AMMONIA INVESTIGATION
OUACHITA RIVER

INTRODUCTION

The City of Malvern uses the Ouachita River as its source of municipal drinking water, and it has experienced difficulty in maintaining the chlorine residual in the distribution system as mandated by the Safe Drinking Water Act. The City has attributed this water treatment problem to occasional elevated levels of ammonia in the Ouachita River. These elevated levels utilize large quantities of chlorine and require much higher levels of chlorination. Ammonia concentrations at the City of Malvern intake were measured frequently by employees of the city during 1995. Monthly median values were normally near or below 0.1 mg/L. Frequent peaks occurred around 0.3 mg/L and occasional peaks were near 1 mg/L. The Arkansas Department of Pollution Control and Ecology agreed to conduct a preliminary study to evaluate the problem.

STUDY DESIGN

Water chemistry samples were taken at five stations in Lake Catherine, four stations below Remmel Dam in the Ouachita River, one in Cove Creek, and one in Stone Quarry Creek. Four stations in Lake Catherine were sampled at three depths (upper, middle, and lower). Water grab samples were taken at the six river/stream stations and at the lake station below Carpenter Dam at the upper end of Lake Catherine. The river/stream and lake stations were sampled on April 8,9,10, and 11. An additional sampling of the river stations was conducted on April 18, 1996. An attempt was made to coordinate the sampling on April 18 with the hydropower releases from Remmel Dam. On the morning of the 18th, ADPC&E employees were prepared to sample three flow patterns at four stations on the river. Each were to be sampled at (1) a low, pre-generation flow; (2) an increasing flow during generation; and (3) at high river flow (stabilized generation). In addition to the data collected during the study period, data from the Discharge Monitoring Reports (DMR) of the City of Hot Springs, which discharges to the upper part of Lake Catherine, and U.S. Vanadium Co., which discharges just above mid-lake, were obtained.

Parameters

All samples were analyzed for dissolved oxygen, temperature, pH, chlorides, ammonia nitrogen, nitrate nitrogen, ortho-phosphate, sulfate, total dissolved solids (TDS), total organic carbon (TOC), total suspended solids (TSS), total hardness, and the dissolved portion of cadmium, chromium, lead, aluminum, copper, calcium, iron, potassium, magnesium, manganese, sodium, zinc, nickel, boron, beryllium, barium, cobalt, and vanadium. Dissolved oxygen, temperature, and pH were analyzed in the field; all other parameters were analyzed in the laboratory.

Collection of samples and analyses were performed in accordance with the Department's QA/QC plan for ambient water quality monitoring. Metals samples were filtered and preserved in the field as collected and ammonia samples were preserved immediately after collection.

Station Description

Water quality sampling stations were chosen for the purpose of assessing the water chemistry upstream and downstream of major point source contributors, i.e. the effluent discharges of U.S. Vanadium and the City of Hot Springs sewage treatment plant (STP). The river/stream stations were located to monitor the fate of ammonia downstream from Remmel Dam and the input of ammonia from tributary sources. Station locations are shown in Figure 1 and descriptions are as follows:

LC1 Headwaters of Lake Catherine, three feet below the surface, 150 feet downstream of Carpenter Dam

LC2-U Lake Catherine 100 yards downstream of Hwy 128 bridge; 40 yards downstream from the City of Hot Springs STP outfall; three feet below the surface

LC2-M As above; six feet below the surface

LC2-L As above; nine feet below the surface

LC3-U Lake Catherine 200 yards upstream of the U.S. Vanadium discharge; five feet below the surface

LC3-M As above; 15 feet below the surface

LC3-L As above; 25 feet below the surface

LC4-U Lake Catherine 100 feet downstream of the U.S. Vanadium discharge; five feet below the surface

LC4-M As above; 15 feet below the surface

LC4-L As above; 25 feet below the surface

LC5-U Lake Catherine 100 yards upstream of Remmel Dam; five feet below the surface

LC5-M As above; 20 feet below the surface

LC5-L As above; 35 feet below the surface

OR-01 Ouachita River 100 feet downstream of Remmel Dam

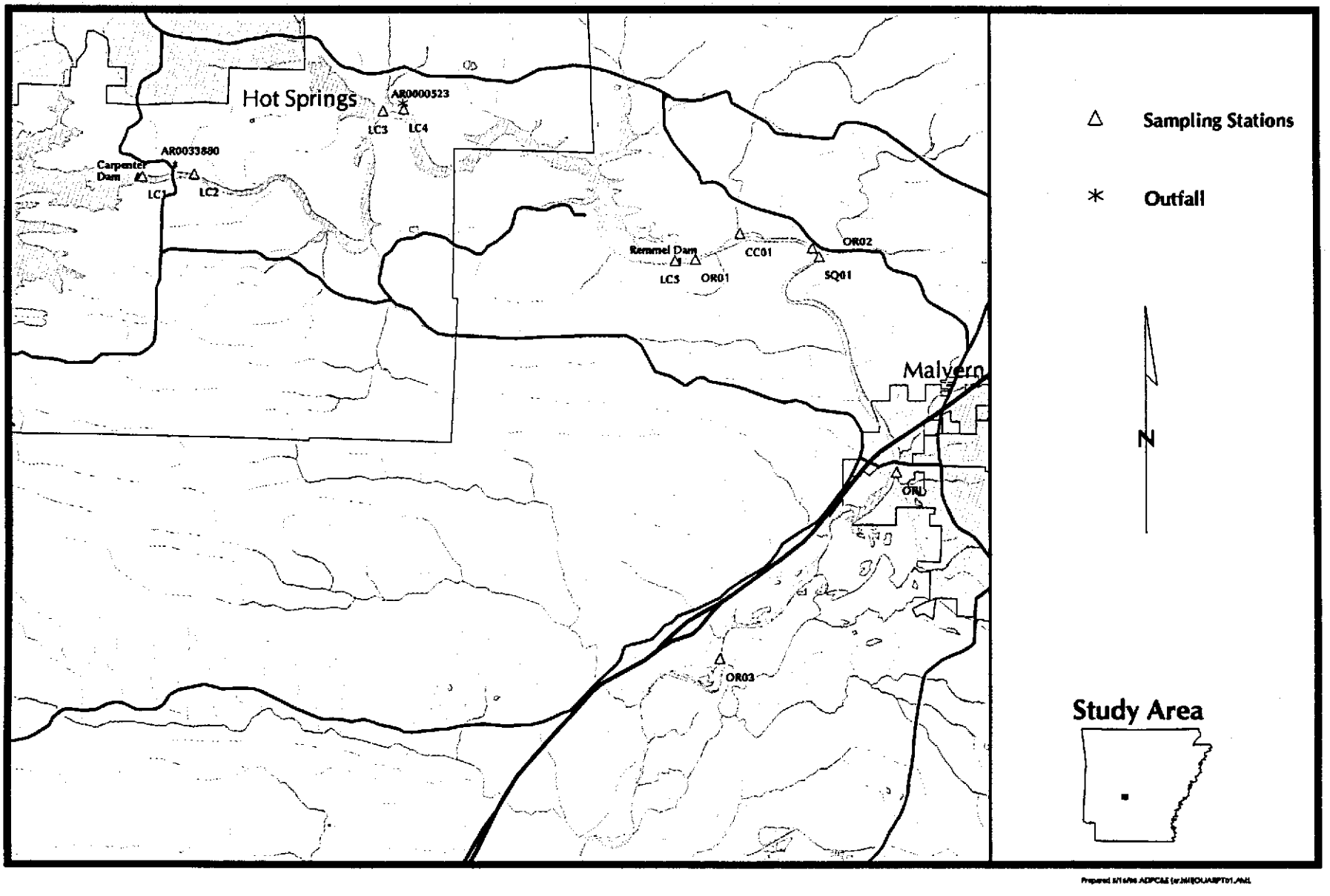


Figure 1 - Ouachita River Study Area and Sampling Stations

CC-01 Cove Creek near the confluence with the Ouachita River

OR-02 Ouachita River above confluence of Stone Quarry Creek; approximately 2.25 miles below Remmel Dam

SQ-01 Stone Quarry Creek at Ouachita River

OR-I Ouachita River at the City of Malvern water intake approximately 6 miles below Remmel Dam

OR-03 Ouachita River at the Grigsby Ford Bridge approximately 9 miles below Remmel Dam

RESULTS

Lake Catherine Data

In Lake Catherine, ammonia concentrations noticeably above detection levels were found only downstream of the U.S. Vanadium Co. discharge. During this study, ammonia values at LC4 immediately below U.S. Vanadium, ranged from <0.05 mg/L at LC4-U to 0.955 mg/L at LC4-L (Table 1). Typically the highest ammonia values were in the lower strata of LC4. Concentrations upstream of LC4 remained very low during the study period.

