EVALUATION OF METAL TRANSPORT INTO AND OUT OF TERRACE RESERVOIR, CONEJOS COUNTY, COLORADO, APRIL 1994 THROUGH MARCH 1995

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INTRODUCTION

Terrace Reservoir is a small irrigation reservoir located on the Alamosa River in the San Juan Mountains near Capulin, Colorado (fig. 1). The Alamosa River and Terrace Reservoir are the primary sources of water for crops and livestock in the southwestern part of the San Luis Valley. Much of the drainage basin upstream from Terrace Reservoir contains extensive areas of hydrothermally altered rocks that contribute a substantial metal load to Terrace Reservoir. Significant gold mining activities have occurred intermittently at the Summitville mine, and historically highly acidic, metal-enriched water has drained from the mine site into Wightman Fork, a tributary of the Alamosa River, where it flows into Terrace Reservoir. The drainage waters from the Summitville mine generally have a pH less than 3 and have contained high concentrations of aluminum, copper, zinc, and other metals (King, 1995). In 1992, the operator of the Summitville mine declared bankruptcy, and the U.S. Environmental Protection Agency (USEPA) took over operation of the water-treatment facility at the mine. Preliminary ecological and human-health risk assessments indicated that the concentrations of total and dissolved aluminum, cadmium, copper, iron, manganese and zinc were high enough to be of environmental concern. In 1994, the U.S. Geological Survey (USGS), in cooperation with the USEPA, began a study as part of risk assessment and remediation efforts to evaluate metal transport into and out of Terrace Reservoir.

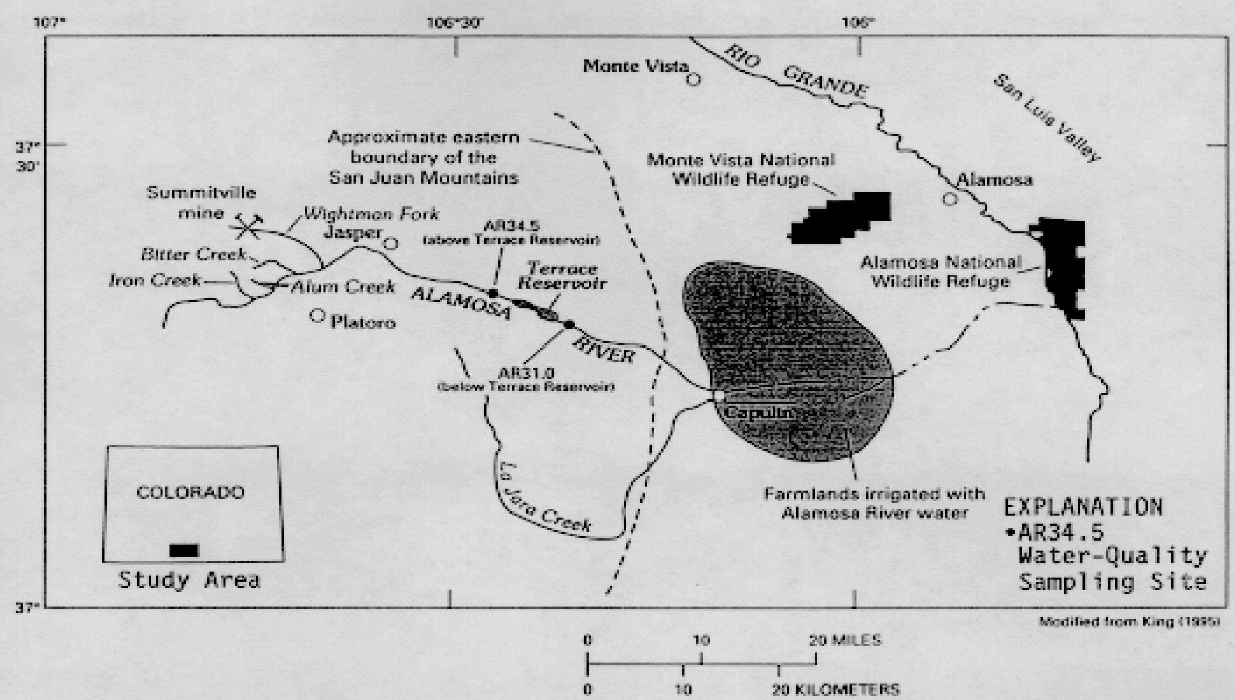

Figure 1.-- Location of study area and water-quality sampling sites.

