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A Preliminary Survey of Water Quality in the Upper Embarras River Basin, Illinois

by Shun Dar Lin and Raman Raman
Office of Water Quality Management

Prepared for the
U.S. Soil Conservation Service

December 1991

Illinois State Water Survey
Chemistry Division
Peoria, Illinois

A Division of the Illinois Department of Energy and Natural Resources

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A PRELIMINARY SURVEY OF WATER QUALITY IN THE UPPER EMBARRAS RIVER BASIN, ILLINOIS

Shun Dar Lin and Raman Raman

INTRODUCTION

To assess the water quality of the Upper Embarras River, the Office of Water Quality Management of the Illinois State Water Survey cooperated with the U.S. Soil Conservation Service, Champaign office, to conduct a one-year water quality survey from October 1, 1990, to September 30, 1991. The specific objective was to provide an inventory that will identify the condition and characteristics of the river waters and the factors or sources that degraded the water quality.

STUDY AREA

In this study, the Upper Embarras River basin was designated as the watershed, encompassing the area upstream of Camargo, which is located in Douglas County, Illinois (figure 1). The drainage area of the Upper Embarras River upstream of Camargo is 186 square miles (482 square kilometers). The drainage basin consists of the sourthern part of Champaign County and the northern part of Douglas County. The northernmost portion of the watershed drains the southern part of the University of Illinois campus, which covers most of the land south of Kirby Avenue in Champaign (Florida Avenue in Urbana).

The headwaters of the Embarras River are on the University of Illinois campus at the southern edge of Champaign and Urbana and along the eastern side of Savoy. The river then runs generally south through rural agricultural land to the city of Villa Grove. There the Embarras River converges with a major tributary, Jordan Slough, which enters from the east.

The main communities in the watershed are the southern portions of Champaign and Urbana, Savoy, Philo, Allerton, Broadlands, Longview, Fairland, Villa Grove, and Camargo (figure 1). Except for the cities and villages, most of the area is cropland. The land is very flat. Ditches were constructed in the past to improve agricultural drainage.

Poor drainage, agricultural flooding, intensive use of agricultural chemicals, and the contribution of urban runoff from medium-sized cities are concerns common to the Upper

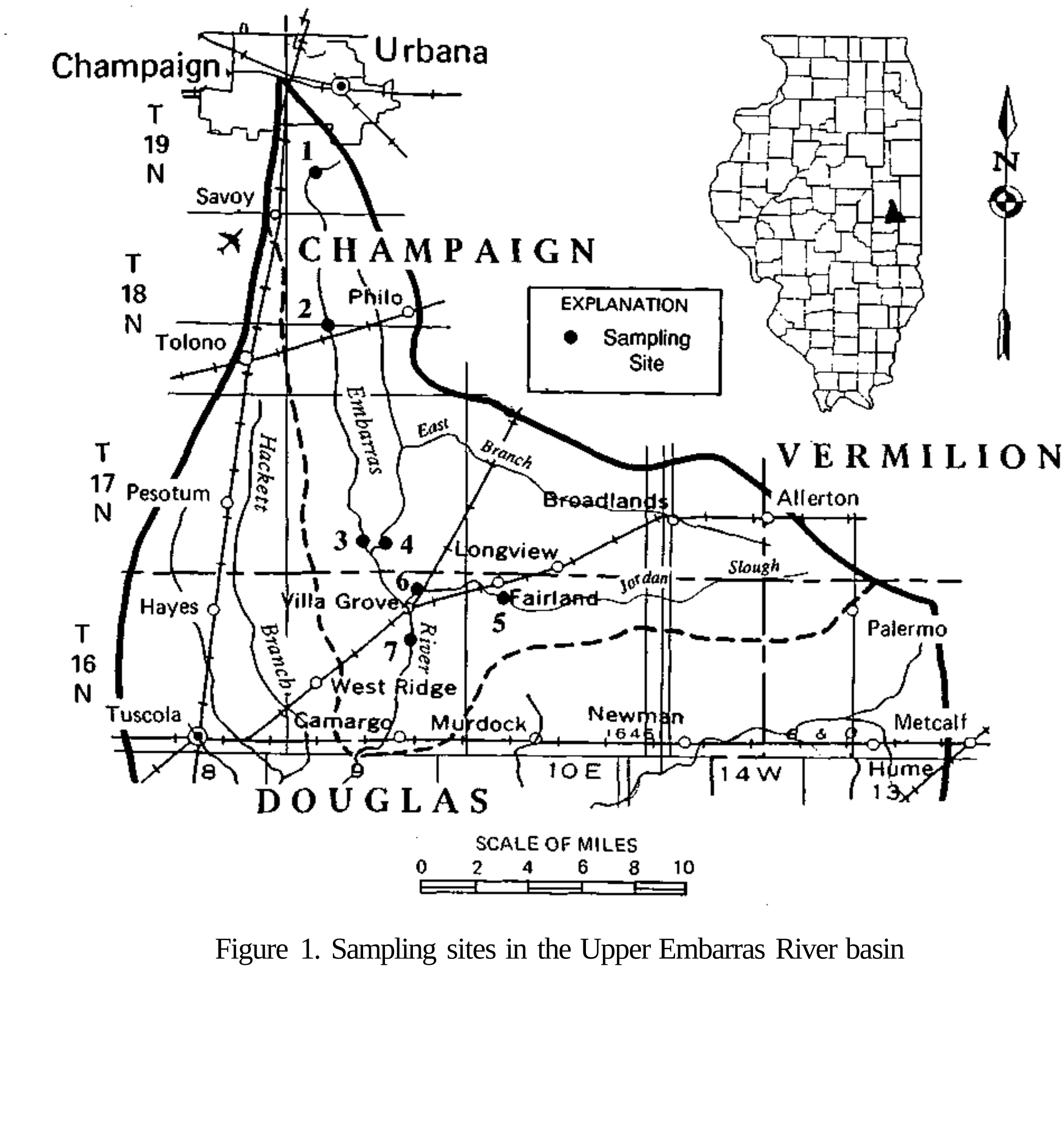

Figure 1. Sampling sites in the Upper Embarras River basin

Embarras River basin and other areas of the midwestern Corn Belt. Hydrological data and water quality information are lacking.