Sulfate values were also found to be elevated downstream of the U.S. Vanadium discharge. The pattern was similar to that of ammonia with the highest values near the bottom and declining values toward the surface (Figure 2). It was also noticed that slightly elevated sulfate values occurred upstream from the discharge at LC3; however at this station, highest values normally occurred near the surface. This phenomenon was caused by periodic backflows in the lake caused by the intermittent generation pattern from the upstream and downstream hydropower plants.

Lake pH values were noticeably elevated near the surface throughout this study. The range of pH was from 7.26 to 9.43 with the highest surface and mid-depth values occurring near the middle of the lake at stations LC3 and LC4. There was an obvious phytoplankton bloom at these stations.

Slightly elevated nitrate-N and measurable ortho-phosphate levels were consistently found at station LC2 which was located just below the Hot Springs STP discharge into upper Lake Catherine.

Dissolved metals data demonstrated significantly elevated concentrations of vanadium at all stations below the U.S. Vanadium discharge (Table 2). Vanadium concentrations upstream of LC3 were below detection limits throughout the study period. Concentrations at LC3 and below ranged from 44.6 ug/L at LC3-U to 269.5 ug/L at LC4-L. As shown in Figure 3, mean vanadium concentrations around

TABLE 1. LAKE CATHERINE AMMONIA STUDY, ROUTINE PARAMETERS

STATION	TIME	DO	pH	NH3-	NO3-	O-PHOS	SO4	CL	TOC	TSS	TDS	FLOW
		mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
		DATE: 960408										
LC-1	1240	10.1	7.33	<0.05	0.129	<0.03	5.2	2.62	3.3	< 1	41	NO GEN
LC2-U	1215	10.0	7.33	<0.05	0.607	0.128	7.5	4.44	3.6	< 1	52	NO GEN
LC2-M	1220	9.9	7.3	<0.05	0.592	0.122	6.4	3.99	3.9	1.0	51	NO GEN
LC2-L	1225	9.9	7.64	<0.05	0.41	0.048	6.4	3.28	3.6	1.0	46	NO GEN
LC3-U	1130	11.1	8.51	<0.05	0.253	<0.03	13.5	4.07	4.2	4.5	51	NO GEN
LC3-M	1140	10.5	7.71	<0.05	0.269	<0.03	7.5	3.51	3.7	2.5	42	NO GEN
LC3-L	1145	10.1	7.58	<0.05	0.226	<0.03	9.6	3.79	3.7	3.5	48	NO GEN
LC4-U	1045	11.4	8.44	0.087	0.297	<0.03	19.6	6.01	4.5	5.0	66	NO GEN
LC4-M	1100	10.8	7.8	0.302	0.246	<0.03	25.3	5.68	3.8	3.5	70	NO GEN
LC4-L	1100	10.8	7.82	0.727	0.273	<0.03	47.9	6.46	4.1	4.0	105	NO GEN
		DATE: 960409										
LC-1	1200	11.4	7.38	<0.05	0.094	<0.03	5.2	2.23	3.4	< 1	40	NO GEN
LC2-U	1140	10.0	7.34	<0.05	0.775	0.097	7.5	3.81	3.7	< 1	51	NO GEN
LC2-M	1145	9.9	7.32	<0.05	0.789	0.108	7.5	3.94	3.7	< 1	52	NO GEN
LC2-L	1150	9.8	7.29	<0.05	0.875	0.11	7.5	3.82	3.6	< 1	52	NO GEN
LC3-U	1056	12.3	8.75	<0.05	0.297	<0.03	22.9	4.01	5.1	4.5	61	NO GEN
LC3-M	1100	11.5	8.16	<0.05	0.207	<0.03	12.5	3.22	4	4.0	48	NO GEN
LC3-L	1105	11.0	7.75	<0.05	0.24	<0.03	28.5	5.55	3.8	3.0	78	NO GEN
LC4-U	1030	11.6	9.02	<0.05	0.328	<0.03	21.3	3.86	5.1	4.0	65	NO GEN
LC4-M	1035	11.6	8.52	0.176	0.278	<0.03	29.3	4.98	4.2	4.0	75	NO GEN
LC4-L	1040	11.1	7.91	0.955	0.281	<0.03	52.8	5.71	3.9	4.0	112	NO GEN
		DATE: 960410										
LC-1	1330	10.3	7.33	0.057	0.116	<0.03	6.4	2.35	3.4	< 1	40	NO GEN
LC2-U	1300	9.8	7.3	0.071	?0.113	<0.03	7.5	2.33	3.9	1.5	50	NO GEN
LC2-M	1305	9.6	7.23	0.074	0.637	0.075	7.5	3.54	3.8	1.5	46	NO GEN
LC2-L	1310	10.0	7.32	0.052	0.212	<0.03	6.4	2.7	3.4	2.0	40	NO GEN
LC3-U	1230	11.6	9.02	0.064	0.282	<0.03	20.5	3.74	5	6.0	58	NO GEN
LC3-M	1235	11.1	8.33	<0.05	0.27	<0.03	20.5	4.02	4.2	5.5	59	NO GEN
LC3-L	1240	10.1	7.66	<0.05	0.28	<0.03	15.3	2.29	4	4.5	55	NO GEN
LC4-U	1210	11.6	9.03	0.09	0.298	<0.03	21.3	3.74	5	5.5	57	NO GEN
LC4-M	1215	11.0	8.4	0.194	0.29	<0.03	24.6	4.03	4.1	5.5	62	NO GEN
LC4-L	1220	10.6	7.97	0.196	0.312	<0.03	28.5	4.3	3.9	6.0	69	NO GEN
		DATE: 960411										
LC-1	1225	10.3	7.48	0.074	0.11	<0.03	6.2	2.39	3.7	1.0	39	NO GEN
LC2-U	1155	9.2	7.48	<0.05	0.467	0.042	5.3	3.16	3.8	1.5	46	NO GEN
LC2-M	1200	10.0	7.47	<0.05	0.584	0.06	4.3	3.43	3.6	1.0	46	NO GEN
LC2-L	1207	9.5	7.39	0.055	0.321	<0.03	4.3	2.96	3.7	1.5	42	NO GEN
LC3-U	1120	11.0	9.08	<0.05	0.309	<0.03	19.2	3.9	5.3	5.5	61	NO GEN
LC3-M	1120	11.0	8.66	<0.05	0.248	<0.03	20	4.55	4.6	5.5	61	NO GEN
LC3-L	1129	10.7	7.84	<0.05	0.282	<0.03	10.9	3.51	4.2	5.0	52	NO GEN
LC4-U	1100	10.7	9.43	<0.05	0.295	<0.03	18.4	3.93	5.4	6.0	64	NO GEN
LC4-M	1106	10.3	8.59	0.218	0.297	<0.03	23.9	4.27	4.7	5.5	71	NO GEN
LC4-L	1111	10.4	7.89	0.261	0.31	<0.03	23.9	4.2	4.2	5.0	71	NO GEN
LC5-U	1350	8.6	7.46	0.292	0.31	<0.03	23.9	4.21	4	4.0	69	NO GEN
LC5-M	1355	8.7	7.50	0.217	0.315	<0.03	20.8	4.01	3.9	4.0	63	NO GEN
LC5-L	1404	8.5	7.26	0.428	0.292	<0.03	24.7	4.12	3.8	1.5	72	NO GEN

