State Water Survey Division
WATER QUALITY SECTION
AT
PEORIA, ILLINOIS

ENR
Illinois Department of
Energy and Natural Resources

SWS Contract Report 338

EVALUATION OF WASTES FROM THE EAST ST. LOUIS WATER TREATMENT PLANT AND THEIR IMPACT ON THE MISSISSIPPI RIVER

By Shundar Lin, Ralph L. Evans,
Donald Schnepper, and Thomas Hill

March 1984

SEAL OF THE STATE OF ILLINOIS
AUG. 26th 1818

CONTENTS

PAGE

Appendices

EVALUATION OF WASTES FROM THE EAST ST. LOUIS WATER TREATMENT PLANT AND THEIR IMPACT ON THE MISSISSIPPI RIVER

by Shundar Lin, Ralph L. Evans,
Donald Schnepper, and Thomas Hill

INTRODUCTION

Most surface and ground waters are not suitable for human consumption without treatment. About 70 percent of water treatment facilities in the U.S. use the coagulation/sedimentation/filtration process (Westerhoff and Cornwell, 1978). Treatment methods that are auxiliary to these include presettling; iron and manganese removal; aeration and chlorination; softening by lime, soda ash, and ion exchange; taste and odor control by carbon; and chlorination alone.

With the exception of chlorination, each treatment process generates waste (solids or liquids). The waste residue consists mainly of impurities in the form of suspended, colloidal, and dissolved material contained in the raw water. Only small quantities of particulate residue are produced by chemical additions and the resultant chemical reactions.

The type, amount, and characteristics of waste vary considerably depending on the treatment process, raw water quality, pH, water temperature, chemical additions, and season of the year. The principal wastes in water treatment plants are particle residue retained in settling basins and wastewater generated from filter-backwash operations. The solids accumulation in the basins is basically a mixture of aluminum hydroxide, polyelectrolytes or other coagulant aids, inorganic debris, and organic matter. Waste residue from lime-softening units consists mainly of calcium carbonate, hydroxides of magnesium and of iron, inorganic and organic matters, and other substances. The quantity and composition of the filter-backwash wastewaters are functions of the filter process and the efficiencies of the treatment units used prior to the filter. Wastes from ion exchange units are derived from the recharge operation and are extremely high in dissolved solids.

Water treatment plant wastes cannot be destroyed, and their disposal is an ongoing problem. In practice, most wastes from water treatment plants are returned to the stream from which the raw water was taken. These waste flows can be considered potential pollutants for two reasons (Fulton, 1979): 1) they may inhibit biological activity in the receiving waters, and 2) they may create esthetically objectionable conditions. It has been argued that the largest portion of settled sludge and filter-backwash wastewater originates from the raw water source and therefore should be allowed to be returned to its source. In terms of total weight this may make sense. Nevertheless it generally is the case that the concentrations in the waste returns far exceed similar concentrations in the raw water intake.

The disposal of wastes has been both troublesome and costly for the water industry. For nearly two decades a number of alternative methods (Fulton, 1969; AWWA Research Foundation, 1969; Bishop, 1978; Reh, 1980) for handling water treatment plant wastes have been practiced. They include: lagooning, mechanical or gravity thickening, disposal to sewerage systems, barging to the ocean or other sites, pipeline transport, alum and lime recovery, polymer or pellet flocculation, sand bed or wedge wire drying, centrifuging, vacuuming, pressing or belt filtration, and freezing.

Although the effects of waste discharges from water treatment plants on receiving waters have not been well evaluated and defined, regulatory agencies have mandated that many water treatment plants stop releasing discharges to water courses. Frequently the standards applied to the effluent of wastewater treatment plants are similarly applied to waste discharges from water treatment plants.

Unfortunately, little information on the impact of waste from water treatment plant discharges on receiving streams is available. Evans and his associates (1979, 1982) are probably the first in Illinois to have conducted such impact studies. They found that there was no environmental degradation of source/receiving streams from the discharges of either the Pontiac or Alton water works. A similar conclusion for the Ohio River was reported by Gates et al. (1981). Evans et al. (1979, 1982) suggest that one must not generalize about the production and characteristics of wastes from a water treatment process nor about the impact of wastes on aquatic environments. Rather, an intelligent examination at each site in question is necessary to permit rational decisions concerning the impact of wastes on the water quality of receiving streams.

Study Area

The water treatment plant serving the city of East St. Louis (population 70,000) in St. Clair County, Illinois, is operated and owned by the Illinois-American Water Company. The plant serves approximately 350,000 customers in the metropolitan East St. Louis area. The plant (Figure 1) is located along the Mississippi River east of St. Louis, Missouri. The treatment facilities consist basically of three distinct treatment systems. The quality of the intake water is different for each system. Wastes from treatment units are returned to the Mississippi River below the raw water intakes.

The drainage area of the Mississippi River above the treatment facilities is about 697,000 square miles (1,805,000 km^2). The average streamflow is about 177,000 cfs (5040 m3/s). Streamflows are quite variable. For example, during the 1981 water year the maximum flow was 511,000 cfs

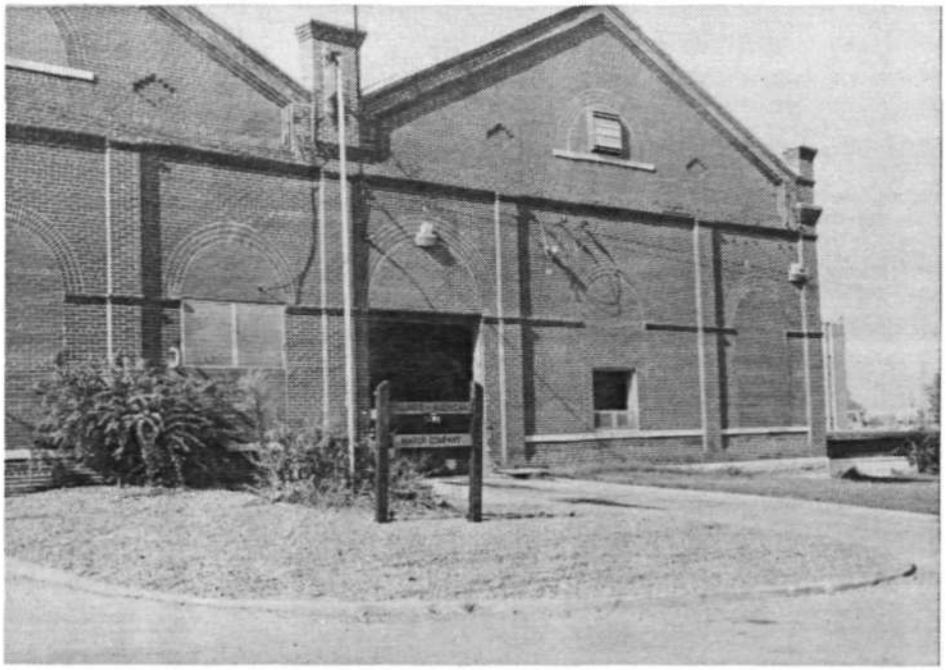

Figure 1. East St. Louis water treatment plant

(14,470 m^3/S) on May 21, 1981, while the minimum flow was 51,800 cfs (1470 m3/s) on February 12, 1981 (U.S. Geological Survey, 1982). The 7-day 10-year low flow is about 46,000 cfs (1300 m3/s). As shown in figure 2a, the high normal mean flows based on daily records occur during March through July.

Like the river flows, the turbidity of the river water is also quite variable. On the basis of the six years of data obtained from operation reports maintained by plant personnel at East St. Louis, the monthly mean turbidities were calculated. They are depicted in figures 2b and 2c. The highest levels of turbidity generally occurred in March and in the period June through August. During the study period, September 1981 through August 1983, the river turbidity at East St. Louis ranged from a low of 40 Jackson turbidity units (JTU) on February 12, 1982, to a high of 1500 JTU on June 21, 1982. The daily average turbidity was 318 JTU during 1982.

During an 8-year period monthly observations were made for turbidity and total suspended solids in the Mississippi River water at East St. Louis, as part of a cooperative effort between the Illinois State Water Survey and Illinois-American Water Company. The results are shown in table 1. It should be noted that the unit of turbidity in table 1 is the nephelometric turbidity unit (NTU). Unfortunately, there is no direct relationship between NTU and JTU. During the period of study total suspended solids varied from 14 to 738 mg/L with an average of 197 mg/L.

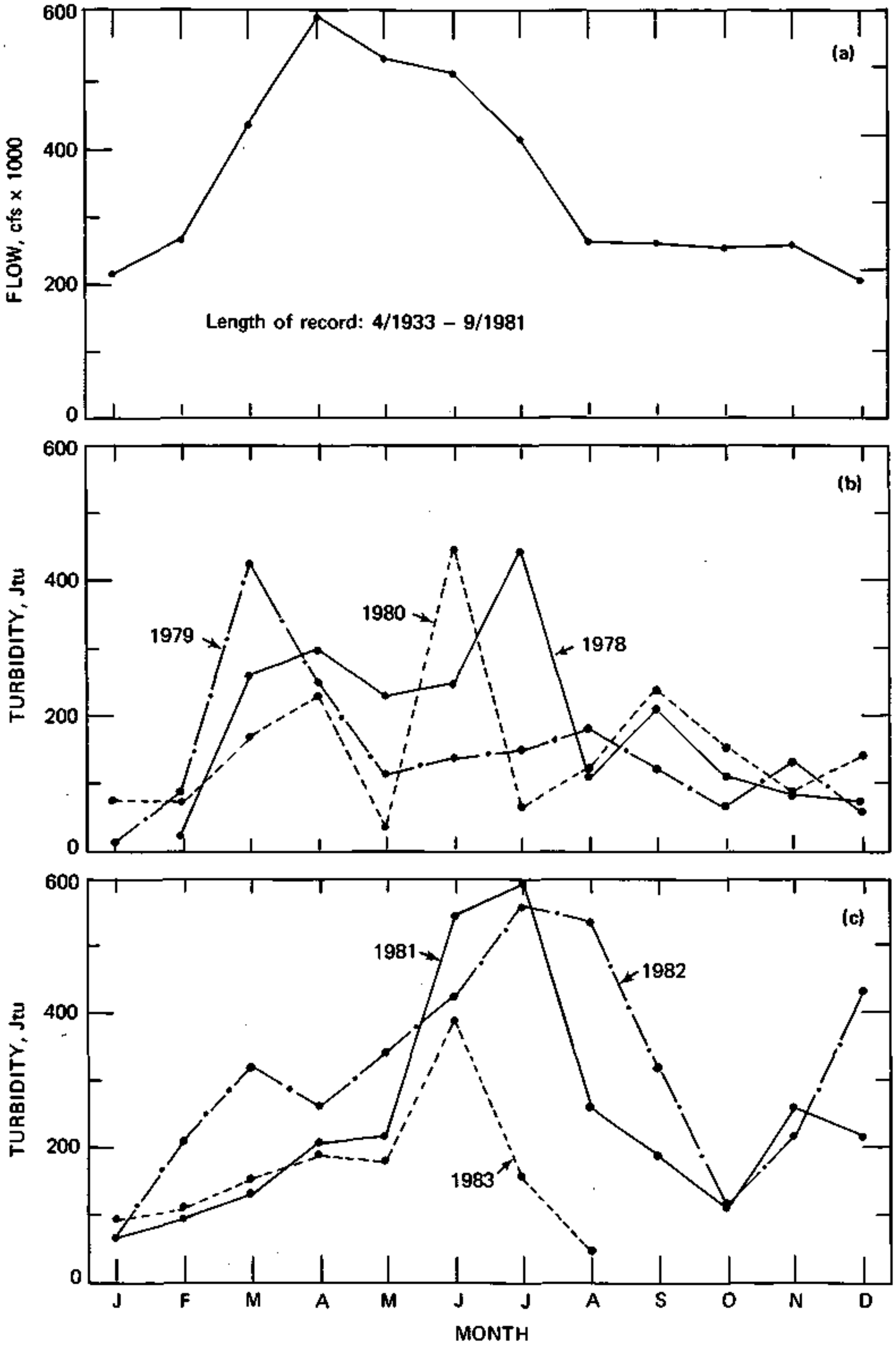

Figure 2. Temporal variations in mean flow and turbidity in the Mississippi River at East St. Louis

Table 1. Observed Turbidity (NTU) and Total Suspended Solids (mg/L) in the Mississippi River at E. St. Louis

Date	Turbidity, NTU	TSS, mg/L		Turbidity, NTU	TSS, mg/L		Turbidity, NTU	TSS, mg/L
11/22/71	74	175	11/27/74	28	59	08/09/77	39	77
12/21/71	291	400	12/12/74	50	86	09/23/77	95	209
01/31/72	32	53	02/11/75	62	98	10/25/77	72	162
02/22/72	40	113	02/25/75	355	683	11/21/77	34	67
03/27/72	127	263	03/24/75	367	689	12/21/77	76	220
04/25/72	321	525	04/14/75	63	111	01/19/78	80	37
05/30/72	50	64	05/29/75	417	638	02/20/78	8	22
06/08/72	52	94	06/26/75	234	437	03/23/78	190	578
07/31/72	56	116	07/30/75	46	83	04/29/78	70	223
08/21/72	86	169	08/26/75	52	129	05/23/78	100	278
09/26/72	103	158	09/30/75	47	90	06/29/78	142	356
11/30/72	31	68	10/30/75	28	55	07/29/78	228	596
12/26/72	34	66	12/19/75	85	196	08/31/78	30	81
01/18/73	69	154	01/21/76	18	46	09/29/78	90	247
02/22/73	51	107	02/27/76	88	230	10/18/78	40	85
04/27/73	302	329	03/29/76	67	171	11/28/78	53	127
05/31/73	313	400	04/27/76	292	738	12/26/78	15	37
06/29/73	199	360	05/26/76	43	94	01/31/79	7	44
09/28/73	337	655	06/24/76	71	210	02/27/79	124	344
10/31/73	91	166	07/29/76	26	75	03/31/79	50	162
12/28/73	132	334	08/27/76	22	55	04/27/79	45	149
01/25/74	193	421	10/28/76	29	70	05/24/79	18	147
02/19/74	41	96	11/03/76	21	51	06/26/79	41	117
03/07/74	104	235	12/31/76	15	35	07/30/79	124	290
04/19/74	122	237	01/26/77	7	14	08/29/79	90	267
05/15/74	112	220	01/31/77	14	50	10/01/79	24	76
06/24/74	171	259	02/09/77	26	103	10/24/79	23	68
07/22/74	155	346	03/31/77	164	324	12/17/79	15	33
08/27/74	41	74	04/19/77	13	26	01/ /80	23	64
09/10/74	43	74	05/18/77	73	143	03/21/80	79	233
09/27/74	38	71	06/15/77	120	284	05/09/80	17	46
10/28/74	29	54	07/11/77	48	93	06/26/80	136	404

	Turbidity, NTU	TSS, mg/L
Number of observations	96	96
Mean	94	197
Maximum	417	738
Minimum	7	14

TSS = 33.4 + 1.73(Turbidity)
r = 0.93

Objectives and Scope of Study

The principal purpose of the study was to evaluate the impact of wastes generated by the water treatment facilities on the water quality of the Mississippi River. The basic tasks performed to attain the objective were as follows:

1) Quantities, characteristics, and release patterns of wastes produced within the treatment system were determined.

2) Pertinent physical and chemical characteristics of bottom sediments of the Mississippi River were documented within and outside of the area of waste discharge influence.

3) The relative loads of wastes discharged were compared to the loads conveyed by the river water.

4) The type and abundance of benthic organisms in the river bottom sediment were ascertained.

The findings reported here pertain to two main areas: the water treatment plant wastes and the benthic characteristics (biological, chemical, and physical) of the river bottom. All pertinent data developed during the course of the study (September 1981 - August 1983) are included in the appendices.

Acknowledgments

This study was conducted under the general administrative direction of Stanley A. Changnon, Chief of the Illinois State Water Survey. Clarence Blanck, Director of Water Quality of the American Water Works Service Company, proposed the site for the study and provided encouragement and cooperation throughout. All operation personnel at the East St. Louis plant capably assisted in sampling and measurements. Kenneth Clark, Water Quality Superintendent, and Donald Brown, chemist of the water treatment plant, were most helpful in arranging for sampling schedules, offering guidance, and making available operational data. This study was partially funded by the Illinois-American Water Company.

The authors are grateful to other members of the Water Survey who participated in the study. David Hullinger, Dana Shackleford, and Brent Gregory performed chemical analyses. Mike Miller and Richard Twait analyzed grain size distribution of sediments, and Ralph Jones, Dana Shackleford, and Dave Cooksley assisted in. sample collections. Gail Taylor edited the report, Linda Johnson typed the original manuscript, and Kathleen Brown typed the camera copy. John Brother, Jr., and William Motherway, Jr., prepared the illustrations.

WATER TREATMENT PLANT WASTES

Treatment Units

The water treatment facilities at East St. Louis are located on the bank of the Mississippi River at river mile 180.8. They are served by two intakes. One intake (low service) is in the Mississippi River near the plant site about 15 miles (24 km) downstream of the river's confluence with the Missouri River. The other intake is located in the river at Chouteau Island (river mile 192.0), about 10 miles (16 km) upstream of the plant site and about five miles (8 km) below the confluence of the Mississippi and Missouri Rivers. The quality of the water at the low service intake is influenced by the Missouri River. However, the quality of the water at the Chouteau Island intake is not (Miller et al., 1974). A grit chamber is maintained at the Chouteau Island intake, where a coagulant (Cat-Floe "T") is added to the pumped water.

The low service intake is served by four pumps (#7, #8, #9, and #10). There are three pumps (#1, #2, and #3) at the Chouteau Island intake. Their rated pumping capacities are included in table 2.

The water treated at the facilities is of three different qualities. In addition to the waters derived from the low service intake and Chouteau Island, each of distinctive quality, the waters from these two sources are in turn blended and treated.

As shown in figure 3, the treatment systems consist of two types of processes. One process, which treats the water from the Chouteau Island intake, provides seven Dorr-Aldrich hydrotreators. The other process, a conventional process employing four settling basins and 20 granular activated carbon mixed media filters, treats water from the low service intake as well as blended water from the low service and Chouteau Island intakes.

From an operational viewpoint, the conventional process functions as two separate treatment plants. The nonblended low service water is processed by two basins (#1 and #2), shown in figures 4 and 5, and by four filters (#17 through #20). The blended water is processed by two basins (#4 and #5), shown in figure 6, and by 16 filters (#1 through #16).

During the two-year period of study the quantity of water treated at the East St. Louis facilities averaged 43.5 mgd (164,700 m3/d). On the average, during this period, about 8 mgd (30,300 m^3/d) of nonblended water was treated from the low service intake, about 22 mgd (83,300 m3/d) of blended water was treated, and the Dorr-Aldrich units processed about 13.5 mgd (51,100 m3/d) of water from the Chouteau Island intake. Pumpage at the low service intake averaged 25 mgd (94,700 m3/d), while that at Chouteau Island averaged 18.5 mgd (70,000 m3/d). Generally the ratio of the low service pumpage to the

Table 2. Rated Capacities of the Intake Pumps

Pump number	Capacity, mgd	At a total dynamic head, ft	Location
1	20.4	41	Chouteau Island
	14.3	57	
2	26.3	49	Chouteau Island
	16.8	74	
3	29.6	70	Chouteau Island
	26.5	80	
7	12.0		Low service
8	12.0		Low service
9	12.0		Low service
10	17.5		Low service

Note: 1 mgd = 3785 m^3/d; 1 ft = 0.3048 m

Chouteau Island pumpage for the blended water was about 3:1. However, to satisfy demand periods higher than average, pumpage was increased at Chouteau Island at times and the water routed to the blended treatment process, thus lessening the ratio.

All raw water is prechlorinated at the water treatment plant site. In addition to the Cat-Floc "T" added at the Chouteau Island intake, either alum or ferric chloride is added to all raw waters at the site. These dosages vary, but on the average 41 mg/L of alum and 27 mg/L of ferric chloride are added to the raw water processed by the conventional facilities. About 25 mg/L of alum and 8 mg/L of ferric chloride are added to the raw water processed by the Dorr-Aldrich units.