METHODS AND PROCEDURES

Even though it is necessary to monitor water quality conditions during storm events for a streamwater quality survey, the lack of adequate resources precluded this approach. Instead, water samples were collected for analyses from seven locations four times each: once during the months of November 1990, and April, June, and August 1991. The latter three sets of samples are indicative of stream conditions during spring rainfall and the crop-growing season.

Seven sampling sites were chosen, as shown in figure 1: four on the main stem of the river and three on tributaries. These sampling stations were selected to reflect the impacts of land uses in the chosen sub-basins, including urban, agricultural, livestock management, and landfill. The locations of the seven sampling stations, as well as a U.S. Geological Survey (USGS) long-term sampling site are as follows:

Sampling station	*Latitude*	*Longitude*	*Remarks*
1	40° 04' 10"	88° 13' 24"	Embarras R., main stem, 2 miles S of U. of I. campus
2	39° 58' 53"	88° 12' 15"	Embarras R., main stem, 2.5 miles SW of Philo
3	39° 53' 36"	88° 11' 15"	Embarras R., main stem, 3 miles NW of Villa Grove
4	39° 53' 33"	88° 10' 44"	East Branch, 2.5 miles NW of Villa Grove
5	39° 52' 33"	88° 07' 18"	Jordan Slough, upstream side of a landfill
6	39° 52' 26"	88° 09' 03"	Jordan Slough, downstream side of a landfill
7	39° 50' 20"	88° 09' 15"	Embarras R., main stem, 1 mile S of Villa Grove
USGS	39° 47' 59"	88° 10' 13"	Embarras R., main stem, 0.4 miles west of Camargo at mile 168.1

The following tests were carried out:

- Instantaneous flow rates at each of the seven stations at the time of sampling using a Teledyne Gurley Price AA rotating bucket velocity meter or a Marsh-McBirney model 201 portable water flow meter.
- On-site determinations of water temperature, dissolved oxygen (DO) using a DO meter, pH, and total alkalinity at the time of sampling.
- Laboratory analyses of each sample for hardness, conductivity, turbidity, total dissolved solids, total suspended solids, volatile suspended solids, ammonia nitrogen (soluble and total), dissolved nitrate nitrogen, total kjeldahl nitrogen, soluble and total phosphorus, and heavy metals (barium, cadmium, iron, lead, manganese, nickel, and zinc).
- Particle-size analyses on two of the four sets of water samples.
- Enumeration of total coliform, fecal coliform, and fecal streptococcus densities for each sample.

Chemical analyses were performed in accordance with *Standard Methods*.[1] Free and total carbon dioxide concentrations were calculated from pH and total alkalinity values, also according to *Standard Methods*.[1] Heavy metals were determined using inductively coupled plasma (ICP) spectroscopy. Particle-size analyses were made by filtering samples through 0.45- and 0.65-micrometer (μm) membrane filters and dried with air flow at 60°C.

Bacterial densities were determined by the membrane filter method.[1] Total coliform bacteria were assayed with m-Endo agar (Difco) and incubated for 24 hours at 35°C. Fecal coliform was recovered with m-FC agar (Difco) at 45°C after 24 hours incubation. KF streptococcus agar (Difco) was used for recovery of fecal streptococcus at 35°C after 48 hours incubation. All assays were performed according to *Standard Methods*.[1]

WATER QUALITY

Results of physical, chemical, and bacteriological analyses for the seven sampling locations for each of the four visits are shown in tables 1-4. Bacterial samples were collected on October 30, 1990, during a reconnaissance visit. The bacterial data for that

Table 1. Results of Water Quality Monitoring, Upper Embarras River Basin, November 13, 1990

Parameter	*Station* 1	2	3	4	5	6	7
Time of collection	16:00	15:15	12:50	13:05	14:25	13:45	10:00
Flow rate, cfs	1.57	8.04	15.0	20.8	5.14	9.88	52.0
Water temperature, °C	9.6	10.2	7.9	8.9	9.3	10.5	7.6
Dissolved oxygen, mg/L	11.0	15.6	12.4	10.4	12.6	14.6	10.7
pH	8.20	8.20	8.15	8.15	8.25	8.38	8.32
Alkalinity, mg/L as $CaCO_3$	231	216	214	231	220	227	225
Carbon dioxide, mg/L							
Free	2.9	2.7	2.0	3.2	2.4	1.9	2.1
Total	205	189	189	205	194	199	197
Hardness, mg/L as $CaCO_3$	322	309	317	355	316	325	332
Conductivity, μmhos/cm at 25°C	688	628	607	707	645	649	682
Turbidity, NTU	15	11	14	12	8	10	13
Dissolved solids, mg/L	436	412	354	388	410	360	386
Total suspended solids, mg/L	23	11	13	17	8	11	10
Volatile suspended solids, mg/L		10	2	0		12	2
Ammonia nitrogen, mg/L							
Soluble	0.19	0.03	0.06	0.03	0.02	0.01	0.03
Total	0.19	0.03	0.06	0.03	0.05	0.04	0.04
Dissolved nitrate nitrogen, mg/L	2.89	7.90	9.29	9.25	10.5	10.4	9.15
Total kjeldahl nitrogen, mg/L	0.36	0.38	0.34	0.10	0.22	0.29	0.04
Phosphorus, mg/L							
Soluble	0.10	0.03	0.04	0.02	0.02	0.02	0.05
Total	0.12	0.03	0.04	0.03	0.02	0.04	0.05
Heavy metals, mg/L							
Barium	0.06	0.05	0.05	0.05	0.04	0.04	0.05
Cadmium	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Iron	0.69	0.31	0.45	0.39	0.20	0.26	0.42
Lead	0.05	0.01	0.05	0.03	0.04	0.02	0.03
Manganese	0.14	0.03	0.03	0.02	0.02	0.02	0.02
Nickel	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Zinc	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Bacterial densities, colonies/100 mL							
Total coliform	700	6,400	18,000	810	5,600	5,300	9,200
Fecal coliform	230	80	220	160	70	150	590
Fecal streptococcus	140	20	45	100	36	25	80