Previous studies of water quality indicate that Wightman Fork is the predominant source of aluminum, copper, iron, manganese, and zinc during peak and post-snowmelt peak periods, and the source of most of the copper, manganese, and zinc during most of the year (Walton-Day and others, 1995). In addition to mining as a source of contamination, degradation of the water quality of the Alamosa River has occurred from natural sources of acidity and metals. The Alamosa River upstream from Iron Creek contains only moderate concentrations of aluminum and iron and very minor amounts of copper, manganese, and zinc (Walton-Day and others, 1995); however much of the dissolved aluminum, iron, and most of the copper, manganese, and zinc in the Alamosa River upstream from the confluence with Wightman Fork is the result of natural processes (Kirkham, and others, 1995).

APPROACH

Two water-quality sampling sites, AR34.5, Alamosa River above Terrace Reservoir (USGS site identification number 08236000), and AR31.0, Alamosa River below Terrace Reservoir (USGS site identification number 08236500) were selected for study to describe the metal chemistry and evaluate metal transport into and out of Terrace Reservoir (fig. 1). These sites were selected because of their proximity to the reservoir, and both sites are currently operated as streamflow-gaging stations by the State of Colorado, Division of Water Resources. The gaging station downstream from the reservoir is operational during the entire year; the gaging station upstream from the reseservoir is operational from approximately March through mid-November. The gaging stations provide continuous streamflow records used to compute metal loads. During April 1994 through March 1995, 36 water samples were collected at AR34.5 to evaluate metal transport entering the reservoir, and 23 samples were collected at AR31.0 to evaluate metal transport out of the reservoir. The samples were collected using the equal-width increment method which results in a representative constituent concentration for the entire river cross section (Edwards and Glysson,1988; Ward and Harr, 1990). Samples were collected and processed using standard USGS methods. Chemical analyses were done by a USEPA contract laboratory. The samples were analyzed for dissolved (filtered through a 0.45-micron filter) and total (whole water) metals. Additional samples were collected at AR34.5 using an automatic sampler at a single point within the river cross section during rainfall-runoff events.

METAL LOADS

Metal loads were computed to estimate the quantity of metals that were transported into and out of Terrace Reservoir between April 1994 and March 1995. Loads were computed using a modified time-interval method. In this method, the data record was divided into several discrete time intervals based on changes in metal concentration, streamflow, or events (such as snowmelt-runoff or storms). The mean metal concentration for each time interval was multiplied by the mean daily streamflow from the streamflow gaging station to determine daily metal loads. Daily metal loads were summed into seasonal and annual metal loads. Because metal loads are a function of concentration and streamflow, loads varied considerably as a result of changes in stream-flow and/or changes in metal concentration. The largest loads occurred during the peak snowmelt runoff period (mid-May through mid-June), and the post-snowmelt peak runoff period (mid-June through mid-July). Substantial metal loading also occurred during storm events. The smallest metal loads occurred during the winter (November through February) when streamflow was greatly reduced.

Aluminum

Large variations in aluminum loads occurred during the study. The largest daily loads of aluminum were transported into and out of Terrace Reservoir during the peak snowmelt period between mid-May through mid-June (fig. 2). The maximum daily total-aluminum load that entered the reservoir was about 11 tons (fig. 2). An estimated 81 percent of the 363 tons of total aluminum that entered the reservoir during the study period remained in the reservoir, indicating that the reservoir was a sink for an estimated 295 tons of aluminum (table 1). Only 68 tons of total aluminum load were transported out of the reservoir during the study period, primarily during the peak snowmelt period. Almost all of the total-aluminum load that entered the reservoir during the winter (October through March) remained in the reservoir.

Iron

The largest daily iron loads were transported into and out of Terrace Reservoir during the peak snowmelt period, and the maximum daily total-iron load that entered the reservoir was about 25 tons (fig. 2). About 76 percent of the 790 tons of total iron that entered the reservoir during the study period remained, indicating that the reservoir was a sink for about 597 tons of iron (table 1). Most of 193 tons of iron that was discharged out of the reservoir was transported downstream during the peak and post-snowmelt peak periods, from mid-May through mid-July (fig. 2).

Copper

The maximum daily total-copper load of about 1.9 tons entered the reservoir on June 8, about a week later than the maximum daily total-aluminum and total-irons loads and was substantially smaller than the daily total- aluminum and iron loads (fig. 2). The largest daily total-copper loads were transported into and out of the reservoir during the post-snowmelt peak period (mid-June through mid-July) (fig. 3). During the study period, an estimated 61 tons of total copper entered the reservoir, approximately 39 tons of total copper was discharged downstream to the Alamosa River, and an estimated 22 tons of total copper remained in the reservoir (table 1).