Occasionally small quantities of Nalco 8793, Nalco 8174, Magna floc 587C, and other polymers are used as supplemental coagulants and/or filter aids. A small quantity of lime is added for pH adjustment at the influent of the Dorr-Aldrich units.

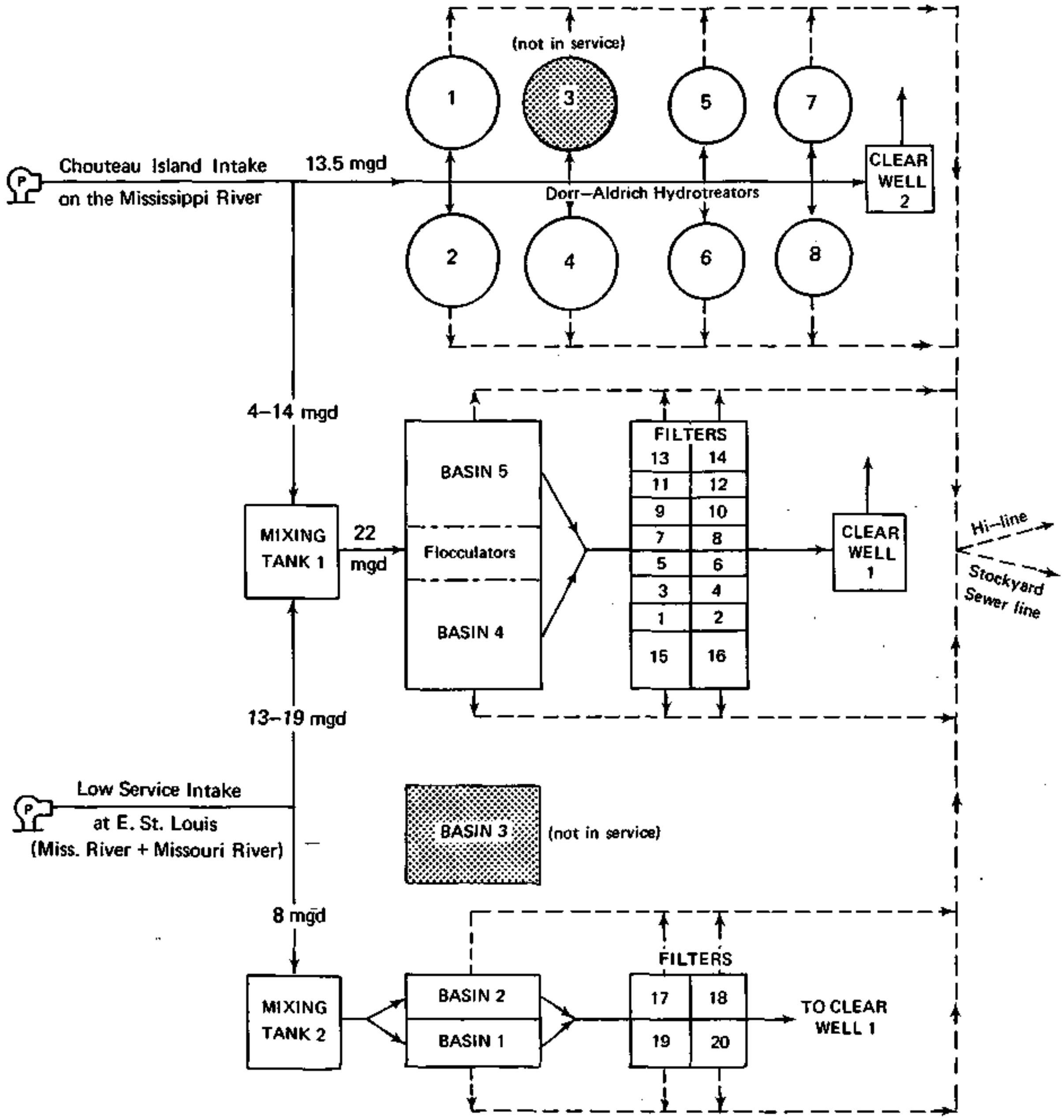

Figure 3. Schematic flow diagram of the East St. Louis water treatment plant

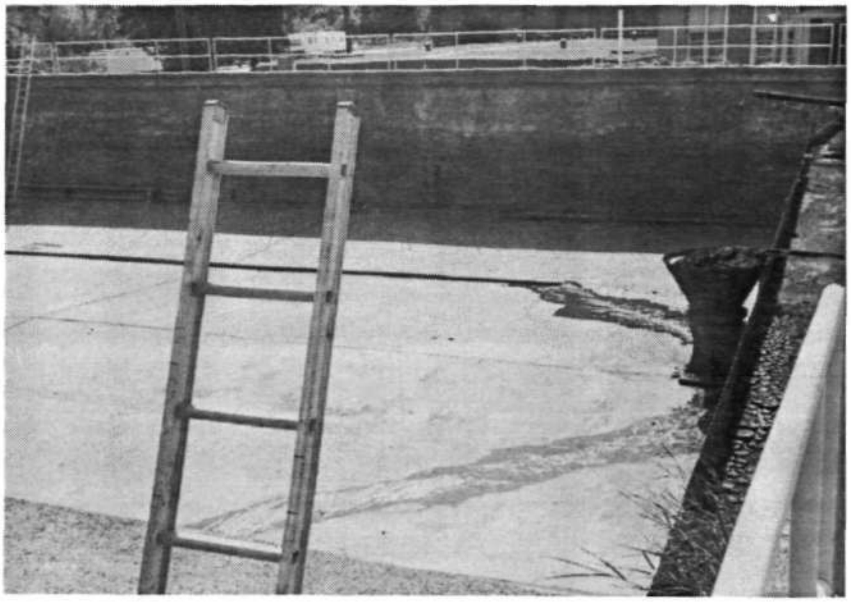

Figure 4. Basin 1, outlet end

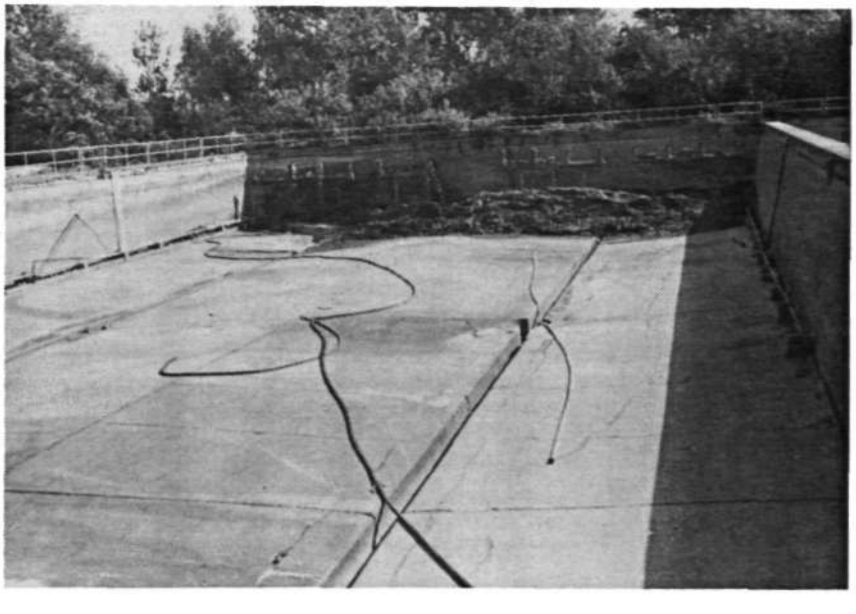

Figure 5. Basin 2, inlet end

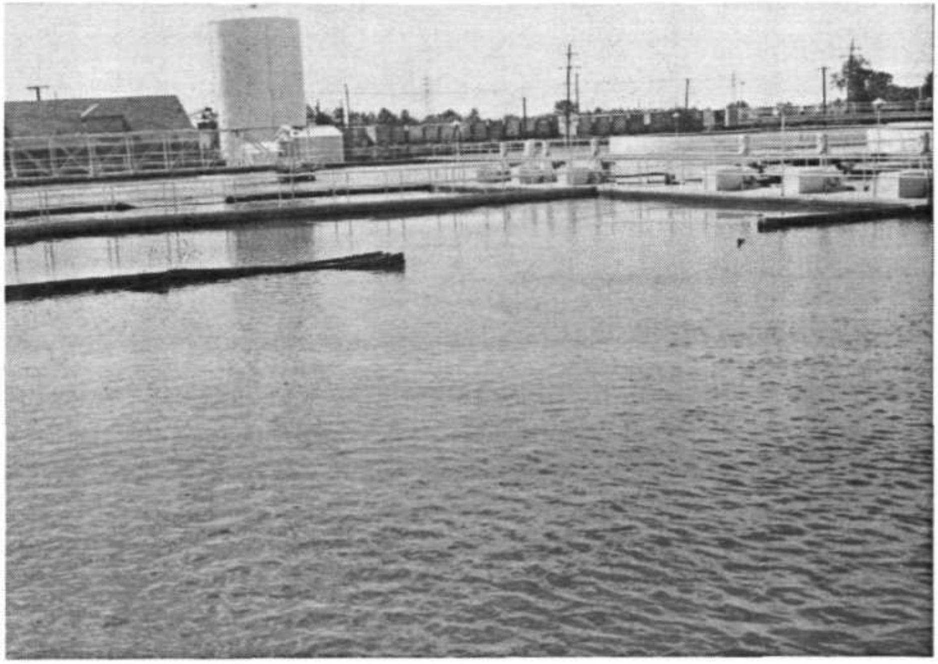

Figure 6. Basin 4, flocculators, and basin 5

Settling basins 1 and 2 both have volumes of about 2.3 MG (8700 m3) with areal dimensions of 100 by 220 feet. Flow from these basins is routed to four filters (#17 - #20). About 8 mgd (30,300 m^3) of nonblended low service water is treated by these facilities. The basins operate on the fill and draw principle, and they require cleaning about twice a year.

Settling basins 4 and 5 have volumes of 3.75 MG (14,200 m3) with areal dimensions of 160 by 169 feet. Flow from these basins is routed to 16 filters (#1 - #16). Generally about 22 mgd (83,300 m3/d) of blended water is treated by these facilities. Although the basins are equipped with solids residue withdrawal equipment, it is not sufficient, and the basins must be drawn down about twice a year for cleaning. Before entering the basins, the blended water goes through two flocculators, each with areal dimensions of 48 by 75 feet.

The 20 mixed media filters consist essentially of 18 inches of granular carbon atop 12 inches of sand resting on graded gravel and supported by a Leopold bottom. A typical arrangement is shown in figure 7. Each of the filters numbered 1 through 12 has a capacity, at a filtration rate of 2 gallons per minute per square foot (gpm/ft^2), of about 1 mgd (3785 m^3/d). Each of the filters numbered 13 through 20 has a capacity of 2 mgd (7570 m3/d) at a similar filtration rate. The overall design capacity of the 20

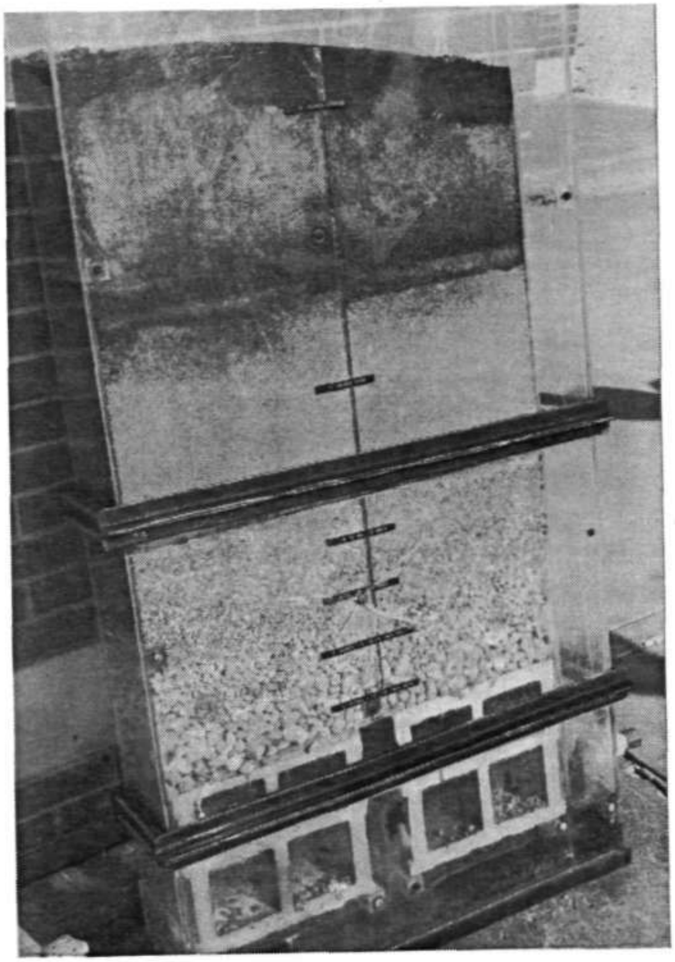

Figure 7. Model of granular activated carbon mixed media filter

filters is about 28 mgd (106,000 m3/d). These filters are backwashed about once or twice a day. Figure 8 shows a filter undergoing a backwash operation.

The Dorr-Aldrich hydrotreators are of circular construction with steel sidewalls. Each unit consists of an inner clarifier with overflow at its periphery to a sand filter (30 inches deep) with 4 inches (10 cm) of anthracite atop it. The clarifier portion of a Dorr-Aldrich unit is shown in figure 9. Three of the units contain clarifiers with design capacities of 2.75 mgd (10, 400 m^3/d) and diameters of 81 feet (25 m). Four of the units contain clarifiers with capacities of 2.5 mgd (9460 m3/d) and diameters of 60 feet (18 m). During the study period, the filters for all the units were

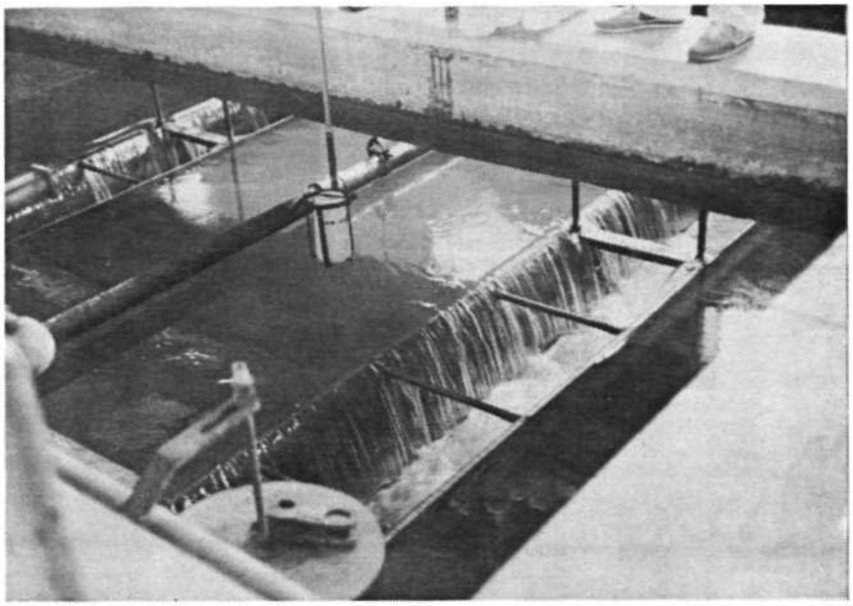

Figure 8. Filter backwashing

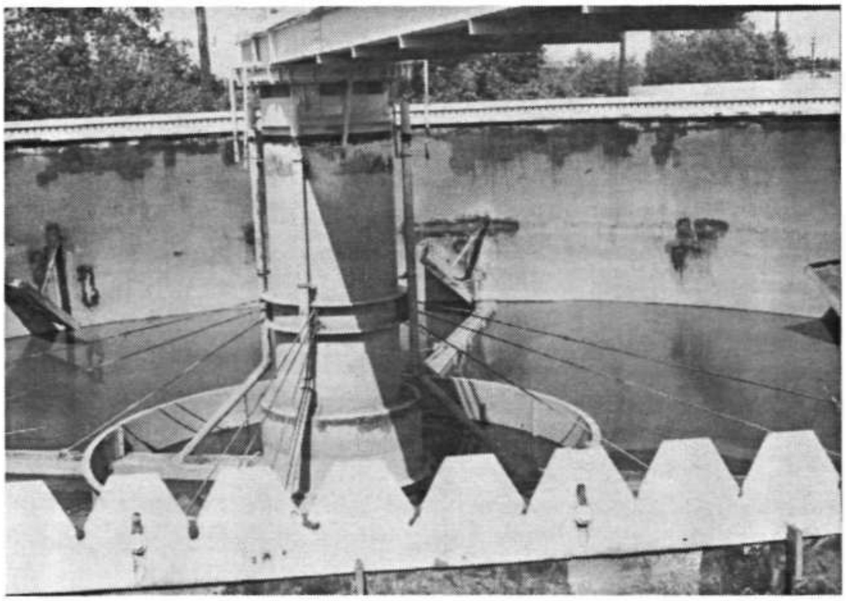

Figure 9. Clarifier portion of Dorr-Aldrich hydro treator

operated at equal capacities of 2 mgd (7570 m3/d). Each clarifier is equipped with mechanical devices permitting the periodic removal of accumulated residue. Nevertheless the units are drawn down once or twice a year for cleaning purposes.

The filters at the East St. Louis facility vary in size because they were built at different times during periodic plant expansions. For purposes of sampling and evaluation, the filters were grouped into seven sets: A, B, C, D, E, F, and G. Groups A through E were the filters that served the conventional system; groups F and G were those serving the Dorr-Aldrich units. Table 3 indicates the filters in each group; their dimensions, areas, design capacities, and construction materials; and the year they were built. The total filter area for the conventional process is about 9800 sq ft (910 m^2); the filter area provided by the seven Dorr-Aldrich units in service is about 6500 sq ft (604 m^2). At an average pumpage of 30 mgd (113,600 m3/d) for the conventional plant and 13-5 mgd (51,100 m^3/d) for the Dorr-Aldrich units, the filtration rates are 2.1 and 1.44 gpm/sq ft, respectively. This is assuming that all flow is distributed equally among the filters.

Post-chlorination and fluoride additions were introduced for all filter effluents. Flow from all filters proceeds to two clear wells.

The principal waste-producing units at the plant site are the flocculators, settling basins, Dorr-Aldrich clarifiers, and filters. Wastes from these units are discharged to the Mississippi River by two lines. One is a gravity line, commonly called the stockyard line. Its outlet is shown in figure 10. The other is a force main, commonly called the Hi-line (pump discharge line). Its outlet is shown in figure 11. The determination regarding which line is used is generally dependent upon the stage of the river as recorded at the St. Louis gage.

Sampling Procedures

The flocculators and sedimentation basins of the conventional plant are designed to decant twice a year, and the residual solids are flushed by fire hose to bottom drains. This operation should be performed during the spring and fall. However, as shown in figure 12, the decant operations for the basins have not followed a regular pattern during the past several years. Basins 1 and 2 are operated and cleaned simultaneously. Basins 4 and 5 cannot be decanted simultaneously. During the period of study (September 1981 - August 1983), basins 4 and 5 both experienced long shutdown periods (up to 73 days) for dewatering, draining, cleaning, and repair.

Measurements for solid residues in the flocculators and sedimentation basins after dewatering were accomplished in the following fashion. Prior to cleaning, the distance from the top of the basin wall to the sludge surface

Table 3. Data on Filters

Group	Filter number	Size	Area, sq ft		Capacity, mgd		Sidewall construction	Year built
			Each	Total	Each	Total		
Conventional								
A	1-8	16′x22′	352	2816	1.0	8.0	Concrete	1917
B	9-12	16′x22′	352	1408	1.0	4.0	Concrete	1918
C*	13-14	24′-6"x28′-10"	704	1408	2.0	4.0	Concrete	1949
D*	15-16	24′-3"x28′-6"	693	1386	2.0	4.0	Concrete	1967
E*	17-20	24′-3"x28′-6"	693	2772	2.0	8.0	Concrete	1967
	Subtotal			9790		28.0		
Dorr Aldrich hydrotreators								
F	5-8	ID: 64′ OD: 73′	888.5	3554	2.50	10.0	Steel	1956
G	1-4	ID: 83′-6" OD: 90′-0"	968	3872	2.75	11.0	Steel	1961
	Subtotal			7426		21.0		
	Total			17216		49.0		

* Contains double filters but each half is backwashed at a time.