Table 2. Results of Water Quality Monitoring, Upper Embarras River Basin, April 23, 1991

Parameter	*Station* 1	2	3	4	5	6	7
Time of collection	13:25	12:45	12:30	11:55	10:35	11:10	10:15
Flow rate, cfs	3.8	19.2	36.0	36.0	5.1	19.5	98.0
Water temperature, °C	15.8	12.4	11.3	11.8	11.1	10.9	11.4
Dissolved oxygen, mg/L	13.6	12.1	11.7	10.8	12.5	13.0	9.9
pH	8.60	8.20	8.22	8.10	8.20	8.21	8.06
Alkalinity, mg/L as $CaCO_3$	251	200	169	216	172	192	176
Carbon dioxide, mg/L							
Free	1.2	2.5	2.0	3.3	2.1	2.2	3.0
Total	218	177	149	191	152	164	157
Hardness, mg/L as $CaCO_3$	320	296	294	313	294	294	300
Conductivity, μmhos/cm at 25°C	624	610	596	621	591	600	613
Turbidity, NTU	34	27	42	37	16	18	38
Dissolved solids, mg/L	436	394	398	398	358	394	408
Total suspended solids, mg/L	29	28	51	34	8	16	39
Volatile suspended solids, mg/L	6	6	8	6	2	3	6
Ammonia nitrogen, mg/L							
Soluble	0.06	0.04	0.07	0.02	0.01	0.02	0.03
Total	0.09	0.07	0.11	0.05	0.07	0.06	0.05
Dissolved nitrate nitrogen, mg/L	4.42	10.5	11.8	11.8	14.2	14.2	12.2
Total kjeldahl nitrogen, mg/L	0.55	0.44	0.67	0.73	0.33	0.42	0.50
Phosphorus, mg/L							
Soluble	0.01	0.01	0.07	0.01	0.01	Tr.	0.01
Total	0.08	0.05	0.14	0.05	0.02	0.02	0.06
Heavy metals, mg/L							
Barium	0.07	0.05	0.06	0.05	0.04	0.04	0.05
Cadmium	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Iron	0.84	0.80	1.49	0.80	0.30	0.41	1.21
Lead	0.01	<.01	<.01	0.01	0.01	<.01	<.01
Manganese	0.09	0.04	0.04	0.04	0.02	0.02	0.04
Nickel	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Zinc	0.02	0.03	0.03	0.04	0.01	0.02	0.04
Particle size analyses							
Air dried: >.45μm	33	30	55	39	11	17	42
>.65μm	33	31	54	39	11	16	41
60°C dried: >.45μm	24	21	45	29	1	8	30
>.65μm	27	24	46	33	4	11	34
Bacterial densities, colonies/100 mL							
Total conform	4,600	2,400	5,600	930	7,600	9,700	9,600
Fecal conform	150	140	370	83	80	38	360
Fecal streptococcus	110	97	90	36	70	36	67

Table 3. Results of Water Quality Monitoring, Upper Embarras River Basin, June 25, 1991

Parameter	*Station* 1	2	3	4	5	6	7
Time of collection	10:00	10:50	11:20	11:30	12:20	12:40	13:20
Flow rate, cfs	1.34	1.49	5.3	7.93	1.61	3.41	16.0
Water temperature, °C	26.0	26.0	26.0	25.4	29.5	29.0	27.0
Dissolved oxygen, mg/L	7.65	8.40	7.60	7.60	13.35	13.30	5.45
pH	8.10	8.09	7.95	8.10	8.59	8.59	8.05
Alkalinity, mg/L as $CaCO_3$	229	220	218	225	168	178	206
Carbon dioxide, mg/L							
Free	3.6	3.5	4.9	3.5	0.8	0.9	3.6
Total	204	196	196	200	146	155	177
Hardness, mg/L as $CaCO_3$	318	295	237	328	253	264	301
Conductivity, μmhos/cm at 25°C	687	622	522	635	471	537	622
Turbidity, NTU	33	28	33	60	11	22	61
Dissolved solids, mg/L	448	386	334	418	328	348	404
Total suspended solids, mg/L	43	41	39	51	11	21	60
Volatile suspended solids, mg/L	9	8	15	11	7	6	11
Ammonia nitrogen, mg/L							
Soluble	0.07	0.04	0.04	0.06	0.05	0.03	0.03
Total	0.13	0.08	0.08	0.08	0.08	0.06	0.13
Dissolved nitrate nitrogen, mg/L	3.20	6.02	5.00	6.17	8.87	8.94	6.68
Total kjeldahl nitrogen, mg/L	0.90	0.94	1.22	0.56	0.79	0.50	0.86
Phosphorus, mg/L							
Soluble	0.13	0.02	0.01	0.03	0.01	0.01	0.03
Total	0.13	0.10	0.12	0.12	0.14	0.07	0.12
Heavy metals, mg/L							
Barium	0.07	0.07	0.06	0.06	0.04	0.04	0.07
Cadmium	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Iron	0.73	0.56	0.44	0.55	0.16	0.42	0.66
Lead	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Manganese	0.13	0.13	0.09	0.06	0.01	0.02	0.07
Nickel	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Zinc	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Particle size analyses							
Air dried: >.45μm	Did not run						
>.65μm							
60°C dried: >.45μm	34	42	12	40	0	7	43
>.65μm	37	31	31	47	1	29	56
Bacterial densities, colonies/100 mL							
Total coliform	2,800	2,600	2,900	1,700	1,500	2,700	6,700
Fecal coliform	440	540	460	220	170	170	590
Fecal streptococcus	530	99	120	220	29	59	180