Manganese

The largest daily manganese loads were transported into and out of Terrace Reservoir during the peak snowmelt runoff period (fig. 3). The maximum daily total-manganese load that entered the reservoir was slightly more than 1 ton (fig. 3) and occurred at the same time as the maximum daily total-aluminum and daily total-iron loads, and a week before the maximum daily total-copper load. Large manganese loads also were transported into the reservoir during storm events during the summer months and were not transported out of the reservoir during that time. An estimated 52 tons of total-manganese were transported into the reservoir, and about 90 percent (47 tons) of manganese load were transported out, indicating that the reservoir was a sink for only a small amount (5 tons) of total manganese (table 1).

Zinc

The maximum daily total-zinc load of about half a ton entered the reservoir on June 8, 1994, the same date as the maximum total-copper load, and near the end of the peak snowmelt runoff period (fig 4). Ninety percent of the 20 tons of total-zinc load that entered the reservoir was transported out, and more than half of the total-zinc load was transported downstream during the peak-snowmelt and post- snowmelt-peak periods of mid-May through mid-July (table 1).

DISCUSSION

Metal loads in the Alamosa River upstream and downstream from Terrace Reservoir varied seasonally as a result of changes in streamflow and changes in metal concentrations. The largest daily loads of total-aluminum, iron, and manganese were transported into and out of the reservoir during the peak snowmelt period (mid-May through mid-June) and the smallest loads occurred during the winter months (November through February). The largest daily copper and zinc loads also occurred during the peak snowmelt-runoff period but approximately one week later than the maximum daily loads for aluminum, iron, and manganese.

SELECTED REFERENCES

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Table 1. Annual and selected seasonal total metal loads (in tons) at AR34.5 and AR31.0, April 1, 1994, through March 31, 1995

SITE	METAL	PEAK SNOWMELT PERIOD (mid-May through mid-June, 1994)	POST-SNOWMELT PEAK PERIOD (mid-June through mid-July 1994	SUMMER AND STORM SEASON (mid-July through September, 1994)	TOTAL ANNUAL LOAD (April 1, 1994 through March 31 , 1995)
AR34.5	Total Aluminum	165	55	71	363
AR31.0	Total Aluminum	43	8	8	68
	Difference	+122	+47	+63	+295
AR34.5	Total Iron	376	125	143	790
AR31.0	Total Iron	93	48	28	193
	Difference	+283	+77	+115	+597
AR34.5	Total Copper	16.9	26	12.1	61
AR31.0	Total Copper	5.4	17	11.6	39
	Difference	+11.5	+9	+0.5	+22
AR34.5	Total Manganese	18.1	11.1	10	52
AR31.0	Total Manganese	14.0	10.8	11	47
	Difference	+4.1	+0.3	-1	+5
AR34.5	Total Zinc	6.0	6.8	3.6	20
AR31.0	Total Zinc	4.6	6.0	4.1	18
	Difference	+1.4	+0.8	-0.5	+2