Note: 1 ft = 0.3048 m; 1 sq ft = 0.0929 m^2

Figure 10. Outlet of stockyard gravity line

Figure 11. Outlet of Hi-line

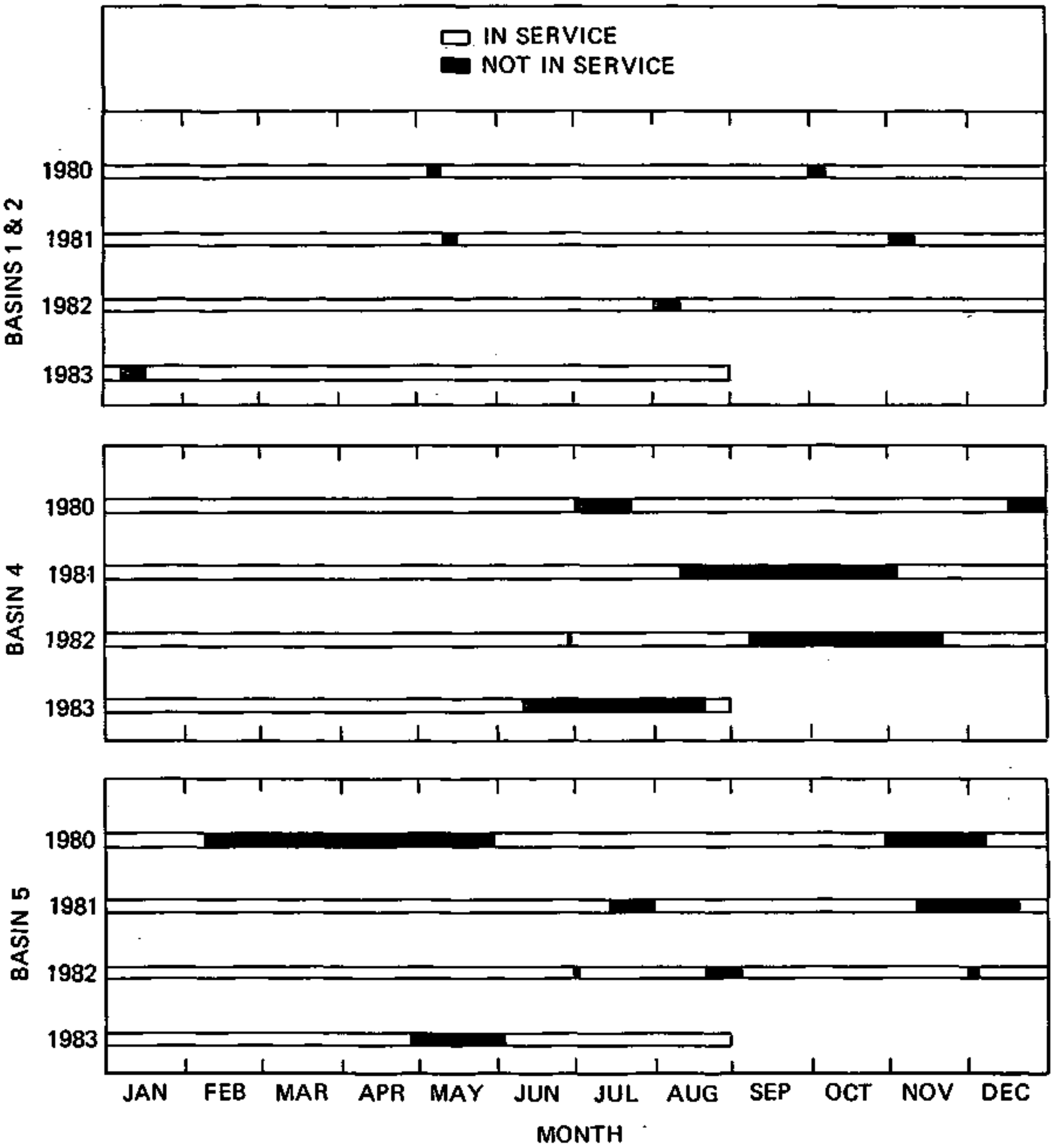

Figure 12. Periods of operation of the sedimentation basins

was measured by using a sounding line. The sludge depth was estimated by the difference between overall basin depth and measured distance above the sludge surface. For basins 1 and 2 the measurements were made at 20-foot intervals along the east and west walls (220-foot length) of the basins. The measurements at basins 4 and 5 were made at 6- to 10-foot intervals along the north and south walls of the basins.

Sludge samples were taken by using an Ekman dredge along the edge of the basin at about 50-foot intervals during each depth measurement. All samples from a basin were combined to provide a composite sample. The composite samples were analyzed for iron (Fe) and aluminum (Al) concentrations, specific weight, and moisture content. Analyses were performed in accordance with Standard Methods (APHA, 1980).

Depth measurements in each clarifier of the Dorr-Aldrich units were performed along the walkway from the sidewall to the tank center at four to six locations. Depth differences at a certain spot for a certain period of time were also determined. Composite sludge samples were collected for each unit, and analyses were performed as previously described.

The activated carbon mixed media filters (conventional facilities) were backwashed at a rate of about 6000 gpm per unit filter on the average of once every 14 hours. The duration of backwash averaged about 5 to 7 minutes. Generally there were 34 filter backwashes per day during the study period. The areal backwash ranged from about 12 to 24 gpm/sq ft.

The backwash rate for the filters in the Dorr-Aldrich units was 14,000 gpm per unit filter with an average filter run of 34 hours. The areal backwash rate varied from 14 to 16 gpm/sq ft. The filter backwash is automatic and is timed. The surface wash is three minutes in length, and backwash starts two minutes after the surface wash is activated. Effective surface wash causes the material removed from the water by the filtration process to be released more rapidly than in filters without surface wash.

Sampling during filter backwash operations was undertaken at five conventional plant filters and two Dorr-Aldrich filters during each visit. Six visits were made during the two-year period. Each of the filters sampled was considered representative of one of the seven groups of filters. Filter backwash samples were obtained sequentially near the wash trough with an extended aluminum rod to which was affixed a sampling bottle carrier. Samples from the conventional plant were generally collected at 15-second intervals during the first two minutes, at 30-second intervals during the next two to three minutes, and at 1-minute intervals thereafter until backwash was finished. This time frame was selected so that in each sample collected there would be approximately the same percentage of the total load released. The sampling procedure required 12 to 15 sample collections per filter backwash.

For the Dorr-Aldrich filters, which have no surface wash, samples were collected at 20-second intervals for the first two minutes of backwash, at

30-second intervals for the next minute of backwash, and at 1-minute intervals thereafter.

Each sample collected during backwash operations was analyzed for total and volatile suspended solids and settleable solids. Data for each backwash sample are listed in appendix A.

Waste Production and Characteristics

The wastes (solids) generated within a water treatment plant are derived from suspended and dissolved solids in the source water, chemical additions, and the resultant chemical reactions. Because the East St. Louis treatment facilities are operated principally as a clarification process with minimal chemical additions, the major quantity of waste generated is that removed from its raw water source, the Mississippi River. Thus, the solid wastes produced within the East St. Louis works are comprised essentially of the TSS (total suspended solids) contents of the raw water with minor additions generated by coagulants (alum or ferric chloride). The quantities of wastes produced by lime and polymer additions are insignificant.

Loads from raw waters

The plant personnel do not routinely perform total suspended solids analyses on the raw water. Nevertheless turbidity measurements are made routinely at least three times a day and the average value is recorded. As a part of this study, plant personnel performed TSS analyses on the low service raw water samples (nonblended), Chouteau Island raw waters, and blended samples in conjunction with turbidity measurements. The results of these measurements are shown in table 4.

The relationships between the turbidity measurements and corresponding suspended solids concentrations were used to estimate the suspended solids concentrations likely to occur in the raw waters during the study period. The data in table 4 were subjected to 3-way regression analyses, i.e., linear, semi-log, and log-log relationships. The linear relationships generally showed the best correlation. The developed relationships and other pertinent data are as follows:

	Low service	Chouteau Island	Blended
Relationship	TSS=1.35 Turb.-100	TSS=0.93 Turb.+50	TSS=1.31 Turb.-28
Number of samples	31	30	34
Correlation coeffficient	0.87	0.88	0.94
Average turbidity, JTU	257	171	247
Average TSS, mg/L	247	210	332

Table 4. Observed Turbidity and Total Suspended Solids in Raw Waters

Date	Low service Turbidity, JTU	Low service TSS, mg/L	Chouteau Island Turbidity, JTU	Chouteau Island TSS, mg/L	Blended Turbidity, JTU	Blended TSS, mg/L
1982						
5/26					1530	2000
6/03					590	784
6/09					290	304
6/15	112	88	450	344	520	572
7/13	600	444	450	344	520	464
7/15	510	244	320	308	470	408
7/19	900	1832	370	424	550	452
7/22	720	556	470	568	600	656
8/25	180	80	120	68	160	112
12/3	550	596	450	544	480	1132
1983						
1/13	100	46	60	34	80	64
1/18	75	82	40	76	110	76
1/21	80	52	40	48	110	78
1/25	100	22	50	40	85	36
2/11	120	182	110	142	120	160
2/15	90	122	30	68	40	80
2/25	155	65	160	331	157	238
3/07	99	75	48	85	76	106
3/10	110	60	50	116	105	130
3/18	160	154	55	392	140	262
3/21	155	160	95	174	130	140
3/25	180	142	110	238	150	216
3/30	200	264	100	127	130	273
4/13	150	74	80	108	95	192
4/19	145	124	38	144	110	186
4/28	100	72	27	86	86	62
5/04	300	75	320	78	305	116
5/13	180	138	130	154	150	92
5/18	90	156	70	106	150	56
5/25	260	148	130	142	180	198
6/14	138	105	77	103	112	103
6/24	900	1096	800	876	650	1104
7/08	300	266	180	188	190	248
7/13	220	136	150	188	150	178

The average observed turbidity and TSS values for the blended water were higher than those for both raw sources. This is probably due to the addition of the coagulant Cat-Floc "T" at the Chouteau Island intake, which produced more floc formation after blending at the treatment plant.

The mean daily TSS concentrations of the Mississippi River at the low service and Chouteau Island intakes were calculated by the regression relationships from corresponding mean daily turbidity. The mean daily TSS contents for the blended raw water were prorated from the TSS and flow rates of the two sources. There was no flow record for the low service intake. Its mean flow rate was estimated to be 8 mgd. The mean flow rate of the blended water was calculated by subtracting 8 mgd from the total flow treated by the conventional plant. It was also assumed that 17 mgd to the blended source was from the low service intake while the rest (5 mgd) was contributed by the Chouteau Island source. The results are shown in table 5.

The mean daily concentration of TSS ranged from about 40 to 650 mg/L at the low service intake with a 2-year average of 233 mg/L. This 2-year average value was about 15 percent greater than the previous observed average value of 197 mg/L (see table 1). The mean daily TSS concentrations at the Chouteau Island intake varied from about 70 to 140 mg/L with a 2-year average of 204 mg/L. During the 2-year study period, the high values of turbidity and TSS occurred in the summer (June through August) of 1982. However, the values were lower in July and August 1983.

On the basis of the recorded and estimated raw water pumpages and flow rates and the TSS contents for the two raw intakes and the blended water, the daily average TSS loadings to the treatment plants were calculated. The estimated mean daily loading (or input) rates for each month are included in table 5.

Figure 2 supported by tables 1, 4, and 5 shows that the flows and turbidities of the Mississippi River are generally high from March through July. As expected, the TSS concentrations of the river water followed the same pattern. Water quality and quantity varied daily, monthly, and yearly. Evans et al. (1982) reported that the average (1978-1981) turbidity of the Mississippi River at Alton during the winter months was considerably less than during the rest of the year.

During the first year of this study, the average TSS concentrations in the raw water sources were estimated from turbidity measurements to be 260 mg/L with a high value (240 - 650 mg/L) from May through August 1982 (table 5). The average daily solids load was calculated for each month from the average pumpage rate and the average TSS concentrations. At the first-year total average flow of about 45 mgd (from table 5), the average daily solids load applied to the treatment facilities was 99,420 pounds (45,097 kg). From the coagulant use recorded, the estimated solids load generated by coagulation precipitation was 960 pounds (435 kg) per day. Therefore the

Table 5. Mean Daily Pumpage, Turbidity, and TSS Concentrations and Loading Rates

	Low service				Blended				Chouteau Island			
	Flow, mgd	Turbidity, JTU	TSS, mg/L	TSS load, lb/d	Flow, mgd	Turbidity, JTU	TSS, mg/L	TSS load, lb/d	Flow, mgd	Turbidity, JTU	TSS, mg/L	TSS load, lb/d
1981												
S	8	190	157	10,480	23.65	173	158	31,160	14.00	120	162	18,920
O	8	110	49	3,270	21.52	106	67	12,020	14.00	90	134	15,650
N	8	260	251	16,750	20.93	229	224	39,100	14.00	95	138	16,110
D	8	120	62	4,140	25.59	103	80	17,070	10.26	70	115	9,840
1982												
J	8	65	44*	2,940	28.47	53	60	14,250	11.16	35	83	7,725
F	8	210	183	12,210	26.90	207	203	45,540	12.00	202	238	23,820
M	8	325	338	22,550	22.56	294	318	59,830	13.42	220	255	28,540
A	8	260	251	16,750	19.35	246	243	39,220	14.00	145	186	21,717
M	8	340	359	23,950	23.63	300	325	64,050	14.00	200	237	27,622
J	8	425	573	38,230	22.79	387	504	95,800	14.00	270	302	35,262
J	8	560	654	43,630	24.95	503	575	119,650	14.00	380	405	47,288
A	8	530	614	40,970	25.16	494	559	117,300	14.00	420	443	51,725
First year avg.	8	283	294	19,620	23.79	258	277	54,960	13.24	187	225	24,840

Table 5. Concluded

	Low service				Blended				Chouteau Island			
	Flow, mgd	Turbidity, JTU	TSS, mg/L	TSS load, lb/d	Flow, mgd	Turbidity, JTU	TSS, mg/L	TSS load, lb/d	Flow, mgd	Turbidity, JTU	TSS, mg/L	TSS load, lb/d
1982												
S	8	322	334	22,280	22.64	314	324	61,180	14.00	260	293	34,210
O	8	120	62	4,140	18.95	117	69	10,900	14.00	90	134	15,646
N	8	220	197	13,140	17.84	217	197	29,310	14.00	160	199	23,235
D	8	440	340	22,680	16.67	440	340	47,270	14.00	335	363	42,384
1983												
J	8	96	68*	4,540	17.43	95	69	10,030	14.00	68	114	13,311
F	8	116	57	3,800	18.81	111	62	9,726	12.79	65	110	11,730
M	8	155	109	7,270	18.03	151	110	16,540	12.75	78	123	13,080
A	8	192	159	10,610	18.07	187	158	23,810	12.92	108	150	16,160
M	8	180	143	9,540	19.42	173	146	23,650	13.07	125	166	18,090
J	8	391	428	28,560	22.23	361	396	73,750	13.43	265	296	33,150
J	8	160	116	7,740	26.65	149	121	26,890	15.07	130	171	21,490
A	8	50	38*	2,540	26.68	39	49	10,900	14.85	20	69	8,550
Second year avg.	8	204	171	11,410	20.29	196	170	28,770	13.74	142	182	20,860
Two year avg.	8	243	233	15,550	22.04	219	224	42,970	13.49	165	204	22,950

*** Log-log relationship**

Note: 1 mgd = 3785 m^3/d

total solids loading to the plant for the first year averaged about 100,380 pounds (45,530 kg) per day.

The estimated average TSS concentration in the raw water sources for the second year of the study was found to be significantly lower than for the first year of the study. High TSS contents in raw waters occurred in September and December 1982 and June 1983 (table 5). Very low values (38 mg/L) were estimated in August 1983 due to the drought. During the second year the average TSS concentration in the raw waters was estimated to be 176 mg/L. At a total average flow of 42 mgd (from table 5), the average daily solids load applied to the treatment facilities during the second year of the study was 61,040 pounds (27,690 kg). In addition 484 pounds (220 kg) per day was produced by alum coagulation. Thus, on the average, about 61,520 lb/d (27,900 kg/d) of solids was applied to the treatment facilities during the second year of the study. The observed and estimated data of the second year probably reflect an abnormal condition. The first year data are indicative of a more likely occurrence.

The mean daily TSS loading rates during the 2-year period were about 15,500, 43,000, and 23,000 lb/d (7,100, 19,500, and 10,400 kg/d) respectively for the low service, blended, and Chouteau Island waters. These represent 19, 53, and 28 percent of the total loading applied to the plant. The ranges of the loadings for the corresponding treatment units were about 3000 to 44,000, 10,000 to 120,000, and 7700 to 52,000 lb/d, respectively.

Based on a two-year average the quantity of solids applied daily at the plant was about 81,500 pounds (37,000 kg). Assuming a mean flow of 177,000 cfs and a suspended solids concentration of 233 mg/L, this withdrawal from the river represents about 0.037 percent of the solids conveyed daily by it.

Loads from Coagulants

Aluminum sulfate (alum) is the most popular coagulant utilized for water treatment. Its first reaction with water is one of solution; its second is one of combination with the OH^- ions made available by the alkalinity of the water. The stoichiometric relation between commercial alum and alkalinity can be written as:

$$\begin{aligned} Al_2(SO_4)_3 \cdot 14\ H_2O + 3\ Ca(HCO_3)_2 \rightarrow\ & 2\ Al(OH)_3\downarrow + 3\ CaSO_4 \\ & + 6\ CO_2 + 14\ H_2O \end{aligned}$$

On the basis of this chemical reaction about 0.262 (156/594.4) pounds of $Al(OH)_3$ precipitate will be produced per pound of dry alum dosed. In addition commercial alum contains only about 17 percent Al_2O_3. Therefore the waste generated by alum coagulation can be estimated as:

$$\begin{aligned} \text{Pounds of precipitate} &= 0.262 \times 0.17 \times \text{pounds of alum used} \\ &= 0.0445 \times \text{pounds of alum used} \qquad (1) \end{aligned}$$

The mean daily dosages of coagulants, coagulant aids, and filter aids to the conventional plant are set forth in table 6. Commercial alum used at this plant during the second year of the study period averaged about 308 pounds per day per million gallons of water treated. The alum dosage averaged 8670 pounds (3933 kg) per day. On the basis of the alum usage (from equation 1), the average residue loading due to alum coagulation was 386 pounds (175 kg) per day. This quantity represents only 0.66 percent of the solids loading contributed solely by the raw water.

Ferric chloride was also used as a coagulant at the East St. Louis plant. Iron coagulant reacts in much the same manner as aluminum. The stoichiometric relation between ferric chloride and alkalinity is as follows:

$$2\ FeCl_3 \cdot 6\ H_2O + 3\ Ca(HCO_3)_2 \rightarrow 2\ Fe\ (OH)_3\downarrow + 3\ CaCl_2$$
$$+\ 6\ CO_2 + 12\ H_2O$$

On the basis of the chemical reaction, 0.395 (213.7 / 540.6) pounds of $Fe(OH)_3$ precipitate will be generated per pound of dry ferric chloride used. The commercial grade of crystal ferric chloride used was 34 percent pure. Thus the following equation was employed to estimate the waste production due to crystal ferric chloride coagulation:

Pounds of precipitate = 0.395 x 0.34 x pounds $FeCl_3$ used
= 0.1343 x pounds FeC12 used (2)

During the study period ferric chloride was employed as a coagulant in the conventional plant for a 9-month period from October 1981 through June 1982 (table 6). The mean daily dosage ranged from about 38 to 287 pounds per million gallons water treated, with an average of 128 pounds per million gallons. Based on raw water pumpage, the ferric chloride applied for the 9-month period averaged 6390 pounds per day. From equation 2, ferric chloride application to_the conventional plant contributed solid residues of 858 lb/d (390 kg/d). This represents only about 1.4 percent of solids loading contributed by the raw water.