Table 4. Results of Water Quality Monitoring, Upper Embarras River Basin, August 27, 1991

Parameter	*Station*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Time of collection	11:50	11:15	10:50	10:10	9:55	9:50	9:30
Flow rate, cfs	0.24	0.020	0.02	0.057	No flow	No flow	0.25
Water temperature, °C	24.9	25.0	24.4	23.5			23.5
Dissolved oxygen, mg/L	14.3	3.5	2.9	4.6			3.3
pH	9.00	8.18	8.18	8.30			8.32
Alkalinity, mg/L as $CaCO_3$	182	174	176	226			238
Carbon dioxide, mg/L							
Free	0.3	2.3	2.3	2.2			2.2
Total	154	154	156	199			210
Hardness, mg/L as $CaCO_3$	226	221	223	321			250
Conductivity, μmhos/cm at 25°C	560	507	531	641			732
Turbidity, NTU	26	31	58	25			57
Dissolved solids, mg/L	328	394	302	324			434
Total suspended solids, mg/L	20	22	44	17			44
Volatile suspended solids, mg/L	0	0	4	1			7
Ammonia nitrogen, mg/L							
Soluble	0.25	2.04	0.03	0.11			0.04
Total	0.39	2.30	0.17	0.20			0.13
Dissolved nitrate nitrogen, mg/L	0.34	0.41	0.07	0.08			0.09
Total kjeldahl nitrogen, mg/L	1.03	4.41	1.24	0.71			0.99
Phosphorus, mg/L							
Soluble	0.05	0.10	0.06	0.10			0.14
Total	0.12	0.30	0.23	0.14			0.36
Heavy metals, mg/L							
Barium	0.08	0.09	0.07	0.07			0.07
Cadmium	<0.02	<0.02	<0.02	<0.02			<0.02
Iron	0.73	0.58	1.50	0.57			1.57
Lead	<0.03	<0.03	<0.03	<0.03			<0.03
Manganese	0.16	0.71	0.57	0.18			0.29
Nickel	<0.05	<0.05	<0.05	<0.05			<0.05
Zinc	<0.01	<0.01	0.01	0.01			0.02
Bacterial densities, colonies/100 mL							
Total coliform	9,900	52,000	1,200	1,500			15,000
Fecal coliform	6,200	20,000	230	450			8,300
Fecal streptococcus	1,900	310	71	280			3,600

date are presented in table 5. For reference purposes, the results of long-term water resources data (September 1979 through August 1989) collected by the U.S. Geological Survey[2] at the Embarras River at Camargo are summarized for means, ranges, and standard deviations in table 6.

Only four samples were collected at each sampling station during this investigation. These data are not adequate to show any seasonal variations in water quality characteristics. But they provide a synoptic view reflecting river water quality characteristics for early spring and the crop-growing season.

Daily precipitation data for Champaign-Urbana, are shown in table 7. Total precipitation for Water Year 1991, which encompasses the project period, was 41.94 inches.

Flow Rate

During the course of this study, the flow rate in the Embarras River ranged from a high in April 1991 for all stations to very low flow (almost none) in August 1991. On August 27, 1991, Jordan Slough (stations 5 and 6) was dry; and stations 2, 3, 4, and 7 appeared to be stagnant. Only station 1 showed running water through a small stream cross section.

Water Temperature

There is no thermal discharge into the river, so variations in streamwater temperature are due to natural causes and the time of sample collection. Samples were generally collected between 9:30 and 16:00. The Illinois Pollution Control Board (IPCB)[3] stipulates that streamwater temperatures at representative locations in the main stream are not to exceed 16°C (60°F) from December through March and 32°C (90°F) from April through November during more than 1 percent of the hours in the 12-month period ending with any month. The observed water temperatures in the Embarras River did not exceed the IPCB's limitations (tables 1-4).

Dissolved Oxygen

The IPCB also stipulates that dissolved oxygen shall not fall below 6.0 milligrams per liter (mg/L) for 16 hours of any 24-hour period, nor below 5.0 mg/L at any time.

Table 5. Bacterial Densities, Upper Embarras River Basin, October 30, 1990

Parameter	*Station* *1*	*2*	*3*	*4*	*5*	*6*	*7*
Bacterial densities, colonies/100 mL							
Total coliform	880	1,800	5,800	2,800	38,000	19,000	23,000
Fecal coliform	280	280	440	480	720	220	720
Fecal streptococcus	230	88	27	88	68	60	40

Table 6. Water Quality, Embarras River at Camargo, Illinois

Parameter	*No. of samples*	*Range*	*Average or geometric mean (G)*	*(Geometric) standard deviation*
Flow, cfs	106	0.001-726	G 48.1	G 8.1
Specific conductance, μmhos/cm	110	320-860	614	79
pH	107	6.4-8.9	-	-
Temperature, °C	110	0.0-27.0	-	-
Turbidity, NTU	65	0.3-72.0	G 6.3	G 2.95
Dissolved oxygen, mg/L	92	3.1-14.8	9.1	2.5
Chemical oxygen demand, mg/L	108	< 1-45	12.3	8.0
Fecal coliform, colonies/100 mL	97	10-36,000	G 280	G 3.866
Acidity, mg/L as $CaCO_3$	66	0.0-0.0	-	-
Alkalinity, mg/L as $CaCO_3$	107	59-334	191	45.6
Hardness, mg/L as $CaCO_3$				
Total	53	120-372	294	41.5
Noncarbonate	43	29-140	93	33.0
Calcium, mg/L				
Total	91	22-88	68	11.5
Dissolved	45	31-80	67	8.8
Magnesium, mg/L				
Total	91	8-38	30	4.9
Dissolved	45	11-35	30	4.0
Sodium, mg/L				
Total	91	2.0-39	12	11.7
Dissolved	45	3.8-38	14	11.7
Potassium, mg/L				
Total	91	0.3-5.8	1.59	1.16
Dissolved	45	0.3-4.0	1.56	1.25
Sulfate (dissolved), mg/L	108	19-110	48	12.8
Chloride (dissolved), mg/L	107	6-113	28	8.7
Solids, mg/L				
Dissolved	18	129-412	312	66.4
Suspended	108	<1-250	46	46.3
Volatile suspended	108	0-48	6.6	4.5
Nitrogen, mg/L as N				
$NO_2 + NO_3$	106	<0.10-17.0	8.5	4.8
Ammonia-Total	106	0.0-0.27	-	-
Unionized	54	0.0-0.005	-	-
Phosphorus, mg/L as P				
Total	51	0.01-0.60	0.144	0.166
Dissolved	51	0.01-0.49	0.082	0.094
Aluminum, μg/L				
Total	53	<50-3600	852	801
Dissolved		<50-1200		
Barium, μg/L				
Total	91	40-96	58.3	14.0
Dissolved	45	34-72	49.5	9.7
Beryllium, μg/L				
Total	90	0-<5	-	-
Dissolved	45	<0.005-<2	-	-

