

Figure 8: Relative contributions of soluble nutrient loading to the Clark Fork River from selected tributaries and wastewater discharges for the period July 1988 through June 1989. Data are percentages of total load from all monitored sources. A-Phosphorus. B-Nitrogen.

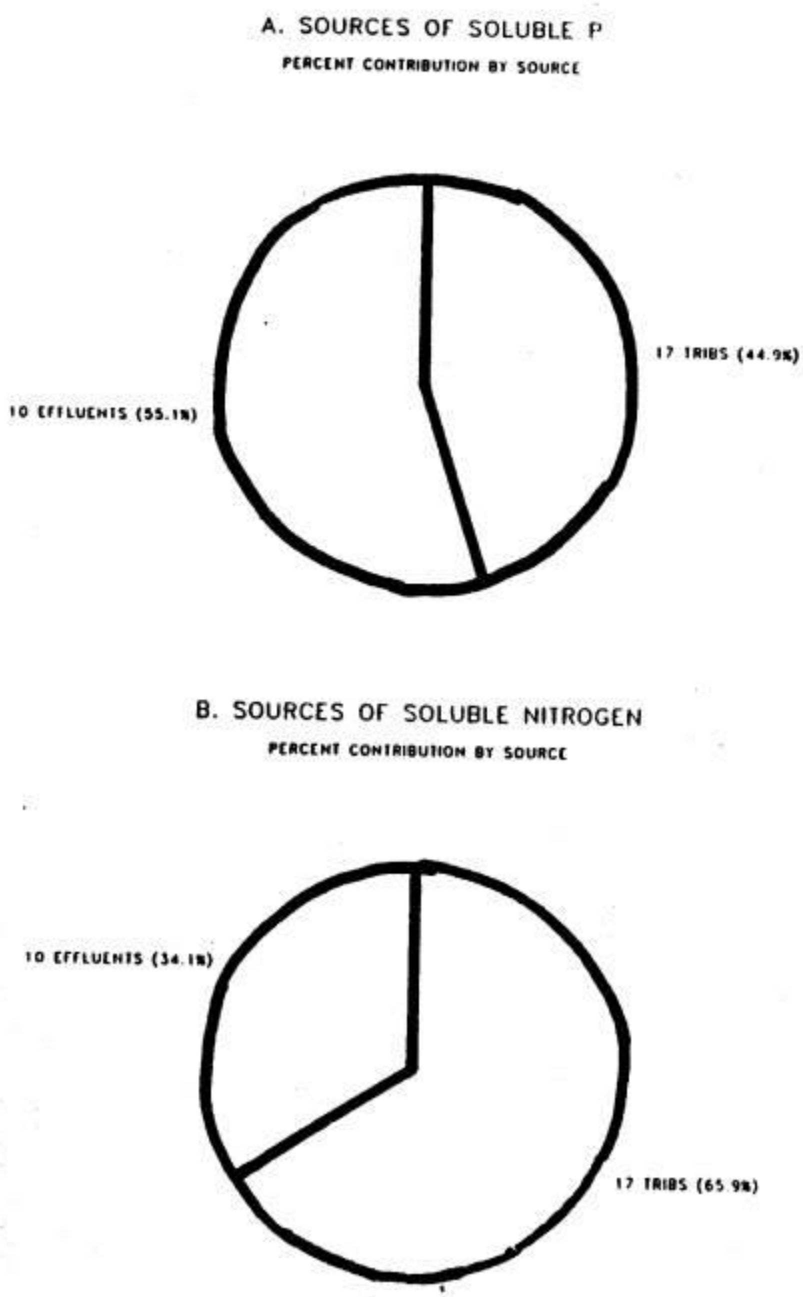


Figure 9: Relative contributions of soluble nutrient loading to the Clark Fork River from selected tributaries for the period July 1988 through June 1989. Data are percentages of total load from all monitored tributary sources. A-Phosphorus. B-Nitrogen.