Other coagulants were not considered significant contributors to the in-plant generation of solids. Because of the discontinuity in the use of alum and ferric chloride from year to year an estimate was required for the solids produced per day as a result of their use. The estimate is 860 lb/d (309 kg/d). Therefore, the total mean daily production of dry solids in the conventional plant is about 59,400 lb/d (27,000 kg/d). This is equivalent to about 1980 pounds (900 kg) of solids per million gallons of water treated.

Three coagulants were used for waters treated by the Dorr-Aldrich units. They are indicated in table 7. Alum, the major coagulant used, was applied at an average rate of about 160 lb/MG water treated. Based on the raw water pumpage and dose rate, alum addition during the 2-year average was 2150 lb/d (975 kg/d). As calculated by equation 1, the solids production due to alum coagulation was about 100 lb/d (45 kg/d). This amount represents about 0.4 percent of the TSS loading from the raw water. It is almost negligible.

Table 6. Mean Daily Pumpage, Volume and Number of Backwashes, and Chemical Dosages in the Conventional System (Low Service and Blended Water)

Month	Raw water pumpage, mgd	Filter backwash, mgd	No. of backwashes per day	Alum, lb/MG	Ferric chloride, lb/MG	Cat-Floe "T", lb/MG	Magna floe 587C, lb/MG	Kalco 8793, lb/MG	Pebble lime, lb/MG
1981									
S	31.65	1.63	28.7			2.54		18.16	
0	29.52	1.45	25.9		59.07*	2.73		18.90	
N	28.93	1.64	29.3		59.04*	4.66		17.75	
D	33.59	2.23	44.0		226.28	7.92		22.00	
1982									
J	36.47	2.18	43.5		158.26*	7.59		26.96	16-34*
F	34.90	1.77	43.6	310.04*	116.62	9.49		27.66	17.13
M	30.56	2.02	44.0	19.32*	286.54	9.79		33.07	101.28
A	27.35	1.54	37.0		102.40	9.58		37.46	52.54*
M	31.63	1.45	32.5		104.45*	9.39		33.02	1.57
J	30.79	1.46	31.0		38.34	9.07		36.21	8.33*
J	32.95	1.55	30.5			9.21		29.73	6.18
A	33.16	1.93	35.1			6.36		20.74	
lst-year average	31.79	1.74	35.7		127.89	7.36		26.80	
S	30.64	1.59	32.7	148.41		7.77	10.84*	16.72*	
0	26.95	1.36	28.2	77.03		8.69	33.11		
N	25.84	1.53	20.7	507.95		8.57	32.29		
D	24.67	1.60	33.4	885.56		11.76	34.14		57.14*
1983									
J	25.43	1.54	36.5	543.07		11.12	27.74		
F	26.81	1.97	42.3	320.87		10.15	28.71		59.43
.M	26.03	1.68	35.8	248.59		11.01	28.52		73.99
A	26.07	2.14	41.2	386.28		10.41	29.72		41.46
M	27.42	1.55	30.7	189.96		11.18	28.54		
J	30.33	1.49	28.8	241.49		9.82	23.72		
J	34.65	1.24	23.2	59.74		6.93	23.11		
A	34.68	1.39	24.7	69.36		5.90			
2nd-year average	28.29	1.59	32.2	306.53		9.44	27.31		
2-year average	30.04	1.66	34.0			8.40			

* Not added daily

Note: 1 mgd = 3785 m^3/d ; 1 lb/MG = 0.1198 g/m^3

Table 7. Mean Daily Pumpage, Volume and Number of Backwashes, and Chemical Dosages in Dorr-Aldrich System

Month	Raw water pumpage, mgd	Filter backwash, mgd	No. of backwashes per day	Alum, lb/MG	Ferric chloride, lb/MG	Cat-Floc "T", lb/MG
1981						
S	14.00	0.95	5.6	21.35*		6.75
O	14.00	0.93	5.6	109.45*		8.36
N	14.00	0.61	4.0	175.19		13.75
D	10.26	0.46	4.3	242.51		18.82
1982						
J	11.16	0.82	7.8	344.27*	6.78*	24.08
F	12.00	0.91	7.6	324.16*	113.20*	27.84
M	13.42	0.77	6.3	108.72*		28.52
A	14.00	0.73	5.1		13.27*	27.61
M	14.00	0.67	4.3		54.01*	28.79
J	14.00	0.65	4.5	169.21*	13.82*	27.74
J	14.00	0.58	4.0	245.78		26.10
A	14.00	0.74	5.0	345.46		17.92
1st-year average	13.24	0.74	5.4	173.84	16.76	21.36
S	14.00	0.69	5.1	186.95		20.22
O	14.00	0.55	3.5	22.12		21.14
N	14.00	0.54	3.6	84.58		20.92
D	14.00	0.76	5.7	171.33		26.65
1983						
J	14.00	0.69	5.6	118.51*		28.32
F	12.79	0.70	4.9	442.52		28.91
M	12.75	0.57	4.4	84.61		30.02
A	12.92	0.60	5.3	281.57		28.81
M	13.07	0.54	4.8	119.56		29.27
J	13.43	0.49	4.2	109.73		28.70
J	15.07	0.45	3.0	31.24		25.32
A	14.85	0.41	3.3	75.87		29.70
2nd-year average	13.74	0.58	4.5	144.05	0	26.50
2-year average	13.49	0.66	4.8	158.94	8.38	23.93

* Not added daily

Note: 1 mgd = 3785 m^3/d; 1 lb/MG = 0.1198 g/m^3

Thus, the total average solids loading to the Dorr-Aldrich plant is about 23,100 pounds (10,500 kg) per day. This is equivalent to about 1700 pounds (770 kg) of solids input per million gallons of water treated. The total load of solids applied to the East St. Louis water treatment plant is about 82,400 lb/d (37,100 kg/d).

Wastes from Filter Backwash

Volume. The average filter backwash rates, duration of backwash, and volume of waste from each filter unit within groups A-G are shown in table 8. The observed backwash rates varied from 12.3 to 24.5 gpm/sq ft at the conventional plant. The backwash rates for groups F and G of the Dorr-Aldrich units were constant during the six observations.

Table 8. Average Backwash Rates, Duration, and Volume of Waste for Each Filter Unit per Backwash

	Avg backwash rate per unit		Avg backwash duration,	Avg waste volume,
Group	gpm/sq ft	gpm	minutes	gallons
A	16.9	5,950	6.8	40,340
B	16.9	5,950	7.0	41,800
C*	19.2	6,780	6.9	47,270
D*	20.9	7,250	6.7	48,330
E*	14.6	7,250	6.7	48,360
F	15.8	14,000	5.6	79,000
G	14.5	14,000	6.8	95,000

* One-half of each unit

Note: 1 gpm/sq ft = 0.679 $L/m^2.s$; 1 gal = 3.785 L

1 gpm = 6.308×10^{-5} m^3/s

Filter backwash duration for each unit ranged from 5 to 8 minutes. The total volume of waste from the 20 filters at the conventional plant during the period of sampling was about 1.26 million gallons per backwash. A 2-year average of 1.7 washes per day per filter was recorded. Therefore the average daily backwash volume for the conventional plant was estimated to be 2.14 mgd. About 0.66 mgd was from the low service units and about 1.48 mgd was from the blended water units. In the case of the low service units the filter backwash volume was 8.3 percent of the water treated; for the blended units it was 6.7 percent of the water treated. Records maintained at the plant site indicated a 2-year average for filter backwash volume of 1.66 mgd (see table 6). Nevertheless the values developed during the sampling of the filters was used to develop waste volumes and weights.

Table 8 shows that at the Dorr-Aldrich system the total volume of waste per backwash for the seven filters was 601,000 gallons (four filters had 79,000 gallons of waste each and three filters had 95,000 gallons of waste each). An average of about 0.69 washes per filter per day were recorded. Thus during the sampling period the average daily backwash volume was 415,000 gallons. This represents about 3.1 percent of the water treated. Although plant records indicated a daily waste volume from the filters of 660,000 gallons (see table 7), the waste flows and loads observed in this study were used. All pertinent data regarding observations of backwash operations are included in appendix A.

Total suspended solids. Typical total suspended solids release patterns for the seven groups of filters during backwash operations on two different dates are depicted in figure 13. Data on the operations performed on these two sampling dates are given in table 9. The purpose of table 9 and figure 13 is to demonstrate that there is considerable variation not only in backwash frequency but also in solids release patterns. Maximum TSS concentrations recorded at the conventional plant varied from 348 mg/L at group A on May 27, 1982, to 1820 mg/L at group D on August 9, 1982. At the Dorr-Aldrich plant the maximum TSS concentrations varied from 330 mg/L at group G on February 28, 1983, to 2700 mg/L at group F on August 9, 1982. The maximum values occurred-generally within 0.5 to 1.5 minutes of the commencement of backwash.

The calculated dry weights of TSS released from the filter groups during backwashes are set forth in table 10. In order to estimate the total weight of TSS released daily from filter backwashes in the treatment plants, the following assumptions were made: 1) each filter within the group generated the same average weight per wash as shown in table 10, 2) all filters were in service all the time, and 3) backwash frequency occurred as noted here.

The quantity and composition of filter backwash wastewater and the frequency of wash are functions of the process, the efficiency of the units preceding the filters, and the quality of the raw water. During the first year of the study, on the average, the filters were backwashed about 36 and 5.4 times daily at the conventional and Dorr-Aldrich facilities, respectively (see tables 6 and 7). The volume of wash water averaged 1.74 and 0.74 mgd

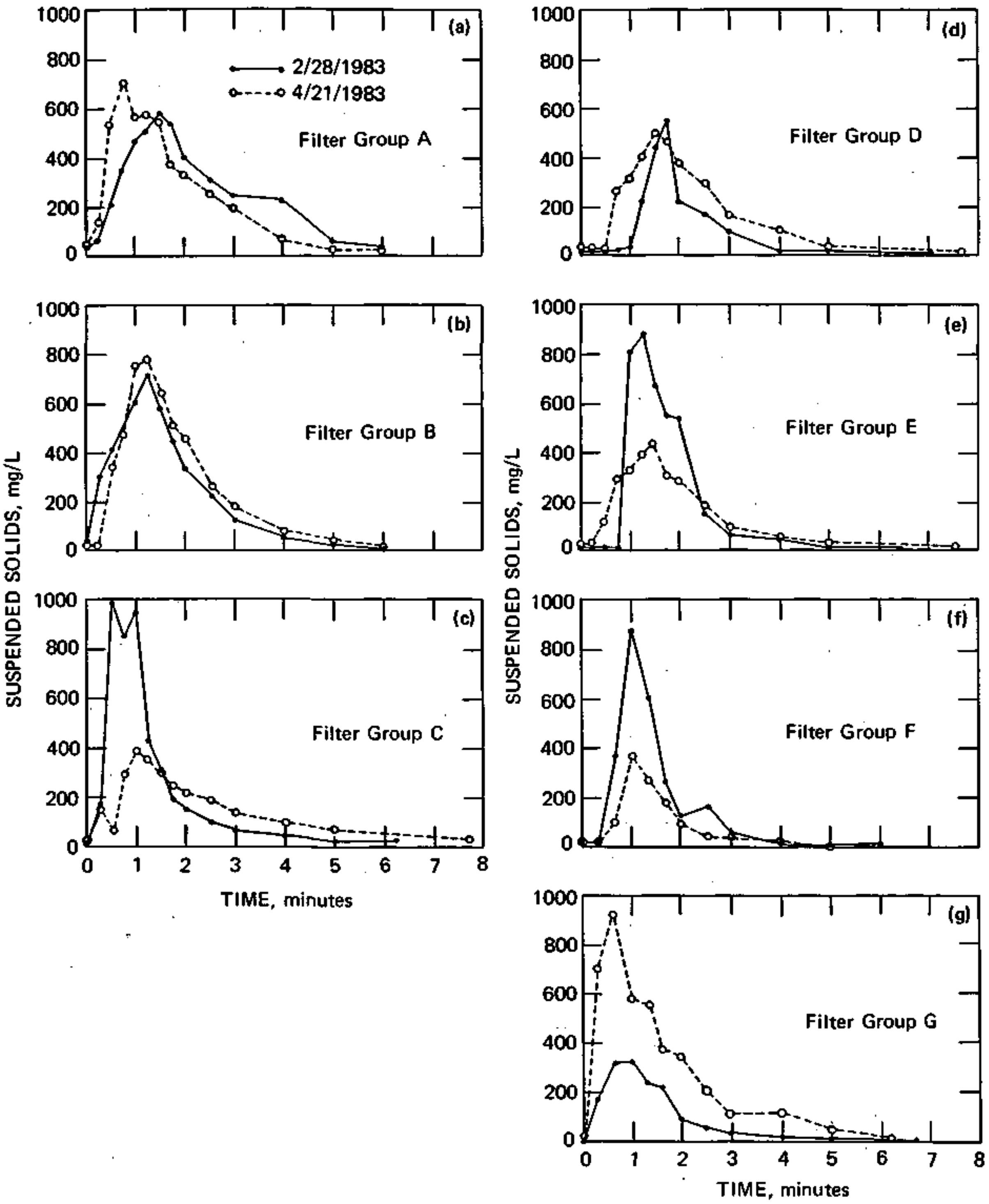

Figure 13. Total suspended solids release during filter backwashes

Table 9. Operational Data on Filter Backwashes

Date	Plant & group	Filter unit number	Hours of operation	Water filtered, mgd	Backwash rate, mgd	Backwash water volume, gal
2/28/83	Conventional					
	A	8	16.2	0.646	17.0	36,000
	B	10	16.2	0.646	17.0	36,000
	C	13*	16.2	0.646	17.0	37,200
	D	15*	16.2	0.646	17.3	42,180
	E	17*	16.2	0.646	16.8	38,520
	Dorr-Aldrich					
	F	7	50.8	3.900	15.8	84,000
	G	4	29.5	2.265	14.5	93,800
4/21/83	Conventional					
	A	8	9.5	0.362	17.0	49,380
	B	9	9.5	0.362	17.0	46,380
	C	13*	14.3	0.545	17.0	46,020
	D	15*	8.5	0.324	17.3	46,320
	E	17*	15.7	0.599	16.8	45,480
	Dorr-Aldrich					
	F	5	20.3	1.619	15.8	70,000
	G	4	28.2	2.249	14.5	88,620

* One-half of each unit

Note: 1 mgd = 3785 m^3/d; 1 gal = 3.785 liters

Table 10. Pounds of Total Suspended Solids Released during Filter Backwashes

Group	2/17/82	5/27/82	8/10/82	11/10/82	2/28/83	4/21/83	Avg/filter	Avg/group
Conventional								
A	77	43	101	90	68	66	74	592
B	60	61	79	69	67	72	68	272
C*	91	150	37	47	59	42	71	284
D*	41	95	111	54	29	50	63	252
E*	123	70	115	56	52	40	76	608
Dorr-Aldrich								
F	88	198	233	142	108	152	153	612
G	59	330	318	40	65	192	167	501

* One-half of each unit

Note: 1 pound = 0.454 kg

for the respective systems. The water used at each plant represented about 5.5 percent of the water treated. Based on the results of six field measurements (table 10) about 100 pounds of solids per filter wash was released from each conventional filter and about 159 pounds was released from each Dorr-Aldrich filter. Thus, the total amount of solids released from both plants was estimated to be 4460 lb/d (100 × 36 + 159 × 5.1) during the first year of the study.

During the second year of the study the filters at the conventional and Dorr-Aldrich plants were backwashed about 32 and 4.5 times daily, respectively (see tables 6 and 7). The estimated total weight of solids released from filter washes of the two plants was 3920 lb/d (100 x 32 lb/d from the conventional plant and 159 × 4.5 lb/d from the Dorr-Aldrich plant). The volumes of wash water used at the corresponding plants were, respectively, 1.59 and 0.58 mgd (representing 5.7 and 4.3 percent of water treated). In an Illinois study, Evans et al. (1970) reported that the volume of backwash water expressed as percent of the amount of water processed was quite variable, ranging from 0.9 to 7.0 percent at 114 water treatment plants studied. From the East St. Louis data, wash water usage is above the average of 2 percent obtained during the Illinois study. The backwash rates of groups C, D, and E during the second year of the study averaged 17.7, 17.3, and 16.8 gpd/sq ft (calculated from appendix A). The reason for these variations from the first study year is unknown.

On the basis of the data summarized in table 10, the total estimated weight of TSS released during each backwash from the 16 filters in groups A through D (blended water) was 1400 pounds. The four filters in group E (low service) released 608 pounds during each backwash. As noted earlier the average frequency of backwash over a 2-year period was 1.7 per day per filter. Therefore the filter backwash operations at the conventional plant generated about 3410 lb/d of dry solids, of which 1030 and 2380 lb/d were released from the low service plant and blended water plant, respectively. These released solids represent about 5.7 percent of the total suspended solids applied to the conventional plant.

Similarly, for the Dorr-Aldrich filters, an average of 1110 pounds was released per backwash from the seven filters. At this plant about 0.69 backwashes per filter occurred. Therefore the estimated TSS generated daily from the Dorr-Aldrich filters was 770 pounds. This represents about 2.3 percent of the TSS load applied to the Dorr-Aldrich plant. Overall the amount of solids released from filter backwashes at the East St. Louis plant was 4180 (3410 + 770) lb/d (1900 kg/d).

Volatile solids. The average volatile content of the released solids ranged from 23 to 29 percent among the seven groups of filters. The overall volatile content of the backwash solids was 26 percent on the average. This is comparable with the 23 percent observed at Alton (Evans et al., 1982).

Settleable solids. Settleable solids are the volume of residues which settle in a 1-liter Imhoff cone after a quiescent period of 30 minutes. It is assumed that this fraction of the total suspended solids is the fraction likely to create waste residue deposits on the bottom of the receiving stream.

The release pattern for settleable solids during filter backwash is similar to that for TSS, as shown in figure 13. From the six observations for each group of filters during backwash, it was seen that 95 to 100 percent of the TSS was released during the first 1.5 to 2.5 minutes of backwash. On the basis of solids analyses alone, the duration of backwash could be shortened.

The measured volumes of settleable solids from the seven groups of filters during backwashes are summarized in table 11. Table 11 suggests that the volume per wash for each group of filters was quite variable. Similar results were reported by Evans et al. (1970). The variability may be due to the water quality of the basin effluent and the operation habits of plant personnel. The average volume of settleable solids ranged from 180 gallons released from group D filters to 1060 gallons per wash from group G filters.

Table 11. Gallons of Settleable Solids Released during Filter Backwashes

Group	2/17/82	5/27/82	8/10/82	11/10/82	2/28/83	4/21/83	Avg/filter	Avg/group
Conventional								
A	315	- 64	141	461	532	212	288	2224
B	295	84	136	338	598	252	284	1136
C*	394	225	53	215	487	135	252	1008
D*	155	155	164	248	230	138	182	728
E*	473	101	184	233	279	187	243	1944
Dorr-Aldrich								
F	898	392	951	740	1909	665	926	3704
G	570	455	778	127	1032	3377	1055	3165

* One-half of each unit

Note: 1 gallon = 3.785 liters

The computations used for estimating the quantity of solids released from the filters were similarly applied to estimate the quantity of settleable solids released daily. The average volume of settleable solids for the conventional plant is about 11,970 gpd. Of this 3300 gpd is contributed from the low service plant (group E), and 8670 gpd is released from the blended water plant (groups A through D). The total volume of settleable solids represents about 0.56 percent of the total volume of backwash.

For the Dorr-Aldrich filters, the estimated total volume of settleable solids is about 4800 gallons per day. This volume represents about 1.15 percent of the total daily volume of filter backwash.

At the East St. Louis plant about 16,770 gpd of settleable solids was discharged from filter backwashes. This volume represents a very small fraction of the average flow (111,300 mgd) of the Mississippi River. There was no sludge deposit observed around the wastewater outfalls.

Wastes from Basins and Clarifiers

The volume of residue in the flocculators and sedimentation basins and in the clarifiers of the Dorr-Aldrich units was estimated from the depth measurements. Depth measurements were performed twice or more for each basin. The weight of solid accumulation was estimated from the volume of residue together with specific weight and the percent solids content of the residue. The estimated weight of the waste in both basins and clarifiers was substantially higher than the solids inputs to the plants. This is probably due to the poor volume estimations. More trans-sections and less distance between them would likely produce better estimates. In addition the buffer boards between the flocculator and sedimentation basins 1 and 5 were frequently broken and the mechanical scrapers in the basins together with the timer-operated sludge drain in the Dorr–Aldrich clarifiers make the volume estimation questionable.