Table 6. Concluded

Parameter	No. of samples	Range	Average or geometric mean (G)	(Geometric) standard deviation
Boron, μg/L				
Total	91	20-280	-	-
Dissolved	45	< 50-170	-	-
Cadmium, μg/L				
Total	93	0-14	-	-
Dissolved	45	<3-<5	-	-
Chromium, μg/L				
Total	93	0-17	-	-
Dissolved	45	<5-12	-	-
Cobalt, μg/L				
Total	90	<1-17	-	-
Dissolved	45	<5-<10	-	-
Copper, μg/L				
Total	106	0-20	-	-
Dissolved	45	<5-10	-	-
Iron, μg/L				
Total	104	<50-4800	1033	936
Dissolved	45	<50-280	-	-
Lead, μg/L				
Total	106	0-110	-	-
Dissolved	45	<5-<100	-	-
Manganese, μg/L				
Total	104	8-950	86	128
Dissolved	45	<5-910	70	168
Mercury (Total, μg/L)	104	0-27	-	-
Nickel, μg/L				
Total	91	0-27	-	-
Dissolved	44	<5-17	-	-
Silver, μg/L				
Total	91	0-10	-	-
Dissolved	45	<3-<10	-	-
Strontium, μg/L				
Total	90	40-181	135	22.5
Dissolved	45	-	137	17.9
Vanadium, μg/L				
Total	90	1-21	-	-
Dissolved	44	<5-10	-	-
Zinc, μg/L				
Total	105	0-300	-	-
Dissolved	44	<50-170	-	-

Table 7. Daily Precipitation above 0.01 Inch, at
Champaign-Urbana, Illinois, Water Year 1991

		1990							*1991*				
Date	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*
1							.34		.28	.01	.09		.05
2				.08			.34				.01		
3		1.19		.76					.78				.30
4			.04					.35					
5			.66		.21	.02			2.00			.28	
6						.02						1.72	
7		1.57										.05	
8		1.50						.01				.10	.03
9		1.49									.36		.61
10		.38			.10				.01		.54		.20
11					.67						1.33		
12					.01		.97	.26		.01	.26		
13			*		.01	.05	.32	.46					.46
14		.03		.50		.05		.84	1.45				
15				.20	.23			.20	.03				
16		.02			.05				1.62				
17		.69		.29			.81		.50	.52		.07	
18				.15		.18			.04				.04
19								.10				.03	
20					.05								
21		.02	.07	.74	.01		.33		2.05				
22			.07	.24			.52			.13			.33
23		.01		.20				*.01					
24													.09
25					.05				.12	*			
26			.25		.06	.01	.64		.21				
27			1.54	.31			.02	.10				*	
28			.01	.28								.02	
29				2.41	.20			.30	.05				
30	.08	*		.02					.17				
31									.01				

* Water samples collected

During the low-flow period, on August 27, 1991, dissolved oxygen at all the Upper Embarras River sampling stations (except station 1) was found to be less than 5.0 mg/L (table 4). Stagnant waters at stations 2, 3, and 7, resulted in low dissolved oxygen levels, while at station 1, the water sample was collected from a narrow ditch with good natural aeration.

Dissolved oxygen concentrations in the Upper Embarras River were found to be very high during fall and spring (tables 1 and 2), and the June samples exceeded the IPCB's limit (table 3). Jordan Slough (stations 5 and 6) had high dissolved oxygen due to good aeration (tables 1-3). In general, dissolved oxygen was lower at station 7 than at all other upstream stations (tables 1-3).

Examination of past data collected by the USGS[2] showed that only one out of 92 observations for the Embarras River at Camargo (July 21, 1987) revealed dissolved oxygen below 5.0 mg/L. Dissolved oxygen on that date was 3.1 mg/L, which was close to the values observed at stations 2, 3, and 7 on August 27, 1991.

pH Values

During the course of this study, pH for all stations ranged from 8.05 to 9.00 (tables 1-4). These values were within the pH range of 6.5 to 9.0 stipulated by the IPCB[3]. Generally, there was no significant variation in pH values among the seven sampling stations.

Alkalinity

Total alkalinity for the Upper Embarras River and its two tributaries ranged from 168 to 251 mg/L as $CaCO_3$ (tables 1-4). As can be seen in table 1, total alkalinity for all seven stations was almost identical in fall 1990. Some variation in alkalinity occurred among stations on the other three sampling dates in spring and summer 1991 (tables 2-4). However, no pattern of variation in alkalinity could be detected.

Carbon Dioxide

Free carbon dioxide ranged from a low of 0.3 mg/L at station 1 (table 4) on August 27, 1991, to a high of 4.9 mg/L at station 3 on June 25, 1991 (table 3). These concentrations of carbon dioxide were expected. Surface waters normally contain less than 10 mg/L of free carbon dioxide, while some ground waters may easily exceed that level[1]. The carbon dioxide content of water may contribute significantly to corrosion.