FIGURE 2. LAKE CATHERINE AMMONIA AND SULFATES
Mean values (08–11 April 1996)

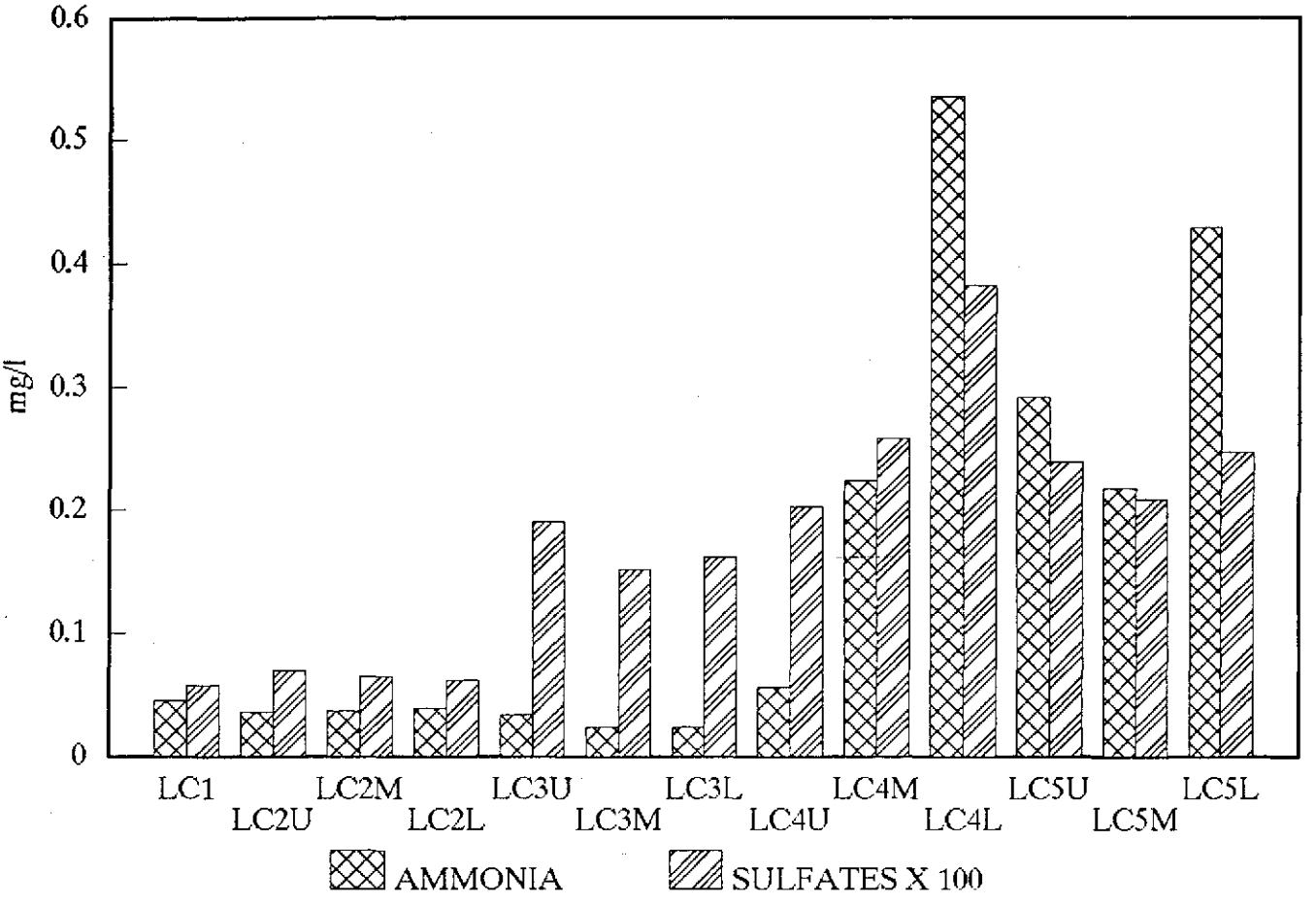


TABLE 2. LAKE CATHERINE AMMONIA STUDY, METALS

DATE: 960408

Station	Time	Cd	Cr	Pb	Al	Cu	Ca	Fe	K	Mg	Mn	Na	Zn	Ni	B	Be	Ba	Co	V
		ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	ug/l	mg/l	mg/l	ug/l	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
LC-1	1240	<0.5	<1	<2	<16	<2	5.9	48.5	0.5	1.6	23.3	2.1	<2.0	<5	9.4	<2	14.7	<3	<5
LC2-U	1215	<0.5	<1	<2	<16	<2	6.6	34.6	0.9	1.7	13.5	3.6	4	<5	18	<2	13.8	<3	<5
LC2-M	1220	<0.5	<1	<2	17.1	<2	6.6	34.7	0.9	1.6	13.4	3.9	4.1	<5	14.6	<2	13.5	<3	<5
LC2-L	1225	<0.5	<1	<2	17.7	<2	6.4	32.9	0.7	1.7	15.4	2.1	2.5	<5	12.1	<2	14.2	<3	<5
LC3-U	1130	<0.5	<1	<2	<16	<2	6.9	20.3	0.9	1.8	25.1	3.4	2.1	<5	11.4	<2	16	<3	44.6
LC3-M	1140	<0.5	<1	<2	16	<2	6.2	21.7	0.8	1.6	11.4	0.7	<2.0	<5	7.2	<2	15.1	<3	<5
LC3-L	1145	<0.5	<1	<2	<16	<2	7.2	27.7	0.6	1.8	57.1	3.7	<2.0	<5	13.8	<2	16.4	<3	<5
LC4-U	1045	<0.5	<1	<2	17.8	<2	6.9	15.3	0.9	1.7	19.7	6.1	7.9	<5	10.6	<2	15.8	<3	84.8
LC4-M	1100	<0.5	<1	<2	22.8	<2	7.5	19.5	1	1.7	47.9	9.6	2.3	<5	7.6	<2	16.6	<3	121.6
LC4-L	1100	<0.5	<1	<2	36.6	<2	8	24.3	1.2	1.8	54.8	19.3	3.7	<5	10	<2	17.2	<3	258.3

DATE: 960409

Station	Time	Cd	Cr	Pb	Al	Cu	Ca	Fe	K	Mg	Mn	Na	Zn	Ni	B	Be	Ba	Co	V
LC-1	1200	<0.5	<1	<2	<16	<2	5.9	31.1	0.6	1.6	13.7	2.5	<2.0	<5	7.5	<2	14.7	<3	<5
LC2-U	1140	<0.5	<1	<2	<16	<2	6.6	27.4	0.9	1.7	11.8	4.3	3.5	<5	16.2	<2	14.1	<3	<5
LC2-M	1145	<0.5	<1	<2	<16	<2	6.6	29.5	0.9	1.7	11.4	4.6	3.3	<5	15.5	<2	13.9	<3	<5
LC2-L	1150	<0.5	<1	<2	<16	<2	6.6	31.6	0.9	1.7	11.4	4	15.3	<5	16.3	<2	14.1	<3	<5
LC3-U	1056	<0.5	<1	<2	<16	<2	6.6	9.8	0.8	1.6	2.6	7.8	<2.0	<5	8.5	<2	14.4	<3	94.9
LC3-M	1100	<0.5	<1	<2	<16	<2	6.8	19.5	0.7	1.8	25.7	3.6	2.5	<5	11.5	<2	15	<3	13.9
LC3-L	1105	<0.5	<1	<2	<16	<2	12.4	16.6	0.9	2.8	250	3.6	2.8	<5	10.3	<2	17	<3	13.4
LC4-U	1030	<0.5	<1	<2	<16	3.5	6.5	15.2	0.9	1.7	2.7	7.4	5.4	<5	12.2	<2	14.8	<3	114.4
LC4-M	1035	<0.5	<1	<2	<16	<2	7.6	17.3	0.9	1.8	38.8	8.8	3	<5	10.9	<2	15.6	<3	122.6
LC4-L	1040	<0.5	<1	<2	19.5	<2	8.7	19.6	1.1	1.9	78.9	21.1	3.1	<5	11.9	<2	16.5	<3	269.5