Weight. The weights of solid residue which accumulated in and were subsequently released from the basins (including the flocculator) and the Dorr-Aldrich clarifiers were calculated from the differences between input loads and the TSS released from the filters. The results are shown in table 12. On a 2-year average, the solids generated from basins 1 and 2, basins 1 and 5 (including flocculators), and the Dorr-Aldrich clarifiers were 11,710, 41,230, and 22,280 lb/d, respectively. The total daily solids residue accumulating within the basins and clarifiers of the facility was about 78,250 pounds. During the study period, the estimated total mean solids residue production was 88,900 lb/d (10,300 kg/d) for the first year and 57,600 lb/d (26,100 kg/d) for the second year. However, solids removal efficiency in the basins for both study years was about 91 - 98 percent. The majority of the solids loads applied to the plant is captured in the basins and clarifiers.

Table 12. Estimated Mass Balance of Solids to the East St. Louis Water Treatment Plant and the Pertinent Characteristics

	Low service	Blended	Conventional plant	Dorr-Aldrich plant	Total
Pumpage, mgd	8.0	22.0	30.0	13.5	43.5
TSS, mg/L	233	224		204	
Solids loads, lb/d					
Raw water	15,550	42,970	58,520	22,950	81,470
Coagulant	220	640	860	100	960
Total	15,770	43,610	59,380	23,050	82,430
Solids from filters					
lb/d	1,030	2,380	3,410	770	4,180
% of total load	6.5	5.5	5.7	2.3	5.1
lb/MG processed	129	108	114	57	96
Solids accumulation in and from basins and other treatment units, lb/d	14,740	41,230	55,970	22,280	78,250
% of total load	93.5	94.5	94.3	97.7	94.9
lb/MG processed	1,843	1,874	1,866	1,651	1,799
Waste volume					
From filters, mgd	0.66	1.48	2.14	0.415	2.555
% of pumpage	8.3	6.7	7.1	3.1	5.9
Gal/MG processed	82,500	67,300	71.300	30,700	58,700
From basins,etc., sludge					
Gpd	6140	13,390	19,530	17,000	36,530
% of pumpage	0.077	0.061	0.065	0.13	0.084
Gal/MG processed	768	609	651	1,260	840
Settleable solids					
From filters, gpd	3,300	8,670	11,970	4,800	16,770
% of pumpage	0.041	0.039	0.040	0.036	0.039
Gal/MG processed	413	394	399	356	385

The daily solids production in the basins is not discharged daily into the Mississippi River. On the average the 28.56 million pounds (14,280 tons) of solids per year are flushed out to the river. The solids consist primarily of concentrated materials already present in the river with additional chemicals from the water treatment plant.

Volume. The volume of solids residue can be calculated from the weight of the residue together with the specific weight and percent of solidity. The estimated volume of solids residue that accumulated in the basins and clarifiers daily is also summarized in table 12. The total daily volumes accumulating within the basins and clarifiers were estimated to be about 36,500 gallons.

Characteristics of Basin Residue. The characteristics of the basin residues at the East St. Louis plant are summarized in table 13. The average specific weights of the solids residues were 1.15, 1.23, and 1.14 in basins 1 and 2, basins 4 and 5, and the Dorr-Aldrich clarifiers, respectively. The average solidities of the residues in these three corresponding groups were respectively 25, 30, and 20 percent by weight.

The densities of the basin residues varied from 1.10 to 1.44. Their water content ranged from 28 to 84 percent, and the volatile portions varied from 4.0 to 9.8.

In previous studies at the water treatment plants at Pontiac and at Alton, Illinois (Evans et al., 1979, 1982) it was found that solids residue from the sedimentation basins at municipal water treatment plants contained considerable amounts of aluminum (Al) and iron (Fe). As shown in table 13, the average iron concentrations in the residues of basins 1, 2, 4, and 5 and in the residues of the Dorr-Aldrich clarifiers were about 42,000, 32,700, 42,800, 30,700, and 30,100 parts per million (ppm), respectively. The average aluminum concentrations in basin residues in the corresponding basins were respectively 36,900, 33,700, 41,600, 37,500, and 36,500 ppm.

In table 14 those concentrations are compared to the concentrations in sediments at other locations. The iron concentrations at the East St. Louis facilities are comparable to those observed at the Alton plant and are higher than those normally found in soil or stream sediments in southern Illinois. The Alton water treatment plant also derives its raw water from the Mississippi River. The aluminum values in the basin residues are in the range of those observed in lake sediments and dry soil.

On the average over a 2-year period the accumulation of solids residue in the basins at the East St. Louis plant was 78,250 lb/d. Based on average concentrations of 35,600 and 37,200 ppm respectively for iron and aluminum, the iron and aluminum loads to the river would be 2790 and 2910 lb/d if continuously discharged. These values represent 64.1 and 66.9 lb/MG of water

Table 13. Basin Residue Characteristics

Unit	Date	Density, g/mL	Water content, %	Volatile, %	Iron, ppm	Aluminum, ppm
Basin 1	11/03/81	1.192	74.2	5.0	44,930	21,300
	1/05/83	1.170	76.0	8.4	39,000	52.400
				Avg	41,970	36,850
Basin 2	11/03/81	1.230	69.9	4.4	32,780	13,900
	8/06/82	1.444	49.7	4.0	32,800	26,100
	1/05/83	1.140	79.2	9.3	23,400	61.160
				Avg	32,660	33,720
Basin 4	6/29/82	1.240	31.2	7.1	42,800	41,600 *
	4/21/83	1.320	60.5	4.1	(14,200	17,500)
Basin 5	6/29/82	1.220	28.0	6.1	36,800	38,200
	4/21/83	1.150	79.7	9.2	24,600	36,800
				Avg	30,700	37,500
Dorr-Aldrich	5/06/83					
1		1.100	83.0	8.4	31,000	38,600
2		1.140	78.8	9.2	31,600	38,600
4		1.160	77.0	8.5	31,700	31,000
5		1.130	81.2	9.6	30,500	36,400
6		1.150	78.6	9.2	28,200	32,200
7		1.100	83.8	9.8	30,000	41.800
8		1.170	77.4	8.0	28,400	37,100
				Avg	30,100	36,500
				Overall avg	35,600	37,200

* Bad sample

Table 14. Comparison of Iron and Aluminum Concentrations in Sludge, Soil, and Sediments

	Iron, ppm	Aluminum, ppm	Reference
E. St. Louis plant			
Basins/Clarifiers	30,100-42,800	33,700-41,600	
Alton plant			
Mixers	32,300-44,000	20,000-26,300	Evans et al.(1982)
Basins	32,950-41,000	39,250-55,000	Evans et al.(1982)
Southern Illinois			
Soil	9,000-20,000		Roseboom et al.(1978)
Stream sediment	10,500-15,000		
Lake sediment	9,300-36,000		
Dry soil		10,000-300,000	Bowen(1966)
Sediment			
Lake Michigan		4,200-40,000	Cahill(1981)
Great Lakes		50,000-81,000	Kemp & Thomas(1976)
Horseshoe Lake		48,900-52,100	*
Mississippi River		27,400	MRPWSA(1972)

* D. L. Gross, Illinois State Geological Survey, personal communication, 1978

treated, respectively. These values also were much higher than those observed at water treatment plants along the Ohio River (Fe - 17.6 lb/MG; Al - 15.4 lb/MG; Gates, 1981). The iron and aluminum concentrations in the sediment of the Mississippi River will be discussed later.

Discussion

A water treatment plant is a solids generator. Sedimentation basin residues and filter backwash wastewater are the major components. From the study conducted by Evans et al. in 1970 of 114 plants in Illinois, about 43 percent of the plants discharged basin residues directly to lakes and streams and about 54 percent of the plants similarly discharged backwash wastewaters. About 16 percent of the plants discharged their waste to dry creeks. It is likely that some changes have occurred in these practices since 1970. Alternative disposal methods are available, such as sanitary sewer disposal, lagooning, mechanical dewatering, sand drying beds, and iron and aluminum recovery.

At the East St. Louis facilities there are two waste streams to the Mississippi River. One stream is discharged daily though intermittently from filter backwashes and from continuous or intermittent underflow from the clarifiers. The other stream is generally discharged twice a year from each basin of the conventional plant and once a year from each clarifier of the Dorr-Aldrich units.

In an earlier study, Evans et al. (1979) reported increases in sulfate, turbidity, and aluminum concentrations in the receiving water (Vermilion River) from waste discharges by the water treatment plant at Pontiac. No significant changes were detected for TSS, dissolved oxygen, silica, and other chemical characteristics. The impacts of water treatment plant waste discharge on a receiving water, based on Illinois experiences, are potentially most significant in terms of TSS, iron, and aluminum.

As shown in table 12, the daily waste stream from the East St. Louis plant is about 2.6 mgd. The average flow of the Mississippi River at East St. Louis is 114,300 mgd (177,000 cfs). Therefore under average daily conditions the dilution ratio of river flow to waste stream is about 44,000:1. At a 7-day 10-year low flow in the river of 45,970 cfs (29,700 mgd or 112.4 x 10^6 m^3/d, Singh and Stall, 1973) and assuming only 10 percent of the flow is available for mixing purposes, the dilution ratio of river flow to waste stream is 1140:1.

Table 15 lists the pertinent data and assumptions used for computations to assess the impact of waste discharge on the TSS concentrations in the Mississippi River. The basic data are given in table 12. Under the worst case conditions, the waste load discharge to the river is released by the flushing out of the solids residue in either basin 4 or 5 and by the routine backwashes from all filters. The timer-operated underdrain of the Dorr-Aldrich clarifier is ignored.

The daily load of TSS from basin 4 or 5 is 20,615 pounds. It is assumed that in a 6-month period (during which the basin is in operation only about 150 days), the accumulation of residue is flushed from the basin in 10 working days at 6 working hours per day. The flushing rate is 500 gpm for a fire hose. With two fire hoses used simultaneously, the flushing rate is 60,000 gallons per hour or 1.44 mgd. The released solids concentration from basin 4 or 5 will be 103,080 mg/L (table 15). The 7-day 10-year low flow of the Mississippi River at St. Louis is 45,970 cfs or 29,700 mgd (Singh and Stall, 1973). This is the assumed low streamflow in combination with maximum waste discharge. At this low flow a 10 percent mixing, as suggested by MRPWSA (1972), is realistic. The TSS concentration of the river is assumed to be 10 mg/L. By mass balance, the resultant TSS concentration in the mixing zone of the river is estimated to be 60 mg/L. The influence of filter backwashes is negligible. An increase of 50 mg/L of TSS above the background level will occur.

The number of days required for flushing the basin residue has a significant impact on the TSS concentrations in the river. If the flushing takes 20 working days, an increase of only 25 mg/L of TSS above background will occur.

Table 15. Data for Assessing TSS Increase in River from Waste Discharge

Basin 4 or 5 operation	
In operation, days	165
Under drain, days	30
Residue accumulation, days	150
Flushing period, days	15
Working days	10
Working hours/day	6
Rate, gpm	1,000
Discharge rate	
Basin 4 or 5, mgd	1.44
All filter backwashes, mgd	2.56
Mississippi River	
7-day 10-year low flow, mgd	29,700
10 % low flow, mgd	2,970
Total suspended solids	
Basin production, lb/d	20,615
150-day accumulation, lb	3,094,750
Release per working day, lb	309,475
Release per working day, lb	51,580
Release concentration, mg/L	103,080
Filters	
Weight, lb/d	4,180
Concentration, mg/L	196
Mississippi R., 7-d 10-y low flow	
Concentration (assumed)	10

The question may arise as to whether or not the selection of 10 percent of the 7-day 10-year low flow of the river is considered an allowable mixing zone. The Illinois Pollution Control Board (1973) stipulates that no single mixing zone shall exceed the area of a circle with a radius of 600 feet. This area is about 1,130,000 square feet. The width of the river at the point of the waste outlets is about 1440 feet (Jordan, 1965). If river flow can be considered commensurate with stream width, at 10 percent flow the allowable mixing zone will be 144 feet wide by 7850 feet long. In earlier work at Pontiac (Evans et al., 1979), the dilution ratio of streamflow at 10 percent of mean flow was only about 180:1. A sampling station was about 3700 feet below the waste outfall. There were no increases in the concentrations of the 15 constituents tested at this station. There were transitory increases in turbidity, sulfate, and total aluminum at Pontiac within a 570-foot reach downstream of the waste outlet. Therefore, solely on the basis of the experience at Pontiac the selection of 10 percent of the 7-day 10-year low flow at East St. Louis appears to be representative of an allowable mixing zone.

As shown in table 13, the average iron and aluminum concentrations in the residues of basins 4 and 5 were 36,800 and 39,600 ppm, respectively. The basin residue concentration in terms of TSS to the river is 103,080 mg/L. Thus the estimated iron and aluminum concentrations in the wastestream of basins 4 and 5 are 3790 and 4080 mg/L, respectively. As illustrated previously, to assess TSS increase in a large river such as the Mississippi, the increased value can be simply determined by dividing loading concentration by the river flow in the mixing zone (2970 mgd). Therefore during the cleaning period of basins 4 and 5, the increases of iron and aluminum concentration in the Mississippi River due to the wastestream discharge are 1.3 and 1.4 mg/L, respectively. - The recorded average iron concentration in the Mississippi River is 3.2 mg/L.

For iron, the generally accepted standard is 1 mg/L (USEPA, 1976; IPCB, 1973). The IPCB (1973) does not have a specific limit for aluminum. A concentration of greater than 1.5 mg/L is considered harmful to aquatic life, while concentrations less than 0.2 mg/L are considered safe (National Academy of Sciences and National Academy of Engineers, 1973). The solubilization of iron and aluminum hydroxides could have a short-term effect on the pH of the receiving water of a stream with less buffering capacity than the Mississippi River.

When a wastestream is discharged to a receiving water, resuspension, colloidalization, and solubilization will not occur instantly. In a high velocity river, the material contained in the wastestream discharge will be swept into resuspension, after which the process of colloidalization, solubilization, and desorption will start (Gates et al., 1981). The time (distance) required for completion of these processes is determined by the rates of diffusion and dispersion, colloidalization, solubilization, and desorption. Determination of these rates is not within the scope of this study.

Summary

Table 12 summarizes the average values of solids loads to and from the treatment units at East St. Louis. A general summary is as follows:

- The solids load applied to the facilities averaged about 82,400 pounds (37,400 kg) per day. About 1.2 percent of the load was derived from coagulant precipitation; the remainder originated from the total suspended solids in the raw water sources. The solids load was equivalent to 1920 pounds (824 kg) per million gallons of water processed.

- The sources of wastes at the East St. Louis facilities are the clarifiers, sedimentation basins, and filters. On the average, the quantity of solids generated daily in the plant represented about 0.037 percent of the solids conveyed by the Mississippi River daily at mean flow.
- The granular activated carbon mixed media filters in the conventional units and the filters in the Dorr-Aldrich units generated an average of 4180 lb (1896 kg) daily or 96 pounds (44 kg) per million gallons of water treated. This represents only 5.1 percent of the total solids produced.
- On the average about 95 percent of the solids load was removed in the clarifiers and sedimentation basins. About 1800 pounds (816 kg) of solids was released daily per million gallons of water treated at the East St. Louis facilities.
- The volume of wastewater discharged from filter backwashes averaged 2.555 mgd and represented 5.9 percent of water treated.
- The sludge volume in the sedimentation basins represented 0.1 percent of the total pumpage. However, during the cleaning of basins 4 or 5, the estimated volume of wastewater discharge is at a rate of 1.44 mgd for 6 hours per working day (table 15). The TSS concentration in the basin wastestream is estimated to be 103,000 mg/L.
- The settleable solids released (16,770 gpd) during filter backwash represented about 0.72 percent of the volume of backwash. The average volume of residue released from the basins was about double the volume of the settleable solids produced by backwash.
- Iron and aluminum were the major chemical constituents in the settled basin residues. The iron concentration in the residue was found to be higher than normally found in natural soils and stream and lake sediments. Aluminum concentrations in the residue were similar to those observed in other aquatic environments.
- Except during 7-day 10-year low flows at 10 percent mixing conditions, increases in TSS (50 mg/L), iron (1.3 mg/L), and aluminum (1.4 mg/L) in the Mississippi River during maximum waste discharges will not be perceptible.

RIVER BOTTOM SEDIMENTS

The ratio of 7-day 10-year low streamflow to waste flow at East St. Louis, assuming 10 percent mixing, is about 1140:1. For a high dilution ratio of this nature there is a need to seek traces or impacts of the waste flows on the receiving stream by means other than examining the flowing waters of the Mississippi River. As described earlier, solids residue and to a lesser extent settleable solids are major components of the waste. A significant characteristic of the waste is its concentration of Fe and Al. It makes sense therefore to examine the bottom sediments of the receiving stream for concentrations of these elements, as well as any other characteristics that will define the extent of the influence of the wastes on the bottom sediments.

Just as important is the need to assess the sediments in terms of their capability to provide a suitable habitat for benthic organisms. One aspect of a suitable macroinvertebrate habitat is the particle size distribution of the sediments. A predominantly sandy bottom with its inherent instability is not a productive benthic habitat, whereas silt in combination with organic (volatile) matter can be very productive. Finally, it is desirable to identify the types and number of macroinvertebrates existing in the bottom sediments for comparative purposes.

With these objectives in mind a sampling program was implemented to determine:

1) The extent and concentrations of iron and aluminum, and the volatile and moisture content of the bottom sediments.

2) The particle size distribution of the bottom sediments.

3) The types and densities of macroinvertebrates in the bottom sediments.

Methods and Procedures

Thirty-five stations were selected for sediment sampling. The general location of the sampling stations is shown in figure 14, and figure 15 shows the locations of all the stations in relation to the water company. Information on the water depths and locations of the stations is given in table 16. The stations were located on seven transects with five stations on each one. One transect was upstream of the water plant waste outfalls, two transects were in the vicinity of but downstream of the outfalls, and four transects were further downstream.

Sediment samples were collected on November 12, 1981, about one week after the cleaning of basins 1 and 2 and on August 12, 1983, during the cleaning of basin 4. Sixty-eight samples were obtained for physical and chemical measurements, requiring 340 analyses. In addition, benthic samples were collected from ten stations for the assessment of macroinvertebrate densities and types during the final collection. No benthic sample was taken during the first collection. One trip (August 10, 1982) was aborted because high water and swift currents prevented the ponar dredge from reaching the river bottom. During the benthic collection on August 12, 1983, two of 12

Figure 14. Sampling area, shoreline at outer harbor line

designated stations (stations 11 and 16) could not be sampled for macroinvertebrate examinations because of a high current.

All samples were collected with a ponar dredge operating from a 21-foot boat equipped with a 70-horsepower motor. Site selection was established by landmarks and an optical rangefinder. After anchoring, the ponar dredge was allowed to free-fall to the bottom. It was retrieved by a motorized winch. Upon retrieval the contents of the ponar dredge were emptied on a tiltable washtable and observations were noted of its physical characteristics.

For physical and chemical examination the dredged material was then thoroughly mixed and placed in a plastic quart bottle, with a plastic bag liner, until the plastic bag was full. All samples were labeled and placed in an ice chest. Upon delivery to the laboratory the samples were refrigerated until analyses were performed.

Each sample obtained for macroinvertebrate examination consisted of one ponar grab. The collections were salt floated, sieved, and preserved. The salt flotation technique consists of adding a saturated salt solution to a bucket containing the sediment sample, stirring vigorously, and decanting immediately through a U.S. Standard 30 mesh sieve bucket. The procedure was repeated at least three times for each sample. The material retained on the sieve was then rinsed with river water and placed in a plastic bottle. All sieved samples were preserved in 95 percent ethanol and labeled. At the laboratory each sample was washed again through a 30 mesh sieve and the residue picked for organisms. The organisms were identified, enumerated, and preserved in 70 percent ethanol.