Total carbon dioxide can be calculated from the sum of free carbon dioxide, bicarbonate alkalinity, carbonate alkalinity, and hydroxide alkalintiy. On the basis of all the data collected, total carbon dioxide ranged from 146 mg/L at station 5 on June 25, 1991 (table 3), to 218 mg/L at station 1 on April 23, 1991 (table 2).

Hardness

The observed hardness values in the Upper Embarras River basin ranged from 221 mg/L as $CaCO_3$ at station 2 on August 27, 1991 (table 4), to 355 mg/L as $CaCO_3$ at station 4 on November 13, 1990 (table 1). High levels of hardness and alkalinity in surface waters are typical of midwestern streams. Hardness was found to be lower for the August 27, 1991, samples than for the other three sets of samples (tables 1-4).

When hardness in a water is numerically greater than the sum of carbonate and bicarbonate alkalinity, the amount of hardness equivalent to the total alkalinity is called "carbonate hardness." Any hardness in excess of total alkalinity is called "noncarbonate hardness." Tables 1-4 show that approximately one-third of the hardness in the Upper Embarras River basin is noncarbonate.

Conductivity

The conductivity of waters in the Upper Embarras River basin ranged from 471 micromhos per centimeter (μmhos/cm) at station 5 on June 25, 1991 (table 3), to 732 μ mhos/cm at station 7 on August 27, 1991. Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. That ability depends upon the presence of ions, their total concentration, mobility, valence, and relative concentrations, as well as on the solution temperature. Aqueous solutions of most inorganic acids, bases, and salts are relatively good conductors. Molecules of organic compounds, however, that do not dissociate in solution conduct current very poorly.

Turbidity

The observed turbidities were generally low, between 8 nephelometric turbidity units (NTU) at station 4 on November 13, 1990 (table 1), and 61 NTU at station 7 on June

25, 1991 (table 3). No samples were collected during or after storm events. Similarly, the USGS data showed no high turbidity (table 6). An examination of the data in tables 1-3 shows that turbidity at stations 5 and 6 in Jordan Slough was generally lower than that at the other five locations for each sampling date.

Solids

Overall, total dissolved solids ranged from 302 mg/L at station 3 on August 27, 1991 (table 4), to 448 mg/L at station 1 on June 25, 1991 (table 3). These values were within the IPCB's limit of 1,000 mg/L[3]. There was no trend for the variation in dissolved solids concentrations among the sampling stations.

On four sampling dates, total suspended solids in the river waters were low: between 8 mg/L at station 5 both on November 13, 1990, and on April 23, 1991 (tables 1 and 2), and 60 mg/L at station 7 on July 25, 1990 (table 3). Generally, total suspended solids are related to turbidity and streamflow. During the course of this study, observed streamflows were representative of normal or dry-period flow.

For most cases, volatile suspended solids were found to be 0 to 2 mg/L with a high of 11 mg/L (tables 1-4). High solids concentrations (dissolved, total suspended, and volatile suspended) were observed in samples taken on June 25, 1991.

Ammonia Nitrogen

With the exception of the samples taken at station 2 on August 27, 1991, soluble and total ammonia nitrogen (NH_3-N) concentrations in the Upper Embarras River basin waters were less than 0.25 mg/L and 0.39 mg/L, respectively, as shown in tables 1-4. At station 2 on August 27, 1991, the highest concentration of soluble ammonia nitrogen was 2.04 mg/L, while total ammonia nitrogen was 2.30 mg/L. At the observed pH and temperature values of 8.18 and 25.0°C, respectively, the maximum permissible total ammonia-N would be only 1.5 mg/L. Hence the observed value of 2.30 mg/L exceeds the water quality standards for total ammonia. Increased ammonia nitrogen concentrations at station 2 may have been indicative of recent contamination of the stream, possibly due to agricultural activity (cattle grazing in the pasture and meadows).

The ratios of soluble NH3-N to total NH_3-N showed a wide range: from 0.14 to 1.00, with an average of 0.57. The ratios of soluble NH3-N to total NH_3-N for sewage in the Princeton, Illinois, municipal wastewater treatment plant ranged from 0.81 to 1.00. Many samples had ratios of 1.00.

Nitrate Nitrogen

Dissolved nitrate nitrogen concentrations in the Upper Embarras River were found to be high for normal streamflows sampled in November 1990 and April and June 1991 (tables 1-3) at 2.89 to 14.89 mg/L. Nitrate nitrogen generally increased from upstream to downstream stations. The highest nitrate levels were found in Jordan Slough (stations 5 and 6) on those three sampling dates, and there was no difference in levels between the two stations. A landfill located between stations 5 and 6 showed no impact on streamwater in Jordan Slough.

Samples obtained on August 27, 1991, contained extremely low nitrate nitrogen levels of 0.07 to 0.34 mg/L (table 4). This might be due to algal growth and the uptake of nitrate in the stagnant waters. Unfortunately, no algal identification and enumeration was made.

Nitrate is a matter of concern as a water contaminant because of its effects on health and because it stimulates algal growth. High levels of nitrate in drinking water have been reported to be linked to methemoglobinemia, a type of anemia especially serious for very young babies. Conventional water treatment processes do not remove nitrate, and a maximum limit of 10 mg/L of nitrate nitrogen has been established for public water supplies. Heavy use of nitrogen fertilizers or leachates from septic tanks, improperly treated sewage, or animal feedlots may cause high local levels of nitrates in soils. Rainfall then washes the nitrate from the soil and into streams, both as ground water and surface water runoff.