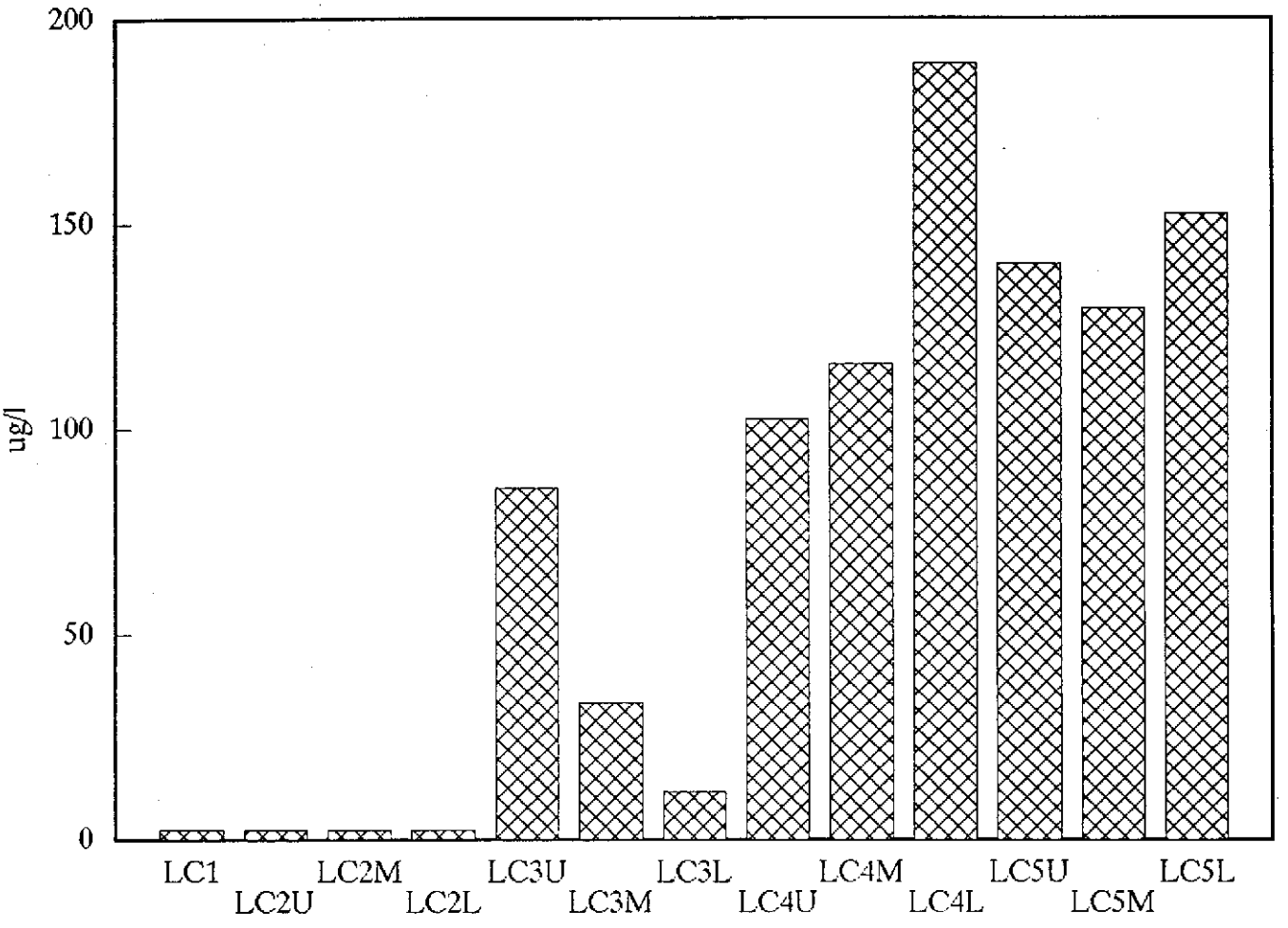
DATE: 960410

Station	Time	Cd	Cr	Pb	Al	Cu	Ca	Fe	K	Mg	Mn	Na	Zn	Ni	B	Be	Ba	Co	V
LC-1	1330	<0.5	<1	<2	<16	<2	5.9	42.5	0.7	1.6	19	2	3.4	<5	10.7	<2	15.5	<3	<5
LC2-U	1300	<0.5	<1	<2	<16	<2	7.7	24.8	1.1	1.7	17.7	5.4	5.3	<5	12.3	<2	15.6	3.3	<5
LC2-M	1305	<0.5	<1	<2	<16	<2	7.2	24.9	0.9	1.7	18.8	4	3.7	<5	9.4	<2	15.8	<3	<5
LC2-L	1310	<0.5	<1	<2	<16	<2	7	23.5	0.7	1.8	26.1	3.7	2.2	<5	4.6	<2	16.1	<3	<5
LC3-U	1230	<0.5	<1	<2	<16	2.4	7.2	<1.8	0.9	1.7	2.4	8.7	3.1	<5	5.5	<2	16.1	<3	85.3
LC3-M	1235	<0.5	<1	<2	<16	<2	9.1	2.8	0.9	1.9	66.9	6.5	2.6	<5	4.5	<2	16.1	3.2	49.6
LC3-L	1240	<0.5	<1	<2	<16	<2	8.8	10.2	0.9	2	72.3	4.3	3	<5	4.9	<2	16.2	3.2	18.5
LC4-U	1210	?18.6	<1	<2	<16	<2	7.1	4.1	0.9	1.7	2.5	9.4	2.3	<5	7.8	<2	16	<3	99.3
LC4-M	1215	<0.5	<1	<2	<16	<2	8.1	5.9	0.9	1.8	36	10.2	2.7	<5	5.4	<2	16.5	3.3	87.1
LC4-L	1220	<0.5	<1	<2	<16	<2	8.7	6	1	1.9	57.5	10.8	2.7	<5	5.6	<2	16.6	3.4	103.6