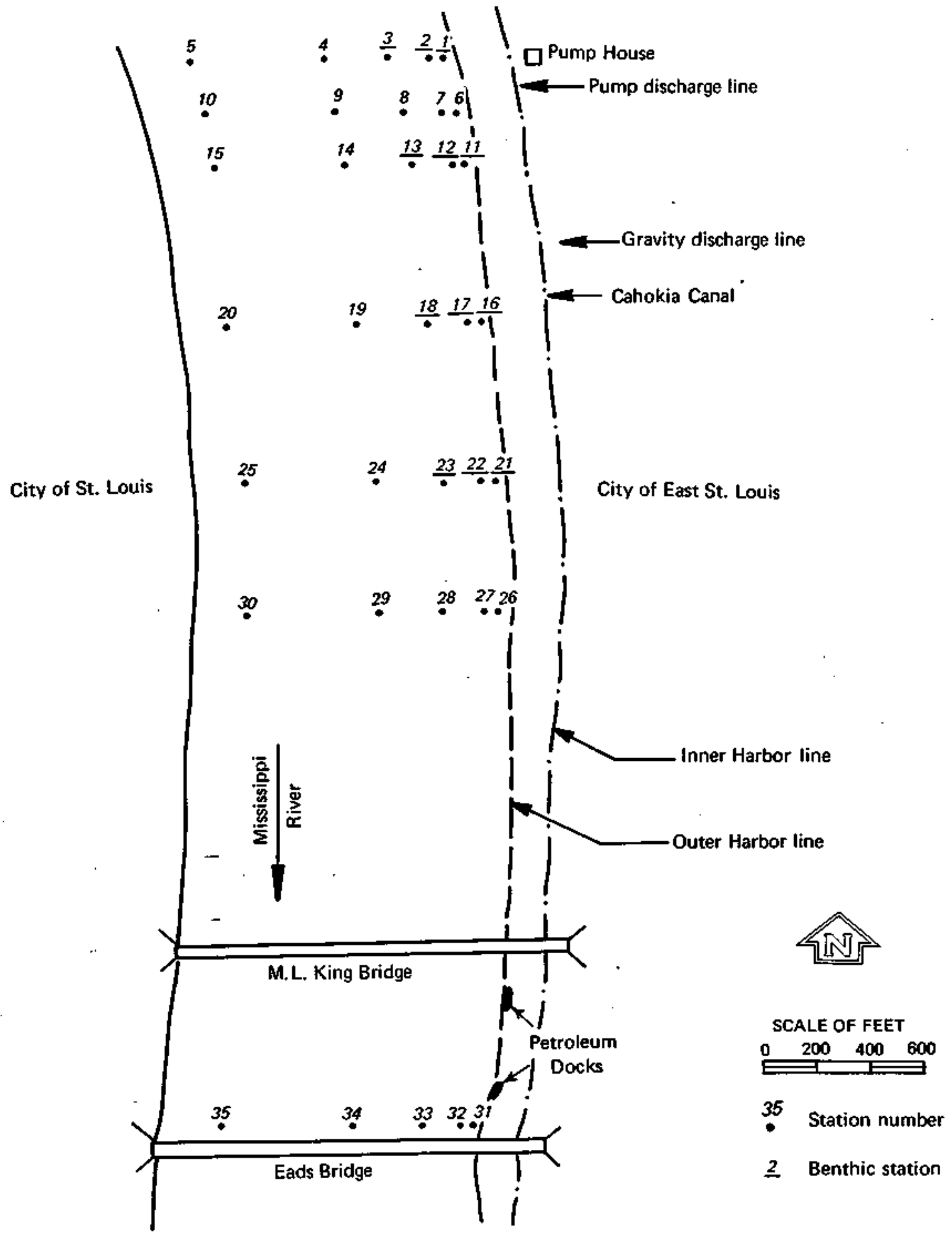

Figure 15. Station location map

Table 16. Data of Mississippi River Sediment Sampling Stations near East St. Louis Water Company Discharges

Station number	Water depth, feet 11/12/81	Water depth, feet 8/12/83	Distance from inner harbor line, ft	Distance from pump discharge line, Upstream ft	Distance from pump discharge line, Downstream ft
1	24	24	50	100	
2	25	23	100	100	
3	26	25	250	100	
4	27	22	500	100	
5	25	22	1000	100	
6	27	27	50		100
7	27	25	100		100
8	24	28	250		100
9	25	28	500		100
10	24	23	1000		100
11	27	27	50		300
12	24	23	100		300
13	23	25	250		300
14	25	24	500		300
15	25	24	1000		300
Gravity discharge line					600
16	28	28	50		900
17	26	28	100		900
18	24	27	250		900
19	23	27	500		900
20	27	23	1000		900
21	29	28	50		1500
22	27	28	100		1500
23	27	25	250		1500
24	25	27	500		1500
25	23	24	1000		1500
26	27	24	50		2000
27	27	27	100		2000
28	25	26	250		2000
29	23	27	500		2000
30	26	24	1000		2000
31	33	29	50		4000
32	31	33	100		4000
33	28	31	250		4000
34	33	28	500		4000
35	28	23	1000		4000

Chemical and Physical Measurements

The samples collected for chemical and physical measurements were examined for concentrations of iron, aluminum, percent volatile, and percent moisture; they were also examined for percent, by weight, of gravel, sand, and silt-clay.

Iron and aluminum analyses were accomplished by digestion with nitric acid and subsequent atomic absorption spectrophotometry. Volatile solids analyses were performed according to procedures set forth by Standard Methods (American Public Health Association, 1975). The percent moisture was determined by decanting the supernatant from the sediment samples after the samples were left undisturbed for at least 24 hours, and then oven-drying the remaining material at 103° Celsius.

Analyses for particle size distribution were performed in accordance with procedures reported by Guy (1969). Sand and gravel were separated from the bottom sediments by mechanical analysis using a wet sieving process. For the purposes of this report the ranges of grain size, in millimeters, for each of the three fractions are as follows:

Gravel	More than 2.0
Sand	0.062 - 2.0
Silt and clay	Less than 0.062

All data derived from the analyses for chemical and physical measurements, including observations noted during sampling, are given in appendices B and C.

Biological Measurements

For this study the aquatic fauna relied upon as indicators of water quality were aquatic macroinvertebrates. Their sensitivity and limited mobility provide a means of assessing the summation of the physical and chemical attributes of the aquatic environment. Aquatic macroinvertebrates as considered here are animals within the aquatic system visible to the unaided eye and capable of being retained by a U.S. Standard 30 mesh sieve.

The tolerance of these organisms to contaminants varies, and this fact has provided the means for developing a classification system (Tucker and Ettinger, 1975) which has been used by the Illinois Environmental Protection Agency to classify streams on the basis of the abundance of organisms intolerant to pollution found in streams. The four tolerance status categories for aquatic macroinvertebrates found in Illinois waters are:

Intolerant: Organisms whose life cycle is dependent upon a narrow range of environmental conditions. They are rarely found in areas of organic enrichment and are replaced by more tolerant species upon degradation of their environment.

Moderate: Organisms which lack the extreme sensitivity to environmental stress displayed by intolerant species but which cannot adapt to severe environmental degradation. Such organisms normally increase in abundance with slight to moderate levels of organic enrichment.

Facultative: Organisms which display the ability to survive over a wide range of environmental conditions and which possess a greater degree of tolerance to adverse conditions than either intolerant or moderate species. The facultative tolerance status also includes all organisms which depend upon surface air for respiration.

Tolerant: Organisms which not only have the ability to survive over a wide range of environmental extremes but which are generally capable of thriving in water of extremely poor quality and even anaerobic conditions. Such organisms are often found in great abundance in areas of organic pollution.

The stream environments at the sampling stations on the Mississippi River were assigned one of the following classifications:

Balanced (B): Intolerant organisms are many in number and species or more in number than other forms present.
Intolerant present ≥ 50% Moderate, facultative, and tolerant
usually present ≤ 50%

Unbalanced (UB): Intolerant organisms are fewer in number than other forms combined, but combined with moderate forms, they usually outnumber tolerant forms.
Intolerant present < 50% Moderate, facultative, and tolerant
but ≥ 10% usually present > 50%

Semi-polluted (SP): Intolerant organisms are few or may not be present. Moderate and/or facultative organisms are present.
Intolerant present < 10% Moderate, facultative, and tolerant
usually present > 90%

Polluted (P): Intolerant organisms absent; only tolerant organisms present.
Tolerant present 100%[*]

[*] Organisms which are not adapted to inhabit a polluted environment are occasionally collected as a result of factors produced by the drift and are not representative.

Naturally or artificially bare area (BA): No organisms present.

As mentioned previously, benthic macroinvertebrate samples were collected from ten stations on August 12, 1983. Twelve stations (stations 1, 2, 3, 11, 12, 13, 16, 17, 18, 21, 22, and 23), shown in figure 15, had been selected for sampling, but stations 11 and 16 could not be sampled as planned.

Results and Discussion

The relative distances of the sampling stations to the pump discharge outfall (Hi-line, figure 11) and outer harbor line are given in table 16 and figure 15. The gravity discharge outfall (figure 10) is located approximately 600 feet downstream of the pump discharge outfall. The outer harbor line is defined in this study as the submerged convergence of the inclined cobblestone levee with the natural river bottom.

The sampling transects varied from 100 feet upstream of the pump discharge (Hi-line) outfall to 4000 feet downstream. Stations on each sampling transect extended from 50 to 1000 feet into the river from the outer harbor line.

Chemical Characteristics

The percent moisture, percent volatile (organic) material, and concentrations of iron and aluminum observed in the bottom sediments are given in table 17. During the first collection (November 12, 1981), one week after the solids residues were discharged from basins 1 and 2, aluminum concentrations varied from 450 ppm at station 13 to 1170 ppm at station 20, with an average of 760 ppm. These values were much lower than those observed in the bottom sediment around the outfall areas of the Alton water treatment plant (Evans et al., 1982). With the F-test, there was no statistical difference in Al concentrations among the 35 stations.

This is also the case for iron. On November 12, 1981, iron concentrations ranged from 1400 ppm at station 13 to 4080 ppm at station 20, with a mean of 2630 ppm (table 17). As with aluminum concentrations, there were no statistical differences in iron concentrations among the 35 stations.

Table 17. Chemical Characteristics of Bottom Sediments near the E. St. Louis Water Treatment Facilities

(November 12, 1981)

Station	% Moisture	% Volatile	Fe, ppm	Al, ppm
1	13.2	0.24	2600	730
2	12.0	0.20	2860	800
3	14.4	0.18	1820	580
4	14.8	0.19	2800	740
5	10.6	0.16	1510	490
6	12.0	0.14	2710	870
7	10.5	0.30	1900	590
8	13.9	0.17	1540	790
9	14.2	0.42	3500	910
10	13.0	0.23	2240	620
11	11.9	0.27	2540	680
12	13.3	0.26	2140	660
13	12.0	0.25	1400	450
14	14.8	0.14	2820	1000
15	13.9	0.32	3670	970
16	12.3	0.18	2910	670
17	14.2	0.16	3520	1010
18	12.4	0.16	1820	470
19	14.0	0.26	2580	660
20	16.7	0.26	4080	1170
21	14.8	0.30	1920	540
22	14.5	0.18	1830	550
23	14.8	0.22	2380	620
24	12.2	0.30	2930	680
25	11.7	0.20	2670	790
26	13.0	0.20	1590	600
27	11.7	0.21	2380	1000
28	14.8	0.15	3730	910
29	14.6	0.36	2960	840
30	16.2	0.23	3430	1160
31	12.8	0.15	2570	820
32	14.5	0.21	2300	750
33	11.4	0.18	2050	510
34	12.0	0.26	3320	840
35	16.5	0.24	3740	1040

Table 17. Concluded

(August 12, 1983)

Station	% Moisture	% Volatile	Fe, ppm	Al, ppm
1	12.8	0.30	1530	500
2	9.4	0.31	1940	940
3	14.8	0.30	2760	1110
4	14.7	0.34	1780	1030
5	12.7	0.55	680	540
6	9.9	0.64	1210	720
7	14.2	0.40	2550	1380
8	12.6	0.35	1330	900
9	14.7	0.36	2060	1070
10	11.7	0.48	2680	1160
11	Could not sample			
12	15.5	0.35	2170	1090
13	12.4	0.20	3290	1160
14	12.4	0.24	2800	1600
15	12.4	0.33	1080	630
16	Could not sample			
17	11.7	0.39	990	510
18	14.7	0.22	1450	540
19	12.3	0.53	3250	1330
20	15.0	0.46	3120	1110
21	11.5	0.31	4310	2210
22	14.7	2.50	9120	4920
23	11.5	0.32	1370	630
24	11.6	0.25	2920	940
25	9.6	0.57	3940	1810
26	11.8	0.42	1530	630
27	7.3	0.60	1220	620
28	13.5	0.26	2270	1070
29	12.4	0.38	3120	1070
30	12.8	0.25	1700	630
31	21.2	0.96	6920	4570
32	25.8	7.80	10750	8780
33	13.1	0.29	1530	720
34	12.4	0.23	840	540
35	10.9	0.26	1740	620

In the sediment samples obtained on November 12, 1981, the moisture content ranged from 10.5 percent at station 7 to 16.7 percent at station 20, with an average of 13.4 percent. The volatile content averaged 0.23 percent and varied from 0.14 percent at stations 6 and 14 to 0.36 percent at station 29 (table 17). There is no difference in stations upstream or downstream of the waste outfalls. For the purpose of this study, the average values observed for this date are designated as the parameter concentrations at the background conditions (table 18). These background concentrations in the East St. Louis area are considerably less than those in the Alton area (Evans et al., 1982).

Solids residue in basin 4 was discharged to the river on and off between July 13 and August 12, 1983. During August 12, 1983, there were two fire hoses flushing out basin 4. On this date, as shown in table 17, aluminum

Table 18. Comparison of Background and Waste Discharge-Affected Stations with regard to Physical and Chemical Characteristics of River Sediments

	Fe, ppm	Al, ppm	Volatile, %	Moisture, %
East St. Louis				
Background(11/12/81)				
(1) All 35 stations	2,590	760	0.23	13.4
(2) Stations 22, 31 & 32	2,230	710	0.18	13.9
During discharge(8/12/83)				
(3) Stations 22, 31 & 32	8,930	6,090	3.80	20.6
(4) Other 30 stations sampled	2,100	960	0.36	12.4
Ratio				
(3):(1)	3.4:1	8.0:1	16.5:1	1.5:1
(3):(2)	4.0:1	8.6:1	21.1:1	1.5:1
(3):(4)	4.3:1	6.3:1	10.6:1	1.7:1
Alton				
(5) Background	8,540	2,900	1.0	16.3
(6) Discharge-affected stations 4,5, & 6	31,360	16.390	5.8	41.1
Ratio				
(6):(5)	3.7:1	5.6:1	5.8:1	2.5:1

concentrations varied from 500 ppm at station 1 to 8780 ppm at station 32. The concentrations of Al at stations 22, 31 , and 32 were significantly higher than those at other stations and they were also higher than background values.

This is also the case for total iron and volatile content in sediments. As shown in table 17, the concentrations of iron and volatile content at stations 22, 31, and 32 were significantly higher than those at other stations. The iron concentrations for the other 30 stations ranged from 680 ppm at station 5 to 4310 ppm at station 21. The elevated concentrations of Fe and Al in the bottom sediment at stations 22, 31 » and 32 are probably due to the residues (silt and clay removed from the raw water during treatment coupled with coagulants) discharged to the river in the waste flows. At station 21, concentrations of Fe and Al were also elevated compared to the background conditions. Upstream stations 17 and 18 did not reveal any impact nor did downstream stations 26, 27, and 28.

On August 12, 1983, at stations 22, 31, and 32, the volatile materials were found to be high, ranging from 0.96 to 7.80 percent, while those at the other 30 stations ranged from 0.20 to 0.64 percent (table 17). The moisture content of the sediment samples was elevated only at station 31 (21 percent) and 32 (26 percent). The moisture content at the other stations ranged from 7.3 to 15.5 percent. The only deviation from the pattern for the other characteristics was a somewhat low moisture content at station 22 (14.7 percent).

For further comparison between stations, the average values for the four chemical constituents were determined for stations 22, 31, and 32 on the samples taken August 12, 1983. This was similarly done for the other 30 stations for August 12, 1983, and for all 35 stations for November 12, 1981. The results are considered here as reasonable estimates of background conditions. The results at East St. Louis and at Alton are shown in table 18.

Iron and aluminum concentrations at stations 22, 31, and 32 during waste discharge increased about 3.4 and 8-fold, respectively. In comparison with the work related to aquatic sediments by other investigators (see table 14), the iron concentrations in the sediment at stations 22, 31, and 32 on August 12, 1983, were elevated but comparable to background level concentrations at Alton in the Mississippi River (table 18). The aluminum values, although considerably elevated at the three stations near East St. Louis, are significantly lower than those observed in other aquatic sediments.

In addition to significant increases of iron and aluminum concentrations • at stations 22, 31, and 32 during the waste discharge, there were also substantial increases (16 times) in organic enrichment as reflected by volatile content. However the liquidity of the sediment increased only at stations 31 and 32.

Physical Characteristics

The particle size distributions of river sediments collected at 35 stations are summarized in appendix B. The physical appearances of these samples are indicated in appendix C. The 35 sediment samples collected on November 12, 1981, were all dominated by clean sand (from 73 percent at station 7 to 99 percent at station 20), with some gravel (1 - 27 percent). There was no significant silt and clay content (appendix B).

In the intervening 21 months between collections, several floods occurred. It is believed that these floods affected the bottom sediments. The river sediments of the August 12, 1983 collection were coarser in nature, as evidenced by the increased percentage of gravel and shells. The data in appendix B suggest that the gravel content at most stations (up to 68 percent) during the second collection was higher than that during the first collection. Floodwaters may also have been responsible for the erosion of levee cobblestones, which prevented the sampling of stations 11 and 16 during August 1983.

An examination of the data in appendix B shows that during the 1983 collection some silt and clay was found at many stations. The percentage was generally small (<1 percent) except at stations 31 and 32 where the silt and clay content was, respectively, about 21 and 48 percent; it was 1.1 percent at station 22. A comparison of the mean composition of the river sediments in terms of gravel, sand, and silt-clay for each collection is summarized in table 19. The composition of sediments at stations 31 and 32 was significantly different from that at the other 31 stations sampled during the 1983 collections. The compositions representative of background conditions for the two collections also shifted.

The stretch of the Mississippi River in the sampling area is constricted on both sides by levees. This produces increases in the velocity of flow, which minimizes the settling of silt-sized particles to the river bottom. Perhaps during low flow the protection afforded by the nearby petroleum loading docks and bridge abutment allowed silt and clay to deposit around stations 31 and 32.

The constricting effects of the cobblestone levee in the East St. Louis study area is a major difference between it and the Alton study area, which is a relatively wide stretch of the Mississippi River just above Lock and Dam 26. The velocity of flow is slower and allows some silt deposition. Near-shore stations (approximately 125 feet out) were often 50 percent silt, and at 500 feet from shore mean values of silt were over 3 percent.

The examination of the sediment did not reveal a measurable blanket of sludge deposits foreign to the sediments of the river during 1981 collections (see appendix C). On the other hand, during the 1983 collections the change in particle size distribution (silty sand) at stations 31 and 32 compared to

Table 19. Particle Size Distribution of River Sediments

	11/12/81	8/12/83	
Composition	**35 stations**	**Stations 31 & 32**	**Other 31 stations**
Gravel, %	**7.9**	**0.6**	**21.1**
Sand, %	**92.1**	**64.9**	**78.5**
Silt-clay, %	**0.0**	**34.5**	**0.3**

other upstream and downstream stations is substantial evidence that suspended sediment removed by the treatment plant from the raw water is impacting stations 31 and 32 upon its reintroduction to the river in waste flows.

On the basis of all of the physical and chemical examinations performed on the river sediments at East St. Louis, it is concluded that the waste discharge is detectable. However, regardless of the detectability of the plant wastes in the sediments, it is also clear that the areal extent of the influence is limited. On the basis of the observed sediment data, it appears that the effluent plume must be very narrow, long, and close to the shore. The areal influence is confined to about 100 feet offshore and 4000 feet downstream of the waste outfall. The remarkably narrow plume affected station 22 but not stations 21 or 23 just 50 feet distant on each side. It also passed through the next downstream transect without detection.