Concentrations of nitrate nitrogen in excess of 0.3 mg/L are considered sufficient to stimulate nuisance algal blooms[5]. However, background levels of about 1 mg/L nitrate nitrogen have been reported in Illinois streams with no algal growth stimulation.[6]

Total Kjeldahl Nitrogen

Total kjeldahl nitrogen (TKN) includes ammonia nitrogen and organic nitrogen, but it does not include nitrite and nitrate nitrogen. Organic nitrogen can be defined as the difference between the values of total kjeldahl nitrogen and free ammonia.

Total kjeldahl nitrogen concentrations in the Embarras River ranged from a low of 0.04 mg/L at station 7 on November 13, 1990 (table 1), to a high of 4.41 mg/L at station 2 on August 27, 1991 (table 4). The August sample also contained 2.11 mg/L (4.41 mg/L of TKN minus 2.30 mg/L of NH_3-N) of organic nitrogen. As mentioned earlier, this high level of total kjeldahl nitrogen was probably due to agricultural activity.

Phosphorus

Phosphorus is essential to plant growth. It has also been implicated as a key nutrient in the eutrophication of many natural and man-made bodies of water. Human waste, agricultural runoff, phosphate detergents, industrial wastes, and atmospheric transport are all major sources of phosphorus in surface water. The sediments of streams and lakes are an additional source of phosphorus. To prevent biological nuisance, the IPCB[3] stipulates that "Phosphorus as P shall not exceed 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more, or in any stream at the point where it enters any such reservoir or lake."

As shown in tables 1-4, most of the samples taken from the Upper Embarras River had total phosphorus exceeding 0.05 mg/L, especially the samples collected on June 25 and August 27, 1991. In fact, soluble phosphorus ranged from trace amounts to 0.14 mg/L, while total phosphorus was between 0.02 mg/L and 0.36 mg/L. The ratios of soluble P to total P varied from 0.07 to 1.00.

Barium

The limits of heavy metal concentrations for general-use water quality standards, according to the IPCB[3], are as follows:

Constituent	*Standard, mg/L*
Barium (total)	5.0
Cadmium (total)	0.05
Iron (dissolved)	1.0
Lead (total)	0.1
Manganese (total)	1.0
Nickel (total)	1.0
Zinc (total)	1.0

Tables 1-4 show that barium concentrations in the Embarras River were low, limited to a narrow range from 0.04 to 0.09 mg/L. The values were far below the standards listed above.

Cadmium

A total of 26 samples was examined, and all contained cadmium levels below the detectable limit of 0.02 mg/L (tables 1-4).

Iron

Iron is next to aluminum as the most abundant metal in the earth's crust. High concentrations of iron are usually found in ground water, while natural surface waters contain variable but minor amounts.

The U.S. Environmental Protection Agency has established a secondary drinking water standard for iron at 0.3 mg/L. The standard is based on aesthetics and is intended to prevent staining of clothes during laundering, staining of plumbing fixtures, incrusting of pipelines, clogging of home water softeners, and discoloration, tastes, and odors in the water supply. Drinking water containing iron in unpalatable concentrations of approximately 1.0 mg/L would have little effect on the total human dietary intake, which is 7 to 35 mg per day[7]. Nevertheless, the IPCB[3] stipulates maximum iron concentrations of 1.0 mg/L for general-use water.

In the Upper Embarras River, iron concentrations were found to range from a low of 0.16 mg/L at station 5 on June 25, 1991, to a high of 1.57 mg/L at station 7 on August 27, 1991 (tables 3 and 4). Tables 1-4 show that low iron levels occurred in Jordan Slough (stations 5 and 6) on all sampling dates, and that very high iron concentrations occurred at stations 3 and 7. On two of the four sampling dates, iron concentrations at these two stations exceeded the general-use water quality standards.

Lead

Lead concentrations in the Upper Embarras River basin generally fell below detectable limits of 0.03 mg/L. The highest lead level observed was 0.05 mg/L (tables 1-4) at two stations, which is still well below the IPCB's 0.1-mg/L limit.

Manganese

As for iron, the limits for manganese in public water supplies also are based on aesthetic and economic considerations. The IPCB limits manganese concentrations to 1.0 mg/L in streams and 0.15 mg/L in public and food processing water supplies.[3]

Manganese levels in the Upper Embarras River basin ranged from 0.01 to 0.71 mg/L (tables 1-4). Higher manganese concentrations (0.16 to 0.71 mg/L) were observed during the low-flow dry period (table 4). Excluding the August 27 samples, the highest manganese was only 0.14 mg/L at station 1 on November 13, 1990 (table 1). Manganese concentrations in all samples were in compliance with the IPCB's standard.

Nickel

Nickel concentrations in the Upper Embarras River basin were low, equal to or below the detectable level of 0.05 mg/L (tables 1-4).

Zinc

As with cadmium, lead, and nickel, zinc concentrations were insignificant in the Embarras River. Many samples had concentrations below the detectable limit of 0.01 mg/L (tables 1-4). The highest zinc levels measured were both 0.04 mg/L at stations 4 and 7 on April 23, 1991 (table 2).

Particle Size Analyses

Particle size analyses were made for samples taken on April 23 and June 25, 1991, through membrane filters with different sizes of pores. The results were not conclusive due to very low suspended solids levels in the water samples (tables 2 and 3).

Total Coliform

Total coliform (TC) densities varied from day to day and from station to station with no apparent trend (tables 1-5). For the upper Embarras River, the maximum total coliform observed, 38,000/100 milliliters (mL), occurred at station 5 on October 30, 1990; the minimum (700/100 mL) occurred on November 13, 1990, at station 1. On most sampling dates, higher total coliform counts generally occurred at stations 3 and 7. Station 7 is immediately downstream of Villa Grove.