DATE: 960411

Station	Time	Cd	Cr	Pb	Al	Cu	Ca	Fe	K	Mg	Mn	Na	Zn	Ni	B	Be	Ba	Co	V
LC-1	1225	<0.5	<1	<2	<16	<2	5.9	38.2	0.6	1.6	18.8	0.1	<2.0	<5	8.2	<2	14.7	<3	<5
LC2-U	1155	<0.5	<1	<2	<16	<2	6.3	30.8	0.8	1.7	13.4	2.4	<2.0	<5	12	<2	14.1	<3	<5
LC2-M	1200	<0.5	<1	<2	<16	<2	6.3	31.6	0.8	1.7	13	2.6	<2.0	<5	12.8	<2	14.7	<3	<5
LC2-L	1207	<0.5	<1	<2	<16	<2	6.1	28.6	0.7	1.6	11.5	2.3	<2.0	<5	10.2	<2	14.7	<3	<5
LC3-U	1120	<0.5	<1	<2	<16	<2	6.3	7.6	0.9	1.7	<2.0	7.1	<2.0	<5	11.7	<2	15.2	<3	115.9
LC3-M	1120	<0.5	<1	<2	<16	<2	8.4	12.1	0.8	2.1	75.9	4.5	<2.0	7.2	13.4	<2	14.8	<3	68.8
LC3-L	1129	<0.5	<1	<2	<16	<2	7.4	20.3	0.8	1.9	49	2.5	<2.0	<5	13	<2	14.2	<3	13.4
LC4-U	1100	<0.5	<1	10.4	<16	<2	6.3	7.6	0.8	1.6	<2.0	8	<2.0	<5	10.3	<2	15	<3	111.2
LC4-M	1106	<0.5	<1	<2	<16	<2	6.6	10.5	0.9	1.7	7.7	10	<2.0	<5	11.3	<2	15.3	<3	131.6
LC4-L	1111	<0.5	<1	<2	<16	<2	6.8	16.5	0.9	1.7	15.1	9.7	<2.0	<5	12	<2	14.4	<3	123.6
LC5-U	1350	<0.5	<1	<2	<16	<2	6.7	18.9	0.9	1.7	21.3	9.1	2.3	<5	11	<2	16.1	<3	140.1
LC5-M	1355	<0.5	<1	<2	<16	<2	6.3	14.4	0.9	1.7	4.2	7.6	<2.0	<5	11.3	<2	16.5	<3	129.3
LC5-L	1404	<0.5	<1	<2	<16	<2	6.5	21.8	0.9	1.6	13.6	9.3	2.6	<5	11	<2	16.7	<3	152.2

FIGURE 3. LAKE CATHERINE VANADIUM



the U.S. Vanadium discharge demonstrated a similar pattern as seen for ammonia and sulfates, but it was much more distinctive. Highest values were near the bottom at LC4 but were lower toward the surface. In contrast, at station LC3 just above the discharge, values were elevated but they were highest at the surface and lower toward the bottom.

The highest iron values were found immediately below Carpenter Dam (LC1); however the highest manganese levels were near the U.S. Vanadium discharge. Slightly elevated sodium values were also found in this area, and the pattern of distribution was the same as described for ammonia, sulfate and vanadium.

Discharge Monitoring Reports(DMR) from the City of Hot Springs STP shows monthly average values for ammonia to range between 0.08 mg/L and 0.58 mg/L for calendar year 1995. Monthly average ammonia values for the U.S. Vanadium discharge for the same time period ranged from 73 mg/L to 173 mg/L and vanadium monthly average values were from 23 mg/L to 56 mg/L (Table 3). Since U.S. Vanadium is restricted to discharge no more than 0.5% of the discharge flow into Lake Catherine, measured as discharges from Remmel Dam, a dilution factor of approximately 200:1 is required for the dilution of the discharge. The in-lake values for ammonia and vanadium were near the 200:1 ratio when compared to the U.S. Vanadium effluent before mixing with lake water (DMR values).

Ouachita River Data

Ammonia concentrations in the Ouachita River ranged from below detection level of 0.05 mg/L to 0.286 mg/L during this study (Table 4). Ammonia values at the Malvern intake were not found above the detection level of 0.05 mg/L. The highest ammonia values in the river were found immediately below Remmel Dam during a generation period(Figure 4).

River pH values were surprisingly high. They ranged from 6.76 to 9.69. The highest values occurred later in the day and during periods of non-generation, except for the April 11 sample taken during the onset of generation. Sulfate levels in the Ouachita River generally were below 25 mg/L, but sulfate levels in Stone Quarry Creek and Cove Creek were approximately double the concentration found in the Ouachita River.

Data from metals analyses show the highest concentrations of calcium, magnesium, manganese, and barium in Cove Creek and Stone Quarry Creek (Table 5). In addition, elevated values of cobalt, nickel, zinc, and aluminum were found only in Cove Creek. In contrast, the highest values of iron, sodium, and vanadium were found in the Ouachita River. Vanadium levels seem to be the most significant. These noticeably elevated values are easily traced to the U.S. Vanadium discharge into Lake Catherine. The concentrations remain fairly constant down the river to the Grigsby

TABLE 3

DISCHARGE MONITORING REPORTS-MONTHLY AVERAGE

	HOT SPRINGS STP	U.S. Vanadium - 001	
	Ammonia (mg/L)	Ammonia (mg/L)	Vanadium (mg/L)
1995			
January	0.31	138	55
February	0.58	173	49
March	0.48	139	40
April	0.38	104	50
May	0.19	156	51
June	0.26	134	49
July	0.24	142	45
August	0.22	168	49
September	0.13	173	50
October	0.21	142	56
November	0.17	86	48
December	0.08	73	23

TABLE 4. OUACHITA RIVER AMMONIA STUDY, ROUTINE PARAMETERS

STATION	TIME	DO	pH	TEMP	NH3-N	NO3-N	O-PHOS	SO4	CL	TOC	TSS	TDS	FLOW
		mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
		DATE: 960408											
OR01	1130	11.8	7.6	15.3	0.096	0.479	<0.03	22.9	8.67	3.6	1	65	NO GEN.
CC01	1130	10.3	7.27	13.5	<0.05	0.195	<0.03	42.4	11.5	1.5	< 1	93	NO GEN.
OR02	1100	7.6	6.71	13.4	0.056	0.575	<0.03	23.7	4.82	3.5	1	70	NO GEN.
SQ01	1100	10	6.69	12.8	<0.05	0.153	<0.03	45.5	4.95	1.2	< 1	92	NO GEN.
ORI	955	10.2	6.76	13.1	<0.05	0.548	<0.03	22.9	4.05	3.6	< 1	69	NO GEN.
		DATE: 960409											
OR01	1030	10.2	7.14	13.5	0.11	0.492	<0.03	23.7	4.06	3.7	< 1	66	NO GEN.
CC01	1000	10.6	7.22	12.2	<0.05	0.171	<0.03	43.9	4.22	1.6	< 1	94	NO GEN.
OR02	1055	7.7	6.87	13.6	0.083	0.479	<0.03	25.3	4.13	3.4	< 1	68	NO GEN.
SQ01	1050	10	6.88	12.2	<0.05	0.12	<0.03	48.7	3.53	1.5	< 1	92	NO GEN.
ORI	1115	11.8	8.62	14.0	<0.05	0.473	<0.03	22.1	3.91	3.7	< 1	63	NO GEN.
OR03	1145	9.1	7.29	14.8	<0.05	0.482	<0.03	22.9	3.84	4.0	< 1	67	NO GEN.
		DATE: 960410											
OR01	1340	12.2	8.48	17.1	0.187	0.499	0.042	27.7	4.72	3.9	2	65	NO GEN.
CC01	1400	10.3	7.46	16.2	<0.05	0.188	<0.03	43.9	3.74	1.6	< 1	89	NO GEN.
OR02	1430	10.9	7.88	16.3	0.136	0.481	<0.03	28.5	3.99	3.6	< 1	68	NO GEN.
SQ01	1425	9.3	6.89	16.8	<0.05	0.129	<0.03	52.8	3.49	1.2	< 1	94	NO GEN.
ORI	1450	13.8	9.69	16.0	<0.05	0.479	<0.03	25.3	4.61	4.0	1	66	NO GEN.
OR03	1510	9.9	7.61	15.8	0.131	0.46	<0.03	24.6	4.17	4.0	4	63	NO GEN.
		DATE: 960411											
OR01	1735	10	6.8	14.4	0.286	0.403	<0.03	25.4	4.7	3.8	2.5	65	GEN.
OR02	1820	10.9	7.4	17.2	0.079	0.474	<0.03	25.4	4.38	3.5	< 1	71	GEN.
ORI	2040	11.9	9.15	17.0	<0.05	0.435	<0.03	23.1	4.41	4.1	9.5	66	GEN.
		DATE: 960418											
OR01-B	635	8.8	7.14	14.5	<0.05	0.222	<0.03	11.7	3.48	4.0	2.5	60	GEN
OR01-C	710	8.7	7.2	14.5	<0.05	0.217	<0.03	10.9	3.77	3.6	2	57	GEN
OR02-A	625	8.3	7.05	15.4	<0.05	0.268	<0.03	18.4	3.45	2.9	3	65	NO GEN
OR02-B	635	7.6	6.89	15.4	<0.05	0.265	<0.03	20.0	3.16	2.7	8.5	65	GEN
OR02-C	725	8	7.05	14.6	<0.05	0.247	<0.03	14.3	3.26	3.7	6.5	61	GEN
ORI-A	740	7.6	7.16	15.3	<0.05	0.209	<0.03	10.9	3.62	3.6	1.5	61	NO GEN
ORI-B	825	8	7.25	15.5	<0.05	0.205	<0.03	10.9	3.63	3.6	8	59	GEN
ORI-C	910	7.6	7.03	15.5	<0.05	0.235	<0.03	10.9	3.24	3.5	11.5	56	GEN
OR03-A	925	7.7	7.12	16.2	<0.05	0.264	<0.03	10.9	3.37	3.7	2.5	59	NO GEN
OR03-B	1020	7.7	7.12	16.3	<0.05	0.265	<0.03	10.9	3.76	3.7	2	61	GEN
OR03-C	1105	7.6	7.04	16.1	<0.05	0.257	<0.03	10.9	3.43	3.7	2	62	GEN