Waste deposits or effects at stations 22, 31, and 32 are probably temporary and are likely to occur only during residue discharge periods at low flow. In the absence of unnatural sludge deposits and without evidence of toxic effects on aquatic organisms resulting from the iron and aluminum concentrations, it is difficult to consider that mere changes in the physical and chemical characteristics of the sediments in the limited area are a mark of environmental degradation.

Benthic Macroinvertebrates

The sampling stations selected for examination of river sediments for benthic macroinvertebrates are also designated in figure 15. Ten samples collected on August 12, 1983, from 10 stations were examined and six taxa were identified. The results are given in table 20. The predominant organisms recovered were biting midges (Ceratopogonidae), asiatic clams (*Corbicula*), sludge worms (Tubificidae), midges (Chironomidae), caddisflies (*Cheumatopsyche*), and mayflies (*Pseudocloeon*). They accounted, respectively, for 76, 8, 6, 4, 3, and 3 percent of the total population.

Table 20. Benthic Macroinvertebrates Collected from the Mississippi River, August 12, 1983
(Individuals per square meter)

IEPA tolerance category and organism	Station 1	2	3	12	13	17	18	21	22	23
Intolerant										
Pseudocloeon (mayfly)								57		
Moderate										
Cheumatopsyche (caddisfly)								57		
Facultative										
Ceratopogonidae (biting midge)	191	287	77	38	172	172	134			229
Tolerant										
Chironomidae (midges)				19				38	19	
Corbicula manilensis (asiatic clam)	38					19		19	57	
Tubificidae (sludge worms)						38		38	19	
Total number of individuals	229	287	77	57	172	229	134	209	95	229
Total number of taxa	2	1	1	2	1	3	1	5	3	1
IEPA aquatic classification	SP	SP	SP	SP	SP	SP	SP	UB	P	SP

The total number of individuals per square meter ranged from 57 to 287, with an average of 172. The number of taxa found at each station varied from 1 to 3 except at station 21, which had 5 (table 20).

Stations were classified according to the IEPA aquatic classification system outlined 'earlier. All stations are classified as semi-polluted except stations 21 and 22. Station 21 is classified as unbalanced, and station 22 is classified as polluted.

In accordance with IEPA procedures all the Chironomidae are considered pollution tolerant if not identified below the family level. There are genera and species of this family that are less tolerant of pollution than indicated. Thus the system as applied to Chironomidae tends to depict a less favorable environmental condition than may actually exist.

Except for stations 21 and 22, the benthos can be characterized as having a low population density and low diversity, and as being somewhat pollution tolerant. These results can be attributed to the unstable sand substrate and high stream velocities rather than the overlying water quality.

Station 21 had the best aquatic classification and the highest diversity, and it was the only station at which a pollution intolerant organism was found. This station has a substrate that is as inhospitable as those of the other stations. It probably benefited from the inflow of drift organisms from the Cahokia Canal (figure 16), located just upstream.

Station 22 had the lowest aquatic classification but not the lowest population density nor diversity. This is the only station impacted by waste discharge that was successfully sampled for benthic macroinvertebrates. Stations 11 and 16, which may have been impacted by the effluent and were scheduled to be examined for benthos, could not be sampled.

It is believed that toxic conditions did not exist in the sediments at station 22. Chronic and high levels of wastes in the sediments near the Alton water treatment plant had no adverse effect on the benthic population (Evans et al., 1982). The waste levels in the sediments downstream from the East St. Louis waste discharge were lower than at Alton and were temporary in nature.

Summary

- The bottom sediments at 35 stations were examined twice for their chemical and physical characteristics, once during a waste discharge and once approximately a week after a discharge. Benthic macroinvertebrates from 10 stations were examined during waste discharge.
- The impact of the wastes on bottom sediments, as measured by their physical and chemical characteristics, was limited to three stations (22, 31, and 32).

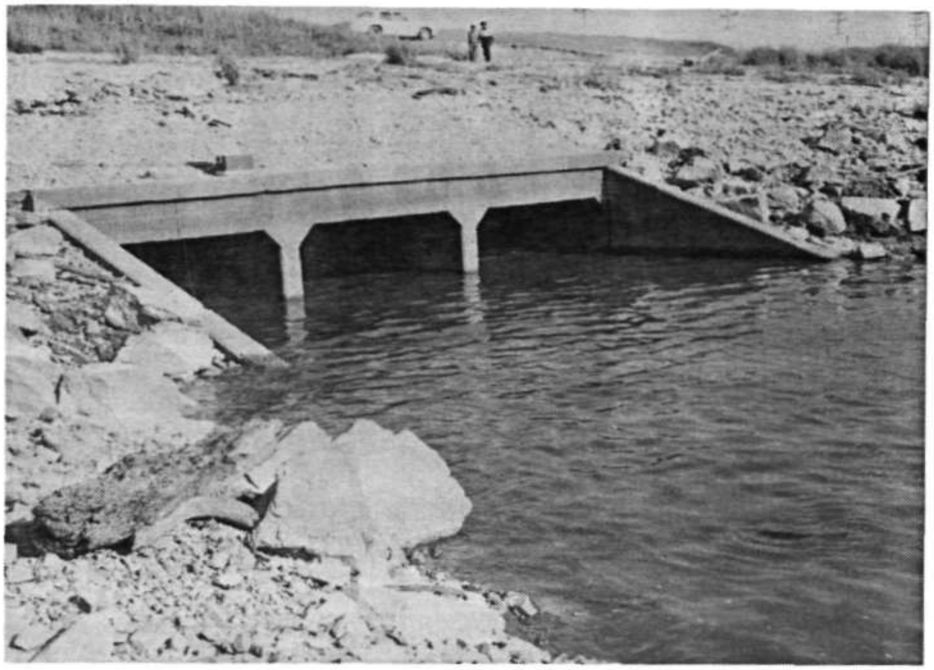

Figure 16. Cahokia Canal

- The impacted area, based upon the location of the three stations, is confined to about 100 feet offshore and 4000 feet downstream of the Hi-Line outfall.
- The impact of the wastes on the bottom sediments could not be detected a week after waste discharge (November 12, 1983).
- The portions of the waste discharge associated with the highest levels of aluminum and iron are in the particle size range of silt and clay. Within the zone of influence iron and aluminum concentrations increased about 3.4-fold and 8-fold above the estimated background concentrations of 2590 and 760 ppm, respectively.
- Within the zone of influence the liquidity (moisture content) and volatile content of the sediments also increased.
- The natural bottom sediment in the Mississippi River consists mostly of sand. At normal river flows, the collected sediments consisted of 92 percent sand, 8 percent gravel, and no silt and clay.
- The constricting effect of the levees in the study area generally resulted in high water velocity, which will not permit silt to settle.
- Silt and clay were found at two somewhat protected stations (31 and 32) at a low flow stage during the waste discharge period. The average particle size distributions for these two stations were 0.6 percent gravel, 64.9 percent sand, and 34.5 percent silt and clay.

- The change in composition of river sediment from <u>sand</u> to <u>sandy-silt</u> was the result of the reintroduction of river silt to the river by waste discharges containing material captured during the treatment process.
- No measurable blanket of unnatural sludge deposits was found within the area of waste discharge influence.
- The benthic macroinvertebrates observed can be characterized as having a low population density and low diversity. This is due principally to the unstable sand substrate rather than to poor water quality.
- Eight of the 10 benthic stations are classified as semi-polluted.
- Station 21 is classified as unbalanced, and pollution intolerant organisms were found there. It probably benefits from the inflow of organisms from the Cahokia Canal. However, the physical and chemical characteristics of this station showed no impact from waste discharge.
- Station 22 is classified as polluted and was the only effluent impacted station examined for macroinvertebrates.

CONCLUSIONS

This study was conducted to determine the quantity and characteristics of waste generated in a large water treatment plant employing the clarification process, and to assess the effects, if any, of the discharge of waste on a large river.

In developing a solids balance for the water treatment plant a basic weakness lies in the inability to evaluate the quantity of waste from clarifiers or sedimentation basins. Another weakness lies in the absence of available data for characterizing the suspended solids content of the source water. In Illinois,-suspended solids determinations are not routinely performed at water treatment plants; sufficient process control is obtained by reliance on turbidity measurements. It was necessary to compensate for these two weaknesses during this study.

The major sources of waste in the water treatment plant at East St. Louis are the clarifiers, the sedimentation basins, and the activated carbon mixed media filters. For the plant, which processes an average of 43.5 mgd, the amount of waste solids generated is about 82,430 pounds per day. About 1.2 percent of the solids load is derived from alum precipitation, with the remainder originating from the suspended solids in the raw water. During backwash, the sand filters release about 5.1 percent of the total solids generated. Details of the solids balance in the conventional plant and the Dorr-Aldrich plant are given in table 12.

The volume of waste produced averaged 2.56 mgd, with about 98 percent of the waste volume originating from the activated carbon mixed-media filters. The volume of waste represents about 5.9 percent of the average daily volume of water treated.

The major chemical constituents of the solid wastes are iron and aluminum. The concentrations of iron are probably inherent in the suspended sediments in transport in the river. Aluminum concentrations are derived from the use of alum as a supplemental coagulant.

Except during 7-day 10-year low flow conditions, increases in suspended solids in the Mississippi River during occurrences of maximum waste discharges will not be perceptible.

The influence of the waste is readily detectable in the bottom sediments of the river by increases in iron, aluminum, moisture, and volatile (organic) content. However, that influence is limited to an impacted area about 100 feet offshore and within 4000 feet downstream of the waste outfalls. Within the impacted area iron and aluminum increased about 3.0-fold and 8.0-fold above estimated background concentrations of 2590 and 760 ppm, respectively. There was also a detectable modification of the composition of gravel-sand-silt relationships within the impacted area. Whereas the natural bottom sediments of the Mississippi River are composed, on the average, of 21.2 percent gravel, 78.5 percent sand, and 0.3 percent silt, the bottom sediments of the impacted sediments are composed, on the average, of 0.6 percent gravel, 64.9 percent sand, and 34.5 percent silt. The change in particle size distribution is brought about by the reintroduction of river "silt" to the river by waste flows containing material captured by the treatment process. Despite the change in bottom sediment composition, there is no measurable blanket of sludge deposits.

In the absence of unnatural sludge deposits and without evidence that the iron and aluminum concentrations observed in the bottom sediments are toxic to aquatic organisms, it would appear that the types of changes in the chemical and physical composition of the sediments in the limited impacted area are not a mark of environmental degradation. This conclusion is strengthened by observations of benthic macroinvertebrates in the East St. Louis locale.

An examination of bottom sediments for the abundance and diversity of benthic macroinvertebrates revealed that populations in sandy sediments were sparse. This is consistent with the consensus that benthic macroinvertebrate abundance is related to the stability of the habitat. Sand is not a stable habitat, especially when influenced by navigation traffic. On the other hand, a mixture of sand, silt, and clay, with some organic enrichment, provides an aquatic substrate which permits "borrowing" and "clinging" organisms to colonize.

All stations sampled at the East St. Louis locale were classified as either polluted or semi-polluted. There was no significant difference in the near-shore stations upstream or downstream of the waste outfalls in terms of types and densities of macroinvertebrates.

REFERENCES

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1980. Standard methods for the examination of water and wastewater. American Public Health Association, New York, NY, 1135 p., 15th edition.

AWWA Research Foundation. 1969. Disposal of wastes from water treatment plants - part 2. Journal American Water Works Association v. 61(11): 619-638.

Bishop, S. L. 1978. Alternate processes for treatment of water plant wastes. Journal American Water Works Association v. 70(9):503-506.

Bowen, N. J. M. 1966. Trace elements in biochemistry. Academic Press, Inc., London, 40 p.

Cahill, R. A. 1981. Geochemistry of recent Lake Michigan sediments. Illinois State Geological Survey Circular 517, 94 p.

Evans, R. L., et al. 1970. Wastes from water treatment plants. A report compiled by the Water Resources Quality Control Committee, Illinois Section AWWA, 33 p.

Evans, R. L., T. E. Hill, D. H. Schnepper, and D. Hullinger. 1982. Waste from the water treatment plant at Alton and its impact on the Mississippi River. Illinois State Water Survey Circular 156, 62 p.

Evans, R. L., D. H. Schnepper, and T. E. Hill. 1979. Impact of wastes from a water treatment plant: evaluative procedures and results. Illinois State Water Survey Circular 135, 39 p.

Fulton, G. P. 1969.- Disposal of wastewater from water filtration plants. Journal American Water Works Association v. 61(7): 322-326.

Gates, W. E., and Associates. 1981. A study of wastewater discharges from water treatment plants. Ohio River Valley Water Sanitation Commission.

Guy, H. P. 1969. Laboratory theory and methods for sediment analysis. Book 5, Chapter C1 , Techniques of Water-Resources Investigations of United States Geological Survey, 58 p.

Illinois Pollution Control Board. 1973. Water Pollution Regulations of Illinois. 42 p.

Jordan, P. R. 1965. Fluvial sediment of the Mississippi River at St. Louis, Missouri. USGS, Water-supply paper 1802, pp. 4-6.

Kemp, A. L. W., and R. L. Thomas. 1976. Impact of man's activities on the chemical composition in the sediments of Lake Ontario, Erie, and Huron. Water, Air and Soil Pollution 5:469-490.

Miller, D. E., L. F. Emmett, J. Skelton, H. G. Jeffrey, and J. H. Barks. 1974. Water resources of the St. Louis area, Missouri. U. S. Geological Survey and Missouri Geological Survey and Water Resources, Water Resources Report 30, 114 p.

Missouri River Public Water Supplies Association. 1972. Report on wastes from Missouri and Mississippi River water treatment plants — sources, quantities, characteristics, impact on water quality. Black & Veatch, Consulting Engineers Project 6044, 70 p.

National Academy of Sciences and National Academy of Engineers. 1973. Water quality criteria. USEPA, Washington D.C.

Reh, C. W. 1980. Disposal and handling of water treatment plant sludge. Journal American Water Works Association v. 72(2):115-118.

Roseboom, D. P., R. L. Evans, and T. E. Hill. 1978. Effects of agriculture on Cedar Lake water quality. Illinois State Water Survey Circular 138, 59 p.

Singh, K. P., and J. B. Stall. 1973. The 7-day, 10-year low flows of Illinois streams. Illinois State Water Survey Bulletin 57, p. 24.

Tucker, W. J., and W. H. Ettinger. 1975. A biological investigation of the South Fork, Sangamon River and tributaries. Illinois Environmental Protection Agency, Springfield, Illinois.

USEPA. 1976. Quality criteria for water. USEPA, Washington, D.C.

U. S. Geological Survey. 1982. Water resources data, Illinois, water year 1981. Vol. 1, Illinois except Illinois River Basin. Water-Data Report IL-81-1, p. 617.

Westerhoff, G. P., and D. A. Cornwell. 1978. A new approach to alum recovery. Journal American Water Works Association v. 70(12):709-714.

Appendix A. Water Quality of Filter Backwash

(February 17, 1982)

Filter A
Area = 352 sq.ft.
Backwash rate = 5900 gpm
Water filtered = 0.480 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	18	10	tr
0.25	18	10	tr
0.50	288	108	11.50
0.75	540	220	18.50
1.00	770	280	27.50
1.25	740	250	27.00
1.50	760	260	27.50
1.75	500	144	19.00
2.00	492	148	18.50
2.50	340	116	11.50
3.00	196	84	6.50
4.00	86	40	1.80
5.00	42	20	0.80
6.78	17	8	0.15

Filter B
Area = 352 sq.ft.
Backwash rate = 5900 gpm
Water filtered = 0.509 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	14	10	tr
0.25	15	5	tr
0.50	284	116	13.50
0.75	730	310	30.00
1.00	1000	310	46.50
1.25	780	310	38.00
1.50	540	250	22.50
1.75	344	136	14.50
2.00	296	112	12.80
2.50	124	54	4.30
3.00	84	44	1.80
4.00	32	21	0.30
5.00	16	10	0.07
6.38	10	8	0.02

Appendix A. Continued

(February 17, 1982)

Filter C
Area = 352 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.438 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	7	0.02
0.25	54	19	1.20
0.50	630	220	28.00
0.75	1380	370	54.00
1.00	1450	400	47.00
1.25	832	212	33.00
1.50	280	100	10.00
1.75	192	58	8.50
2.00	50	20	1.30
2.50	26	10	0.40
3.00	18	8	0.20
4.00	14	8	0.06
5.00	12	7	0.03
6.30	10	8	0.02

Filter D
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.480 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	7	tr
0.25	70	20	1.80
0.50	380	84	14.50
0.75	460	130	16.50
1.00	308	76	12.00
1.25	216	64	7.50
1.50	168	52	5.50
1.75	98	28	2.90
2.00	86	22	2.30
2.50	56	18	1.60
3.00	55	15	1.20
4.00	24	9	0.35
5.00	13	4	0.08
6.48	5	3	0.02

Appendix A. Continued

(February 17, 1982)

Filter E
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.495 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	13	5	tr
0.25	396	88	12.00
0.50	1000	230	36.00
0.75	1420	290	46.00
1.00	1350	280	43.00
1.25	784	144	23.50
1.50	528	108	16.50
1.75	320	88	13.50
2.00	260	72	7.50
2.50	160	42	4.50
3.00	92	32	2.20
4.00	22	8	0.30
5.00	12	6	0.70
5.75	9	6	0.01

Filter F
Area = 888.5 sq.ft.
Backwash rate = 14,000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	17	6	tr
0.50	23	8	tr
0.67	410	114	42.50
1.00	636	180	64.00
1.33	452	136	47.00
1.67	292	96	26.50
2.00	232	60	15.50
2.50	92	36	2.40
3.00	26	13	0.01
4.00	14	7	tr
5.00	10	6	tr

Appendix A. Continued

(February 17, 1982)

Filter G
Area = 968.0 sq.ft.
Backwash rate = 14,000 gpm
Water filtered = 1.042 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	6	tr
0.33	20	8	tr
0.67	560	396	52.00
1.00	304	88	28.00
1.33	162	48	28.00
1.67	130	44	8.00
2.00	88	36	4.60
2.50	39	17	0.14
3.00	Sample lost		
4.00	14	7	tr
5.00	10	6	tr
6.00	5	4	tr
6.69	5	3	tr

Appendix A. Continued

(May 27, 1982)

Filter A
Area = 352 sq.ft.
Backwash rate = 5900 gpm
Water filtered = 0.369 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	6	0.03
0.25	13	5	0.02
0.50	328	60	5.50
0.75	240	48	4.00
1.00	288	48	4.50
1.25	348	60	5.00
1.50	332	64	4.50
1.75	300	68	4.00
2.00	248	48	2.50
2.50	220	56	2.00
3.00	140	32	1.50
4.00	86	22	0.80
4.88	48	14	0.40

Filter B
Area = 352 sq.ft.
Backwash rate = 5900 gpm
Water filtered = 0.369 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	27	14	0.05
0.25	72	20	0.80
0.50	124	26	1.50
0.75	352	72	5.00
1.00	440	84	6.50
1.25	524	100	7.50
1.50	512	88	7.00
1.75	408	80	4.00
2.00	408	76	4.00
2.50	256	60	3.00
3.00	176	44	1.50
4.00	90	30	1.00
5.00	71	17	0.70
7.00	17	6	0.05

Appendix A. Continued

(May 27, 1982)

Filter C
Area = 352 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.332 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	18	6	tr
0.25	15	8	0.02
0.50	15	7	0.02
0.75	124	32	1.80
1.00	1370	250	18.00
1.25	444	88	5.50
1.50	612	104	8.50
1.75	1130	230	13.00
2.00	790	150	8.00
2.50	392	80	5.50
3.00	428	84	6.00
4.00	136	26	1.50
5.00	112	18	1.50
7.73	24	6	0.20

Filter D
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.422 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	9	1	tr
0.25	10	2	tr
0.50	9	1	tr
0.75	10	2	tr
1.00	10	2	0.03
1.25	312	32	5.00
1.50	1440	130	18.00
1.75	1040	110	14.00
2.00	356	44	4.50
2.50	484	52	6.00
3.00	100	16	2.50
4.00	108	20	1.50
5.00	42	9	0.60
6.75	9	1	0.05