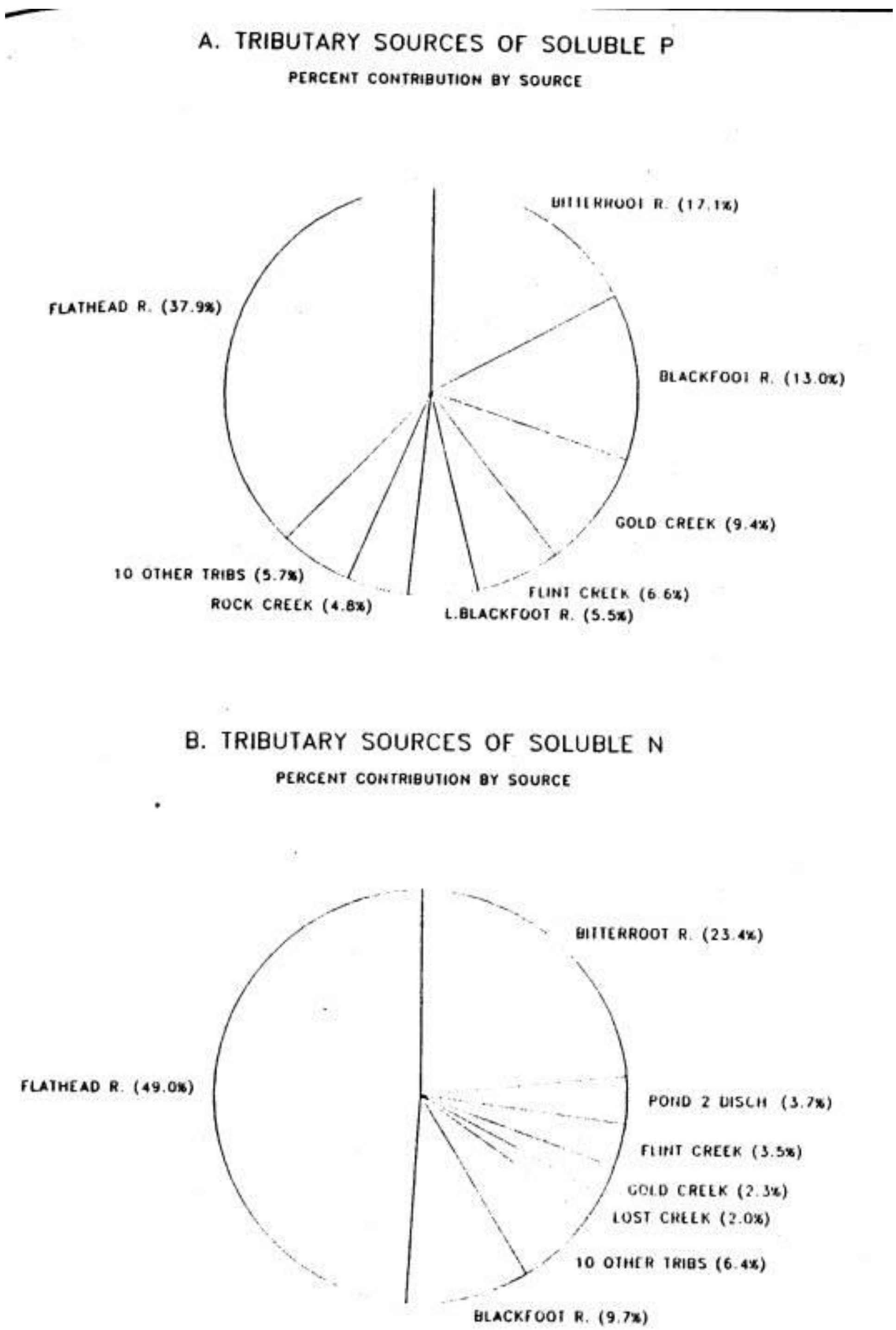


Figure 10: Relative contributions of soluble nutrient loading to the Clark Fork River from selected wastewater discharges for the period July 1988 through June 1989. Data are percentages of total load from all monitored wastewater sources. A-Phosphorus. B-Nitrogen.