FIGURE 4. DAILY VALUES FOR AMMONIA
OUACHITA RIVER (BELOW REMMEL DAM)

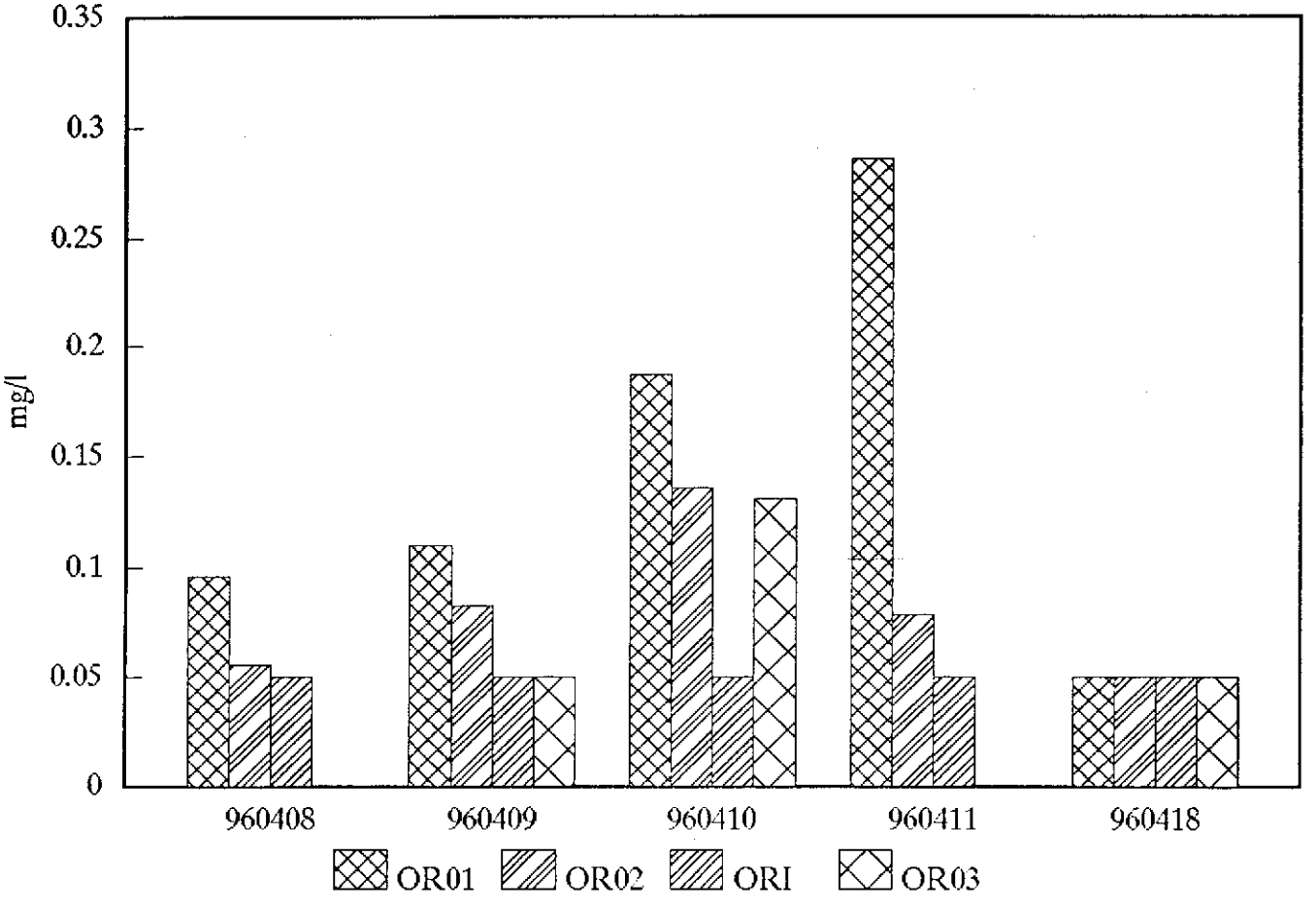


TABLE 5. OUACHITA RIVER AMMONIA STUDY, METALS.