The ratio of fecal coliform/total coliform (FC/TC) was determined for each sample. Excluding dry-period samples collected on August 27, 1991, the FC/TC ratios varied considerably, ranging from 0.004 on April 23, 1991, at station 6 to 0.328 on November 13, 1990. The FC/TC ratios were higher (0.192 to 0.626) for the August 27, 1991, samples. A higher FC/TC ratio was observed at station 1. Many factors can influence FC/TC ratios, such as source of pollution, level of sewage treatment, agricultural activites, characteristics of receiving water, precipitation in the watershed, etc. The ORSANCO Water Users Committee[8] suggests that higher FC/TC ratios might indicate the proximity of inefficient wastewater treatment operations or conditions where treatment facilities are being bypassed during storm runoff. Low ratios (<0.20) are most likely caused by aftergrowth of *Aerobacter aerogenes,* resulting in abnormally high TC densities. Excluding the August 27, 1991, samples, 25 out of 28 samples have FC/TC ratios less than 0.20. This is indicative of *A. aerogenes* aftergrowths in the stream. A similar case was observed in the Spoon River.

Fecal Coliform

High fecal coliform counts of 230-20,000/100 mL were found on August 27, 1991 (table 4). Excluding this date, fecal coliform densities for the other four dates fell within a small range of 38/100 mL on April 23, 1991, at station 6 (table 2) to 720/100 mL on October 30, 1990, at stations 5 and 7 (table 5).

The IPCB's[3] fecal coliform standard, Rule 302.209, which is applicable to most Illinois streams, including the Embarras River, states:

> "During the months May through October, based on a minimum of five samples taken over not more than a 30-day period, fecal coliform shall not exceed a

geometric mean of 200 per 100 mL, nor shall more than 10 percent of the samples during any 30-day period exceed 400 per 100 mL in protected waters."

Fecal coliform densities recorded in the Upper Embarras River basin could not be evaluated in terms of the above FC rules because an inadequate number of samples was taken during a 30-day period. Examination of the data in tables 1-5 indicates that only station 6 showed FC densities below 400/100 mL for the four samples collected. All the other stations had one or more samples exceeding 400 FC/100 mL. Fecal coliform densities were found to be elevated for samples taken on August 27, 1991; the highest count was 20,000 FC/100 mL for the sample taken at station 2.

Fecal Streptococcus

Tables 1-5 indicate that fecal streptococcus (FS) counts ranged from a low of 20 FS/100 mL on November 13, 1990, at station 2 to a high of 3,600 FS/100 mL at station 7 on August 27, 1991. As for the TC and FC counts mentioned previously, FS densities were generally high on August 27, 1991, which was during the dry-flow period.

Geldreich et al.[10] claimed that the FC/FS ratio would be more valuable as an informational tool for assessing pollution sources than the FC count alone. FC/FS ratios greater than 4 suggest a pollution source largely of human origin, such as domestic wastewater. Ratios less than 0.7, however, suggest the likelihood that the pollution source originated with wastes from warm-blooded animals other than humans, such as livestock and poultry. In applying the FC/FS ratio to a natural stream, best results can be obtained if the stream samples are collected within 24 hours of their leaving the pollution source because some species of fecal streptococci, such as *S. bovis* and *S. equimus*, have limited survival capabilities. Furthermore, the ratio values should not be used if FS densities are less than 100 per 100 mL.

Inspection of tables 1-5 reveals that only 12 out of 35 bacteria samples (including all five samples collected at station 1) contained FS densities greater than 100 per 100 mL. In those 12 samples, the lowest FC/FS ratio of 0.83 occurred on June 25, 1991, at station 1; the highest ratio of 64.5 occurred on August 27, 1991 at station 2. With the exception of this extremely high FC/FS value, all other 11 samples have FC/FS ratios between 0.7 and

4.0. This indicates mixed pollution sources. It is difficult to use ratios effectively when mixed pollution sources are present without one or the other source being dominant.

SUMMARY

The physical, chemical, and bacteriological water quality characteristics of the Upper Embarras River basin are summarized based on four sampling visits between November 1990 and August 1991. With only four samples collected at each of the seven sampling locations, it is difficult to assess seasonal or general trends in water quality.

In general, poor water quality was observed at stations 2 and 7. Jordan Slough (stations 5 and 6) has better water quality than the main stem of the river. Station 4, which is located at the East Branch tributary, has water quality similar to that at station 3 on the main stream. A landfill located between stations 5 and 6 showed no impact on water quality. On the basis of bacterial densities, the major cause of bacterial contamination would appear to be of human origin rather than animal origin.

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REFERENCES

1. American Public Health Association, et al. 1989. *Standard Methods for Examination of Water and Wastewater,* Washington, DC.
2. U.S. Geological Survey. 1979-1989. *Water Resources Data, Illinois, Water Year 1979 through 1989,* Urbana, IL.
3. Illinois Pollution Control Board. 1990. *State of Illinois Rules and Regulations. Title 35: Environmental Protection, Subtitle C: Water Pollution,* Springfield, IL.

4. Lin, S.D., and D.B. Shackleford. 1986. *An Assessment of Nitrification in an RBC Plant*. Circular 164, Illinois State Water Survey, Champaign, IL.

5. Sawyer, C.N. 1974. Fertilization of lakes by agricultural and urban drainage. *New England Water Works Association Journal* 61(2): 109.

6. Parker, R. et al. 1974. *Fertilizer Application Rates and Nitrate Concentrations in Illinois Surface Waters*. Nitrogen Task Force, Center for the Biology of Natural Systems, Washington University, St. Louis, MO.

7. McKee, J.E., and H.W. Wolf. 1963. *Water Quality Criteria*. Publication No. 3-A, The Resources Agency of California, State Water Quality Control Board, Sacramento, CA.

8. ORSANCO Water Users Committee. 1971. Total coliform: fecal coliform ratio for evaluation of raw water bacterial quality. *Journal Water Pollution Control Federation* 43(4): 630-640.

9. Lin, S.D., R.L. Evans, and D.B. Beuscher. 1974. Bacteriological assessment of Spoon River water quality. *Applied Microbiology* 28(2): 288-297.

10. Geldreich, E.E., H.F. Clark, and C.B. Huff. 1964. A study of pollution indicators in a waste stabilization pond. *Journal Water Pollution Control Federation* 36(11): 1372-1379.