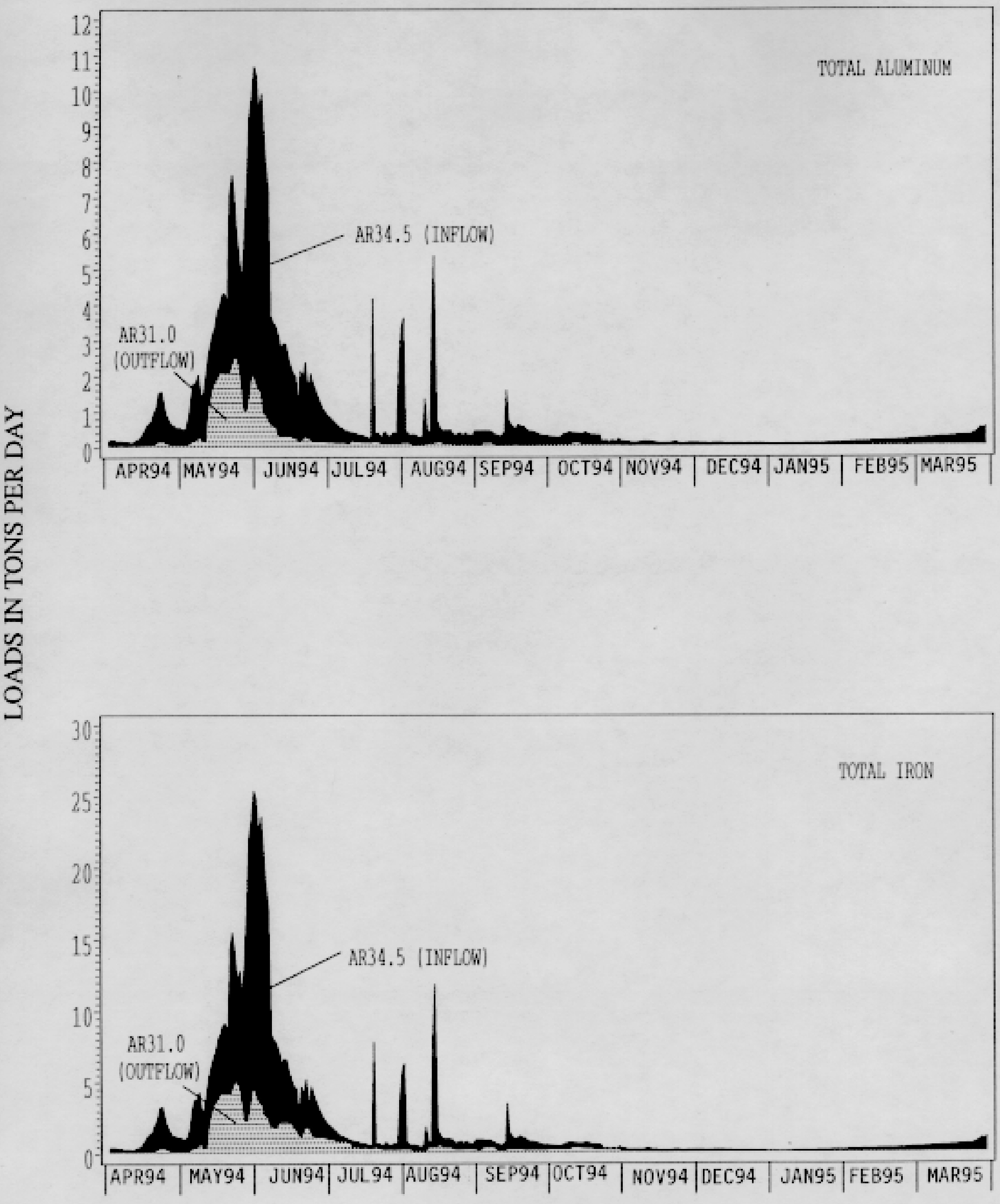

Figure 2. -- Daily total-aluminum and total-iron loads upstream (AR34.5) and downstream (AR31.0) of Terrace Reservoir, April 1994 through March 1995.