Station	Time	Cd ug/l	Cr ug/l	Pb ug/l	Al ug/l	Cu ug/l	Ca ug/l	Fe ug/l	K ug/l	Mg ug/l	Mn ug/l	Na ug/l	Zn ug/l	Ni ug/l	B ug/l	Be ug/l	Ba ug/l	Co ug/l	V ug/l
	DATE:	960408																	
OR01	1130	<0.5	<1	<2	<16	<2	6.1	17.1	0.9	1.6	6.3	8.9	<2.0	<5	11.3	<2	14.7	<3	149.9
CC01	1130	<0.5	<1	<2	30.8	<2	12.1	<1.8	0.8	4.9	806	3.3	24.3	11.7	10.1	<2	62.4	8.1	<5
OR02	1100	<0.5	<1	<2	<16	<2	6.8	24.3	0.9	1.9	56.4	8.3	2.3	<5	11.1	<2	25.8	<3	127.9
SQ01	1100	<0.5	<1	<2	<16	<2	12.4	5	1.1	4.3	107	3.8	3.3	<5	10.3	<2	55.3	<3	<5
ORI	955	<0.5	<1	<2	<16	<2	6.7	42.6	0.9	1.7	37.5	8.5	<2.0	<5	12.9	<2	21.4	<3	130.3
	DATE:	960409																	
OR01	1030	<0.5	<1	<2	<16	<2	6.2	17.1	0.8	1.5	6.4	8.7	<2.0	<5	10.5	<2	14.9	<3	131.1
CC01	1000	<0.5	<1	<2	22.3	<2	12.4	<1.8	0.7	4.8	771	3.9	26.8	12.6	11.9	<2	62.3	7.5	<5
OR02	1055	<0.5	<1	<2	<16	<2	6.5	27.8	0.8	2	55.7	7.9	<2.0	<5	13.5	<2	25.2	<3	119.8
SQ01	1050	<0.5	<1	<2	<16	<2	12.8	6.2	1	4.6	103	4.4	2.9	6.1	13.6	<2	56.9	<3	<5
ORI	1115	<0.5	<1	<2	<16	<2	6.4	39.2	0.7	1.6	26.3	7.6	<2.0	<5	11.7	<2	17.6	<3	119.7
OR03	1145	<0.5	<1	<2	<16	<2	6.4	39	0.8	1.6	57.2	8.9	2.4	<5	10.8	<2	17.8	<3	112.4
	DATE:	960410																	
OR01	1340	<0.5	<1	<2	<16	<2	6.3	19.2	0.8	1.6	10	10.6	7.6	<5	12.5	<2	13.1	<3	150.3
CC01	1400	<0.5	<1	3.1	39.7	<2	12.5	<1.8	0.7	4.9	664	5	16.9	12.7	12.8	<2	60.1	4.3	<5
OR02	1430	<0.5	<1	<2	<16	<2	6.5	20.2	0.9	1.7	23.5	9.6	2.6	<5	11.3	<2	17.7	<3	139.7
SQ01	1425	<0.5	<1	<2	<16	<2	13.6	7.3	1.1	4.7	84.8	3.4	3.6	<5	12.5	<2	57.1	<3	<5
ORI	1450	<0.5	<1	<2	<16	<2	6.2	47.4	0.8	1.6	25.4	8.4	<2.0	<5	12.2	<2	14.6	<3	147.5
OR03	1510	<0.5	<1	<2	18.4	<2	6.3	53.5	0.8	1.7	71.8	9.3	<2.0	<5	13.5	<2	18.9	<3	128.3
	DATE:	960411																	
OR01	1735	<0.5	<1	<2	<16	<2	6.4	22.3	0.9	1.6	15.1	9.9	<2.0	<5	12.8	<2	15.5	<3	153.9
OR02	1820	<0.5	<1	<2	17.7	<2	6.7	28.5	0.8	2	32.6	7.3	<2.0	<5	14.2	<2	19.8	<3	140.8
ORI	2040	<0.5	<1	<2	21.4	<2	6.4	43.9	0.8	1.6	27.2	9	<2.0	<5	13.6	<2	15.8	<3	145.1
	DATE:	960418																	
OR01-B	635	< 0.5	< 1	< 2	29.5	<2	6.0	26.2	0.6	1.6	7.1	3.9	<2.0	<5	5.2	<2	13.9	<3	37.9
OR01-C	710	< 0.5	< 1	< 2	39.8	<2	6.2	33.2	0.6	1.6	8.5	3.5	4.8	<5	6.0	<2	14.3	<3	36.3
OR02-A	625	< 0.5	< 1	< 2	37.8	<2	7.4	33.1	0.6	2.5	193	4.0	14.4	<5	6.7	<2	34.8	<3	24.4
OR02-B	635	< 0.5	< 1	< 2	36.2	<2	7.7	29.5	0.6	2.6	211	3.3	11.8	6.3	7.4	<2	36.5	<3	22.6
OR02-C	725	< 0.5	< 1	< 2	40.4	<2	6.9	24.2	0.6	2.1	108	2.9	3.4	5.3	6.6	<2	24.2	<3	29.9
ORI-A	740	< 0.5	< 1	< 2	39.1	<2	6.7	74.1	0.6	1.7	83.5	3.5	<2.0	<5	5.3	<2	24.4	<3	31.1
ORI-B	825	< 0.5	< 1	< 2	39.3	<2	6.9	64.6	0.6	1.7	87.4	3.0	2.7	<5	5.0	<2	26.6	<3	29.3
ORI-C	910	< 0.5	< 1	< 2	41.9	<2	6.9	43.7	0.6	1.8	72.2	4.5	8.9	<5	3.7	<2	21.2	<3	32.9
ORO3-A	925	< 0.5	< 1	< 2	38.2	<2	6.7	50.2	0.6	1.7	95.1	4.6	<2.0	<5	4.0	<2	21.7	<3	37.5
OR03-B	1020	< 0.5	< 1	< 2	35.6	<2	6.7	51.7	0.7	1.7	135	4.3	<2.0	<5	<3	<2	22.3	<3	36.6
OR03-C	1105	< 0.5	< 1	< 2	34.8	<2	6.8	52	0.7	1.8	137	4.0	<2.0	<5	<3	<2	22.0	<3	37.1

Ford station (OR03). However, there was a significant reduction in the vanadium levels in the April 18 samples (Figure 5).

Hydropower discharges from Remmel Dam into the Ouachita River are plotted in Figure 6. During the first week of the study (April 8 - April 11) generation was limited to only 2 to 3 hours each evening. Over the weekend of April 13-14, discharges were continuous and of a greater magnitude than the previous week. The generation pattern during the second week of the study, which included only the April 18 sample, was modified to include 2 to 3 hours of discharges each morning in addition to the 2 to 3 hours each evening. The substantial reduction in most parameters associated with the U.S.Vanadium discharge during the April 18 sampling may have been related to the change in the generation pattern and/or to a reduction in the U.S.Vanadium discharge.

Vanadium Toxicity

Acute and chronic toxicity values for vanadium are not available in the National Ambient Water Quality Criteria (NAWQC) for Protection of Aquatic Life. However, alternate benchmarks using fewer data than are required by NAWQC have been calculated. The Department of Energy has calculated a secondary acute value of 0.284 mg/L and a secondary chronic value of 0.019 mg/L for vanadium (Suter, et al. 1994). The calculations of these values are described in the EPA's Proposed Water Quality Guidance for the Great Lakes System (EPA 1993).

In 1987, the Michigan Department of Environmental Quality calculated acute and chronic values of 0.3 mg/L and 0.008 mg/L respectively for vanadium. These values are water quality standards based on aquatic life protection in the State of Michigan (R 323.1057 Rule 57).

The majority of research on human health effects of vanadium has been concentrated in the area of exposure from inhalation of dust since that is the most probable pathway for human exposure. Somewhat limited data is available on oral exposure. In the Toxicological Profile for Vanadium published by the Public Health Service an intermediate duration (15-364 days) Minimal Risk Level (MRL) of 0.003 mg/kg/day has been identified. The MRL is a level at which adverse health effects are not expected to be seen in humans (DHHS 1992).

Based on the information above, the vanadium concentrations found during the study could possibly pose a risk to both human health and aquatic life.

FIGURE 5. DAILY VALUES FOR VANADIUM
OUACHITA RIVER (BELOW REMMEL DAM)