Appendix A. Continued

(May 27, 1982)

Filter E
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.397 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	14	3	0.05
0.25	13	4	0.03
0.50	53	10	0.60
0.75	136	22	1.50
1.00	Sample lost		
1.25	560	68	7.50
1.50	424	44	5.00
1.75	536	272	7.00
2.00	344	32	4.50
2.50	266	34	3.00
3.00	136	28	1.50
4.00	73	12	0.70
5.00	20	8	0.20
7.42	8	2	0.03

Filter F
Area = 888.5 sq.ft.
Backwash rate = 14,000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	10	1	tr
0.33	16	2	tr
0.67	12	3	tr
1.00	12	3	tr
1.33	2200	250	45.00
1.67	1110	110	20.00
2.00	700	60	11.00
2.50	372	36	2.50
3.00	116	12	0.60
4.00	11	1	0.02
4.68	8	2	0.02

Appendix A. Continued

(May 27, 1982)

Filter G
Area = 968.0 sq.ft.
Backwash rate = 14,000 gpm
Water filtered = 3.250 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	14	2	tr
0.33	48	4	0.03
0.67	1900	190	30.00
1.00	1790	190	24.50
1.33	1290	160	17.00
1.67	1130	160	14.00
2.00	544	72	4.50
2.50	484	72	3.50
3.00	162	20	0.40
4.00	100	16	0.05
5.00	36	5	0.02
6.00	26	4	tr
7.20	20	2	tr

Appendix A. Continued

(August 10, 1982)

Filter A
Area = 352 sq.ft.
Backwash rate = 5900 gpm
Water filtered = 0.736 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	30	5	0.20
0.25	43	8	0.70
0.50	684	92	8.00
0.75	816	80	12.50
1.00	696	104	12.50
1.25	688	88	11.00
1.50	564	76	9.50
1.75	424	92	4.00
2.00	400	60	3.50
2.50	338	48	5.00
3.00	346	48	2.20
4.00	194	38	2.20
5.00	184	27	0.90
6.52	78	12	0.70

Filter B
Area = 352 sq.ft.
Backwash rate = 5900 gpm
Water filtered = 0.736 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	13	3	0.05
0.25	117	18	1.80
0.50	134	20	2.30
0.75	512	80	8.00
1.00	280	64	5.50
1.25	396	72	6.50
1.50	516	80	7.50
1.75	472	88	8.00
2.00	408	64	7.00
2.50	464	72	7.00
3.00	322	50	4.50
4.00	162	28	2.30
5.00	110	20	0.90
6.80	50	4	0.15

Appendix A. Continued

(August 10, 1982)

Filter C
Area = 352 sq.ft. (1/2 of unit)
Backwash rate = 5900 gpm
Water filtered = 0.736 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	2	0.08
0.25	15	2	tr
0.50	13	1	0.20
0.75	Sample lost		
1.00	262	30	4.50
1.25	464	72	4.20
1.50	444	40	5.30
1.75	384	44	5.20
2.00	364	52	4.80
2.50	100	14	1.20
3.00	62	9	0.80
4.00	34	5	0.30
5.00	26	4	0.20
6.55	18	5	0.10

Filter D
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.713 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	19	4	0.20
0.25	42	7	0.80
0.50	828	132	13.50
0.75	1820	256	20.00
1.00	964	144	12.00
1.25	520	60	7.00
1.50	608	96	7.00
1.75	356	52	3.70
2.00	236	28	3.00
2.50	132	26	2.10
3.00	105	14	0.90
4.00	24	6	0.30
5.00	16	4	0.10
5.85	12	4	0.05

Appendix A. Continued

(August 10, 1982)

Filter E
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 8500 gpm
Water filtered = 0.736 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	20	3	0.07
0.25	18	2	0.08
0.50	101	11	1.70
0.75	368	46	7.00
1.00	852	108	15.00
1.25	1036	152	12.50
1.50	836	120	12.50
1.75	680	100	9.00
2.00	480	68	5.00
2.50	356	56	4.00
3.00	200	30	2.70
4.00	100	16	1.00
5.00	22	5	0.20
6.72	16	2	0.10

Filter F
Area = 888.5 sq.ft.
Backwash rate = 14,000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	9	1	0.02
0.33	1236	200	45.00
0.67	2300	400	80.00
1.00	1330	220	50.00
1.33	440	68	14.00
1.67	216	34	5.50
2.00	99	21	2.40
2.50	106	20	2.60
3.00	54	14	0.80
4.00	12	3	0.10
5.45	15	4	0.10

Appendix A. Continued

(August 10, 1982)

Filter G
Area = 968.0 sq.ft.
Backwash rate = 14,000 gpm
Water filtered = 3.833 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	7	2	tr
0.33	2716	324	60.00
0.67	1770	270	45.00
1.00	892	120	17.00
1.33	872	128	17.50
1.67	552	80	10.00
2.00	316	60	5.00
2.50	192	34	2.50
3.00	121	18	1.50
4.00	66	14	0.70
5.00	31	6	0.30
7.25	17	6	0.07

Appendix A. Continued

(November 10, 1982)

Filter A
Area = 352 sq.ft.
Backwash rate = 6000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	11	5	0.02
0.25	26	14	0.04
0.50	440	112	27.00
0.75	1000	230	50.00
1.00	1030	210	50.00
1.25	700	170	34.00
1.50	600	160	21.00
1.75	376	76	16.00
2.00	344	72	13.00
2.50	280	56	10.00
3.00	200	40	5.50
4.00	108	28	1.80
5.00	84	22	0.80
8.23	31	5	0.50

Filter B
Area = 352 sq.ft.
Backwash rate = 6000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	13	2	0.01
0.25	62	24	1.30
0.50	72	26	2.30
0.75	208	80	10.00
1.00	310	65	10.50
1.25	645	165	35.00
1.50	540	110	29.00
1.75	540	90	26.00
2.00	500	90	23.00
2.50	296	60	12.50
3.00	268	72	10.50
4.00	104	40	3.00
5.00	64	22	1.00
8.23	7	4	tr

Appendix A. Continued

(November 10, 1982)

Filter C
Area = 352 sq.ft. (1/2 of unit)
Backwash rate = 5800 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	4	tr
0.25	15	8	tr
0.50	12	2	tr
0.75	164	74	6.00
1.00	710	260	37.00
1.25	820	270	42.00
1.50	680	250	32.00
1.75	392	116	17.00
2.00	176	80	3.50
2.50	124	42	2.50
3.00	78	26	1.00
4.00	31	15	0.10
5.00	20	8	0.10
7.33	12	7	0.03

Filter D
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	10	2	0.02
0.25	480	148	13.50
0.50	260	96	10.50
0.75	536	152	28.00
1.00	960	290	45.00
1.25	850	280	33.00
1.50	504	132	17.00
1.75	132	66	3.50
2.00	198	58	8.00
2.50	56	26	1.30
3.00	22	11	0.20
4.00	8	5	0.02
5.00	6	4	0.01
6.55	4	3	0.01

Appendix A. Continued

(November 10, 1982)

Filter E
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	14	2	0.02
0.25	16	2	0.04
0.50	180	96	7.50
0.75	118	64	7.00
1.00	700	240	29.00
1.25	810	250	33.00
1.50	580	200	21.00
1.75	400	116	15.00
2.00	344	96	12.50
2.50	228	72	7.00
3.00	124	60	2.50
4.00	60	26	0.50
5.00	23	12	0.10
6.18	14	6	0.03

Filter F
Area = 888.5 sq.ft.
Backwash rate = 14,000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	3	0.01
0.33	284	52	10.00
0.67	860	180	45.00
1.00	820	140	45.00
1.33	535	90	29.00
1.67	368	88	17.00
2.00	200	52	5.50
2.50	148	48	3.00
3.00	68	22	0.40
4.00	24	10	0.10
5.00	10	4	tr
7.65	8	3	tr

Appendix A. Continued

(November 10, 1982)

Filter G
Area = 968.0 sq.ft.
Backwash rate = 14,000 gpm

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	7	2	0.00
0.33	410	100	20.00
0.67	144	44	2.40
1.00	140	44	3.00
1.33	90	28	1.20
1.67	56	14	0.30
2.00	43	8	0.20
2.50	27	9	0.02
3.00	6	5	0.02
4.00	8	2	tr
5.00	7	3	tr
6.55	6	2	tr

Appendix A. Continued

(February 28, 1983)

Filter A
Area = 352 sq.ft.
Backwash rate = 6000 gpm
Water filtered = 0.656 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	16	9	0.01
0.25	28	12	0.03
0.50	204	80	15.00
0.75	350	180	27.00
1.00	470	210	37.00
1.25	510	230	42.00
1.50	570	220	44.00
1.75	540	190	39.00
2.00	400	160	33.00
2.50	309	140	22.00
3.00	254	80	13.00
4.00	116	60	3.70
5.00	54	24	0.70
6.00	28	12	0.20

Filter B
Area = 352 sq.ft.
Backwash rate = 6000 gpm
Water filtered = 0.656 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	13	8	tr
0.25	304	104	23.00
0.50	410	170	34.00
0.75	490	210	41.00
1.00	610	220	54.00
1.25	720	280	60.00
1.50	580	240	47.00
1.75	460	230	36.00
2.00	344	124	27.00
2.50	236	96	18.00
3.00	136	54	7.50
4.00	60	18	1.20
5.00	34	8	0.02
6.00	11	4	0.02

Appendix A. Continued

(February 28, 1983)

Filter C
Area = 352 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm
Water filtered = 0.656 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	11	3	tr
0.25	168	36	11.50
0.50	1000	270	90.00
0.75	850	230	67.00
1.00	940	280	76.00
1.25	430	150	32.00
1.50	304	88	18.00
1.75	184	60	7.50
2.00	156	44	7.00
2.50	100	28	3.60
3.00	55	15	1.50
4.00	37	12	0.12
5.00	15	5	0.02
6.20	11	5	0.01

Filter D
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm
Water filtered = 0.656 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	12	6	tr
0.25	12	6	tr
0.50	12	7	tr
0.75	10	6	tr
1.00	20	8	tr
1.25	214	76	18.00
1.50	430	190	36.00
1.75	550	230	43.00
2.00	216	84	15.00
2.50	168	72	10.00
3.00	95	27	4.60
4.00	12	7	0.04
5.00	9	6	0.03
7.03	8	3	0.01

Appendix A. Continued

(February 28, 1983)

Filter E
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm
Water filtered = 0.656 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	18	5	tr
0.25	15	4	tr
0.50	16	7	tr
0.75	18	6	tr
1.00	810	160	38.00
1.25	880	190	42.00
1.50	670	175	28.00
1.75	550	140	24.00
2.00	540	130	21.00
2.50	156	48	6.00
3.00	76	14	2.60
4.00	28	7	0.60
5.00	5	2	tr
6.42	4	1	tr

Filter F
Area = 888.5 sq.ft.
Backwash rate = 14,000 gpm
Water filtered = 3.892 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	25	9	tr
0.33	24	11	0.05
0.67	368	116	62.00
1.00	880	290	160.00
1.33	610	220	104.00
1.67	264	96	37.00
2.00	128	52	16.00
2.50	168	72	15.00
3.00	56	23	1.50
4.00	17	9	0.04
5.00	9	5	tr
6.00	6	5	tr

Appendix A. Continued

(February 28, 1983)

Filter G
Area = 968.0 sq.ft.
Backwash rate = 14,000 gpm
Water filtered = 2.265 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	8	6	tr
0.33	164	60	24.00
0.67	330	110	55.00
1.00	330	130	50.00
1.33	240	84	34.00
1.67	228	76	31.00
2.00	100	32	12.50
2.50	63	28	5.00
3.00	35	13	0.95
4.00	12	7	tr
5.00	11	4	tr
6.70	2	1	tr

Appendix A. Continued

(April 21, 1983)

Filter A
Area = 352 sq.ft.
Backwash rate = 6000 gpm
Water filtered = 0.362 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	116	26	2.70
0.25	124	28	2.80
0.50	528	104	15.00
0.75	600	160	17.00
1.00	560	150	17.00
1.25	572	128	17.00
1.50	540	100	14.00
1.75	380	76	10.50
2.00	332	52	8.50
2.50	246	54	7.00
3.00	192	40	4.50
4.00	72	14	1.35
5.00	36	7	0.50
8.23	10	2	0.04

Filter B
Area = 352 sq.ft.
Backwash rate = 6000 gpm
Water filtered = 0.362 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	16	7	0.02
0.25	16	6	0.20
0.50	344	88	11.00
0.75	470	150	15.50
1.00	760	180	18.00
1.25	780	220	25.00
1.50	650	200	19.00
1.75	510	160	17.00
2.00	464	108	14.00
2.50	268	72	7.50
3.00	188	64	5.00
4.00	84	30	1.90
5.00	42	11	0.50
7.73	7	5	0.01

Appendix A. Continued

(April 21, 1983)

Filter C
Area = 352 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm
Water filtered = 0.545 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	9	7	0.10
0.25	173	41	2.00
0.50	63	38	2.00
0.75	290	98	9.00
1.00	380	88	13.00
1.25	352	100	10.50
1.50	288	80	8.50
1.75	240	64	7.00
2.00	220	60	5.50
2.50	176	52	4.50
3.00	136	40	3.50
4.00	94	29	2.00
5.00	59	17	1.00
7.67	19	7	0.15

Filter D
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm
Water filtered = 0.324 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	16	7	tr
0.25	14	9	tr
0.50	24	9	0.10
0.75	264	68	4.50
1.00	316	60	9.00
1.25	400	110	10.00
1.50	490	110	11.00
1.75	460	130	12.00
2.00	370	70	9.30
2.50	284	56	6.50
3.00	160	40	3.20
4.00	92	20	2.00
5.00	33	9	0.40
7.72	10	4	0.15

Appendix A. Continued

(April 21, 1983)

Filter E
Area = 347 sq.ft. (1/2 of unit)
Backwash rate = 6000 gpm
Water filtered = 0.599 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	8	6	tr
0.25	8	5	tr
0.50	112	46	4.50
0.75	288	110	12.00
1.00	348	116	14.00
1.25	400	128	18.00
1.50	428	112	18.00
1.75	304	100	12.50
2.00	284	96	10.00
2.50	184	64	6.50
3.00	96	52	3.70
4.00	50	24	1.40
5.00	21	14	0.40
7.58	4	3	tr

Filter F
Area = 888.5 sq.ft.
Backwash rate = 14,000 gpm
Water?filtered = 1.593 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	10	7	tr
0.33	12	8	tr
0.67	100	68	11.50
1.00	360	184	48.00
1.33	272	156	34.00
1.67	180	116	21.00
2.00	108	58	11.00
2.50	41	26	1.50
3.00	36	25	1.10
4.00	14	8	tr
5.00	3	3	tr

Appendix A. Concluded

(April 21, 1983)

Filter G
Area = 968.0 sq.ft.
Backwash rate = 14,000 gpm
Water filtered = 2.212 MG

Time min	SS mg/L	VSS mg/L	Set.S ml/L
0.00	8	7	tr
0.33	710	310	120.00
0.67	920	310	135.00
1.00	580	220	98.00
1.33	560	200	92.00
1.67	384	124	55.00
2.00	372	106	50.00
2.50	204	76	24.00
3.00	108	40	17.00
4.00	116	38	11.50
5.00	52	20	2.80
6.33	3	1	tr

Appendix B. Particle Size Distribution of Bottom Sediments near the E. St. Louis Water Treatment Facilities (%)

(November 12, 1981)

Station	1	2	3	4	5	6	7	8	9	10	11	12
Gravel and shells	3.2	15.2	9.1	3.1	16.8	12.8	27.5	9.9	8.3	1.9	7.5	7.0
Sand	96.8	84.8	90.9	96.9	83.2	87.2	72.5	90.1	91.7	98.1	92.5	93.0
Silt and Clay	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Station	13	14	15	16	17	18	19	20	21	22	23	24
Gravel and shells	8.2	3.4	5.2	6.1	4.4	13.4	7.7	1.2	12.8	3.8	5.4	4.8
Sand	91.8	96.6	94.8	93.9	95.6	86.6	92.3	98.8	87.2	96.2	94.6	95.2
Silt and Clay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Station	25	26	27	28	29	30	31	32	33	34	35
Gravel and shells	3.8	12.4	12.7	3.7	3.3	1.2	5.2	5.1	8.4	2.3	18.6
Sand	96.2	87.6	87.3	96.3	96.7	98.8	94.8	94.9	91.6	97.7	81.4
Silt and Clay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix B. Concluded

(August 12, 1983)

Station	1	2	3	4	5	6	7	8	9	10	11	12
Gravel	18.2	30.0	21.1	11.2	13.8	59.5	15.6	38.8	3.5	23.8	NA	5.4
Sand	81.4	69.9	78.4	88.5	86.1	40.1	84.4	61.1	96.5	76.2	NA	94.5
Silt and Clay	0.4	0.1	0.5	0.3	0.1	0.4	0.0	0.1	0.0	0.0	NA	0.1

Station	13	14	15	16	17	18	19	20	21	22	23	24
Gravel	2.0	19.1	6.3	NA	7.1	2.5	18.2	11.3	37.9	27.4	24.6	54.3
Sand	97.7	80.7	93.4	NA	92.8	97.3	81.7	88.6	61.8	71.5	75.2	45.5
Silt and Clay	0.3	0.2	0.3	NA	0.1	0.2	0.1	0.1	0.3	1.1	0.2	0.2

Station	25	26	27	28	29	30	31	32	33	34	35
Gravel	40.2	10.4	68.4	9.1	20.8	9.8	0.1	1.1	10.8	23.2	14.6
Sand	59.8	88.6	30.1	90.5	79.1	90.1	78.7	51.1	89.2	76.6	85.4
Silt and Clay	0.0	1.0	1.5	0.4	0.1	0.1	21.2	47.8	0.0	0.2	0.0

Appendix C. Physical Characteristics of Bottom Sediments in the Mississippi River near East St. Louis

(November 12, 1981)

Station	
1	Clean, medium sand
2	Clean, medium sand with some pea gravel
3	Clean, medium sand
4	Clean, medium sand with some pea gravel
5	Clean, medium sand with some gravel
6	Clean, medium sand
7	Clean, medium sand and gravel
8	Clean, medium sand
9	Clean, medium sand
10	Clean, medium sand
11	Clean, medium sand
12	Clean, medium sand
13	Clean, medium sand
14	Clean, medium sand
15	Clean, medium sand
16	Clean, medium sand
17	Clean, medium sand
18	Clean, medium sand with some gravel
19	Clean, medium sand
20	Clean, fine sand
21	Clean, medium sand
22	Clean, medium sand
23	Clean, medium sand
24	Clean, medium sand
25	Clean, medium sand
26	Clean, medium sand
27	Clean, medium sand
28	Clean, medium sand
29	Clean, medium sand
30	Clean, dry fine sand
31	Clean, medium sand
32	Clean, medium sand
33	Clean, medium sand
34	Clean, medium sand
35	Clean, medium sand with some gravel

Appendix C. Concluded

(August 12, 1983)

Station	
1	Clean, medium sand with some gravel
2	Clean, medium sand and gravel
3	Clean, medium sand with some gravel
4	Clean, medium sand
5	Clean, medium sand with some gravel
6	Clean, pea gravel and sand
7	Clean, medium sand
8	Clean, medium sand with some small gravel
9	Clean, medium sand
10	Clean, medium sand with some small gravel
11	Apparently large rocks, unable to collect sample
12	Clean, medium sand
13	Clean, medium sand
14	Clean, medium sand with some small gravel
15	Clean, medium sand
16	Apparently large rocks, unable to collect sample
17	Clean, medium sand
18	Clean, medium sand
19	Clean, medium sand with some gravel
20	Clean, medium sand
21	Slightly silty, medium to coarse sand with some gravel
22	Clean, medium sand with some woody detritus and gravel
23	Clean, medium sand with some small gravel
24	Clean, pea gravel and sand
25	Clean, medium sand with some small gravel
26	Clean, medium sand
27	Slightly silty gravel and coarse sand
28	Clean, medium sand
29	Clean, medium sand with some gravel
30	Clean, medium sand
31	Silty sand
32	Silty sand
33	Clean, medium sand
34	Clean, medium sand with some gravel
35	Clean, medium sand