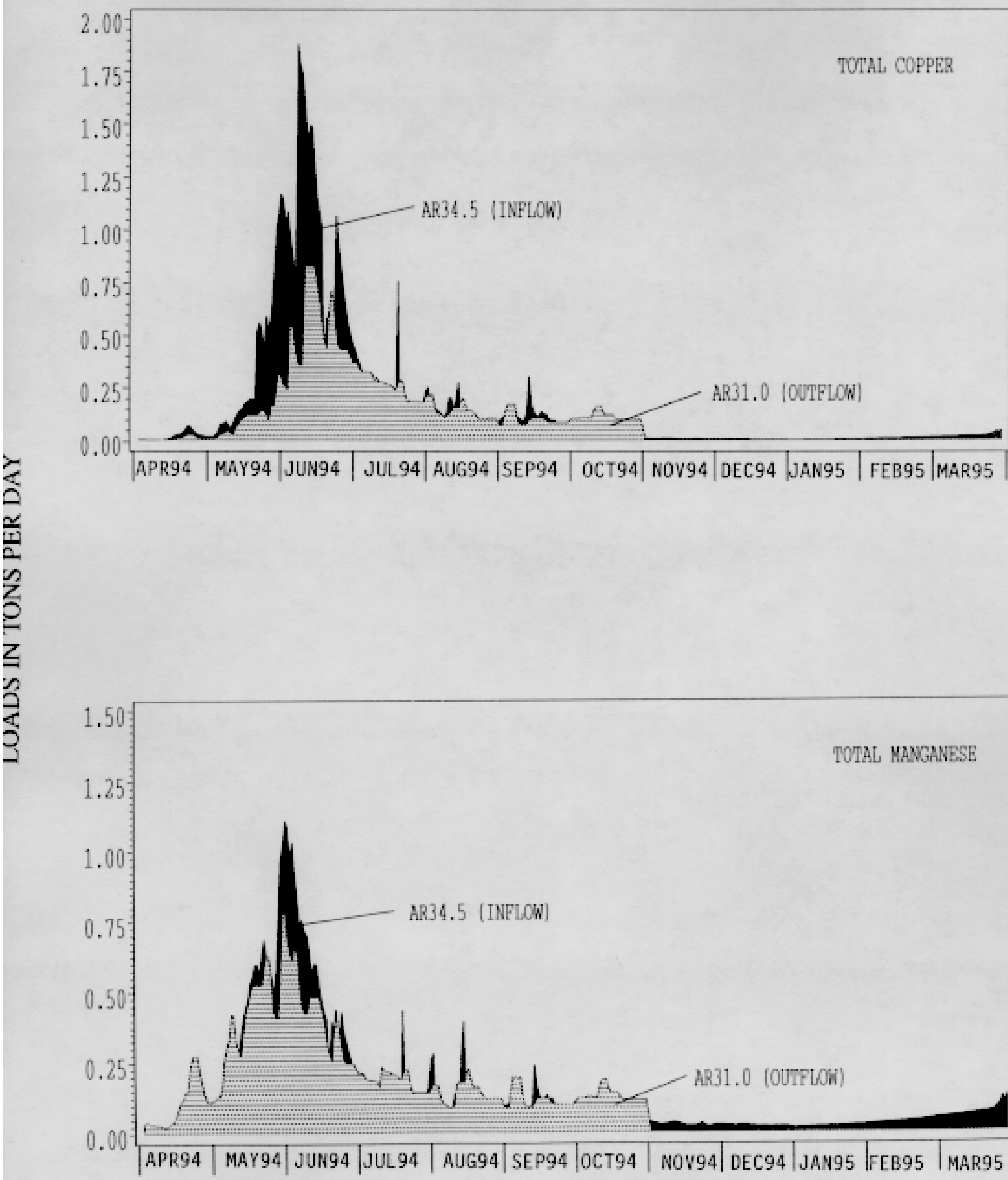

Figure 3. -- Daily total-copper and total-manganese loads upstream (AR34.5) and downstream (AR31.0) of Terrace Reservoir, April 1994 through March 1995.

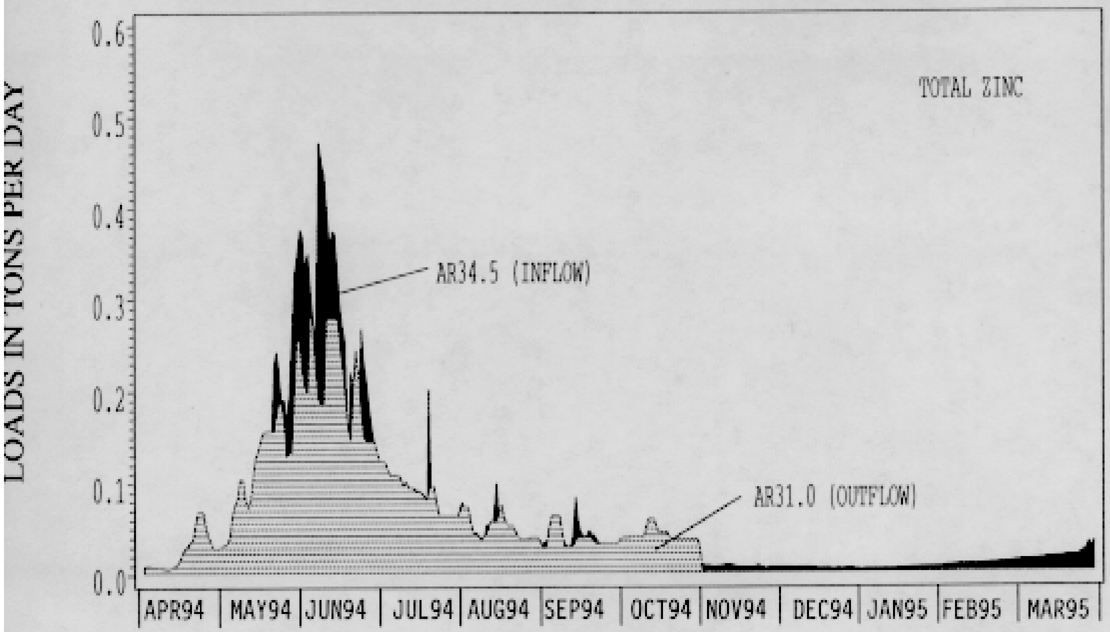

Figure 4. -- Daily total-zinc loads upstream (AR34.5) and downstream (AR31.0) of Terrace Reservoir, April 1994 through March 1995.