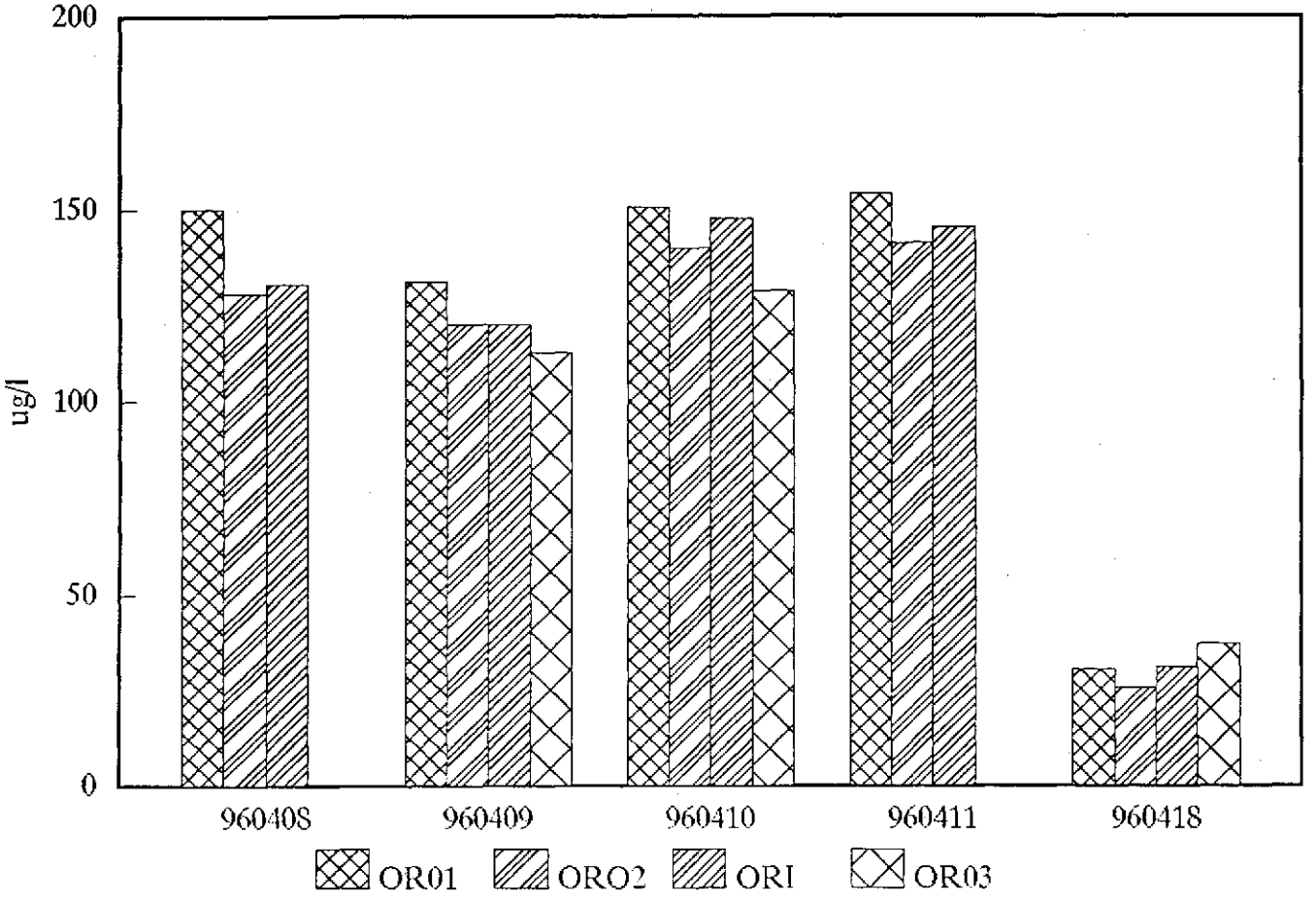
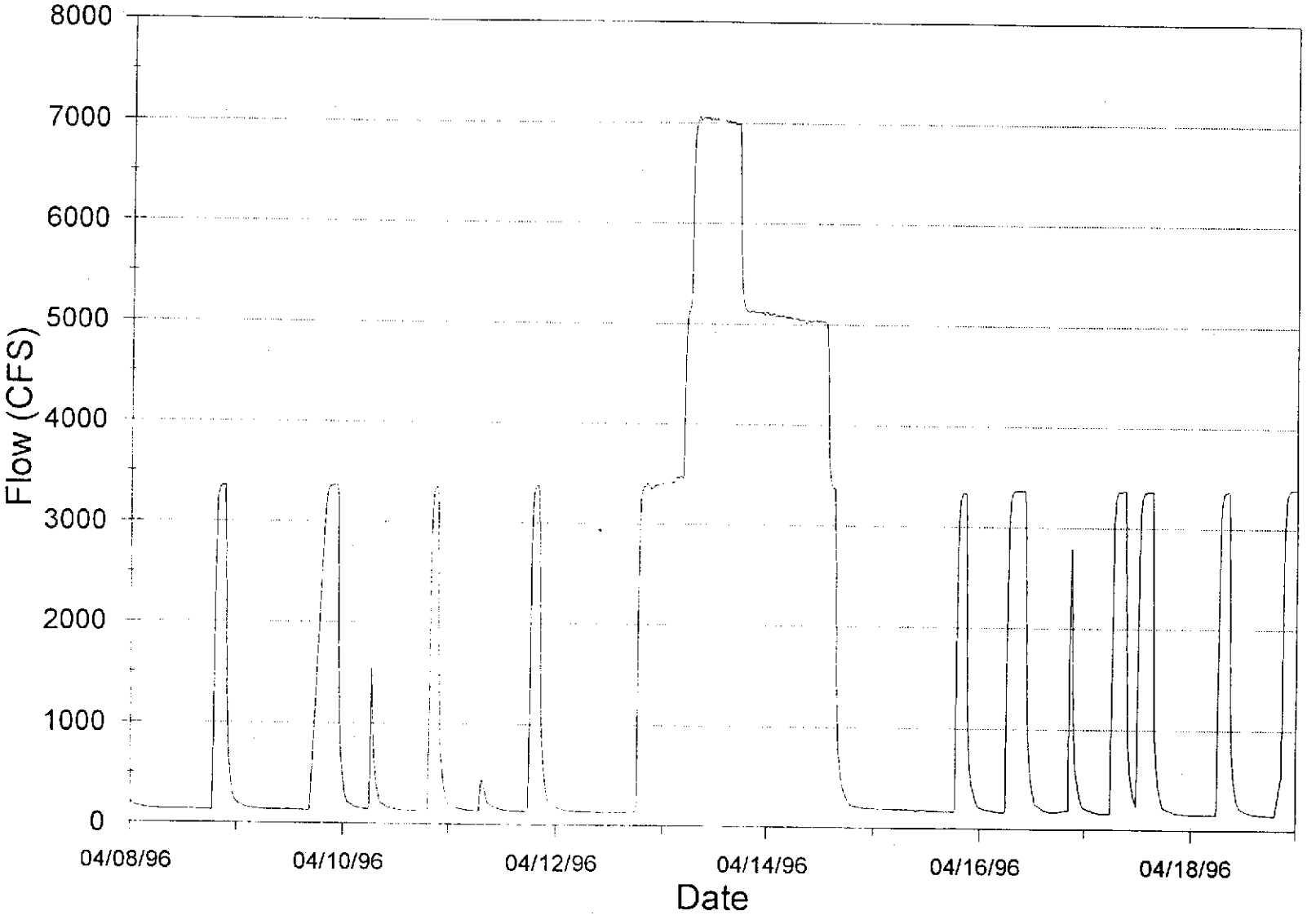


Figure 6 - Ouachita River Flows

USGS Gauging Station blw Remmel Dam



CONCLUSION

During the short term of this preliminary study, elevated ammonia levels were found only downstream from the U.S. Vanadium discharge in the bottom strata of Lake Catherine. Similarly, elevated levels of vanadium, sulfate, and sodium could be associated with this discharge. The distribution pattern of these elevated parameters was similar and was identified by highest values in the lower strata of the lake where the discharge occurs and lesser values toward the surface. In addition, lower but elevated values of these parameters were found just upstream of the discharge. At the upstream site, highest values were near the surface and declining toward the bottom. This resulted from intermittent hydropower discharges into and from Lake Catherine causing occasional surface backflows of generation waters in the lake. Assuming U.S. Vanadium discharges during this study were similar to those in 1995, the in-lake values for ammonia and vanadium represent an approximate 200:1 dilution from the in-pipe values(DMR data). Ammonia values in the Ouachita River at the City of Malvern water intake were not found above the detection level of 0.05 mg/L during this study. Most of these samples were taken during periods of no hydropower releases from Lake Catherine and generally during mid-day to late afternoon. There was an abundance of attached filamentous algae and other aquatic macrophytes in the river during this period which may have influenced the spatial attenuation of ammonia levels in the river. Significantly elevated vanadium levels were found at all river stations, and some literature reports indicate that the values found may pose an increased human health risk and possibly aquatic life toxicity.