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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

Water Quality Features of the Upper Illinois Waterway

by THOMAS A. BUTTS, RALPH L. EVANS,
and SHUNDAR LIN

ILLINOIS STATE WATER SURVEY

URBANA
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Indexing Terms: Algae, bacteria, benthic organisms, coliforms, hydraulic-hydrologic models, modeling, nitrogen, oxygen demand, sediments, streams, water pollution control, water quality, water temperature.

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CONTENTS

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ABSTRACT

The dissolved oxygen resources of the Upper Illinois Waterway are depressed because of a combination of oxygen demand sources including carbonaceous and nitrogenous BOD, benthic biological extraction, and sediments. Because of these demands, maintenance of 6.0 mg/l DO in the stream system will be very difficult. To achieve minimum DO requirements of 5.0 mg/l, the nitrogenous demand as well as carbonaceous demand will have to be substantially reduced.

The principal algal types collected in the waterway are diatoms which make up about 85 percent of the total population. Although algal densities as high as 13,600/ml were detected, the use of the waterway for recreational purposes is not impaired by algal concentrations.

Fecal colifonn bacteria densities decrease with downstream movement at a rate of 0.77 per day in the upper pools and 0.42 per day in the lower pools. Only 3 of 19 stations sampled reflect the bacterial quality required by the Illinois Pollution Control Board. About 9 percent of the total coliform bacteria population are fecal coliforms.

INTRODUCTION

The Illinois Waterway is special among the many water courses within the state of Illinois. It drains 43 percent of the area of the state, and its headwaters, during dry weather, frequently consist of treated Chicago area wastewaters diluted with flow diverted from Lake Michigan. The treated wastewater is derived from approximately 5.5 million people and from numerous industries. Although many municipalities and industries discharge wastes along the 327.2-mile watercourse terminating at the Mississippi River, the Chicago metropolitan area wastewater discharges, averaging over 1400 million gallons a day (mgd), influence the downstream water quality very significantly.

This report summarizes water quality data obtained from field surveys made primarily during July, August, and September of 1971 and July 1972 on the upper part of the waterway from Chillicothe (milepoint 179.0) to Lockport (milepoint 292.1). A limited amount of water quality data was collected during several days in late October and early November in 1971, and bottom sediment oxygen demand characteristics were investigated during August through November in 1972. Presented is an evaluation of the relationships between the types of oxygen consuming materials and the dissolved oxygen resources within the waterway. Generalized wastewater treatment needs to meet designated water quality standards are evaluated. A limited amount of information related to bacterial and algal characteristics of the upper waterway was gathered and is also presented in this report.

Study Area

The Illinois Waterway is a series of eight navigation pools extending 327.2 miles from Lake Michigan at Chicago to its confluence with the Mississippi River at Grafton. Table 1 lists the pools, U. S. Army Corps of Engineers milepoint (MP) designations, and lengths. The actual lengths of the Brandon Road and Starved Rock pools differ from the inclusive milepoint totals because of channel straightening and alterations. Although these pools have been shortened, the Corps maintains the original designations for navigational and reference purposes. For mathematical simulations and models developed in this report, the corrected lengths were used.

The study area is a 113-mile reach extending from MP 179.0 at Chillicothe to MP 292.1 at Lockport. It includes all of the Brandon Road, Dresden Island, Marseilles, and Starved Rock pools, the upper 52 miles of the Peoria pool, and one location at the lower end of the Lockport pool. In this report, the study area is called the Upper Illinois Waterway (figure 1).

Approximately 12.5 miles upstream of the Lockport dam the Chicago Sanitary and Ship Canal and the Calumet-Sag Channel converge. These two watercourses receive the treated effluents and combined sewer overflows from the Chicago metropolitan area. The sampling station above the Lockport dam and below the juncture of the canals was established as a logical point to evaluate the characteristics of the waste loads imposed upon the Upper Illinois Water-

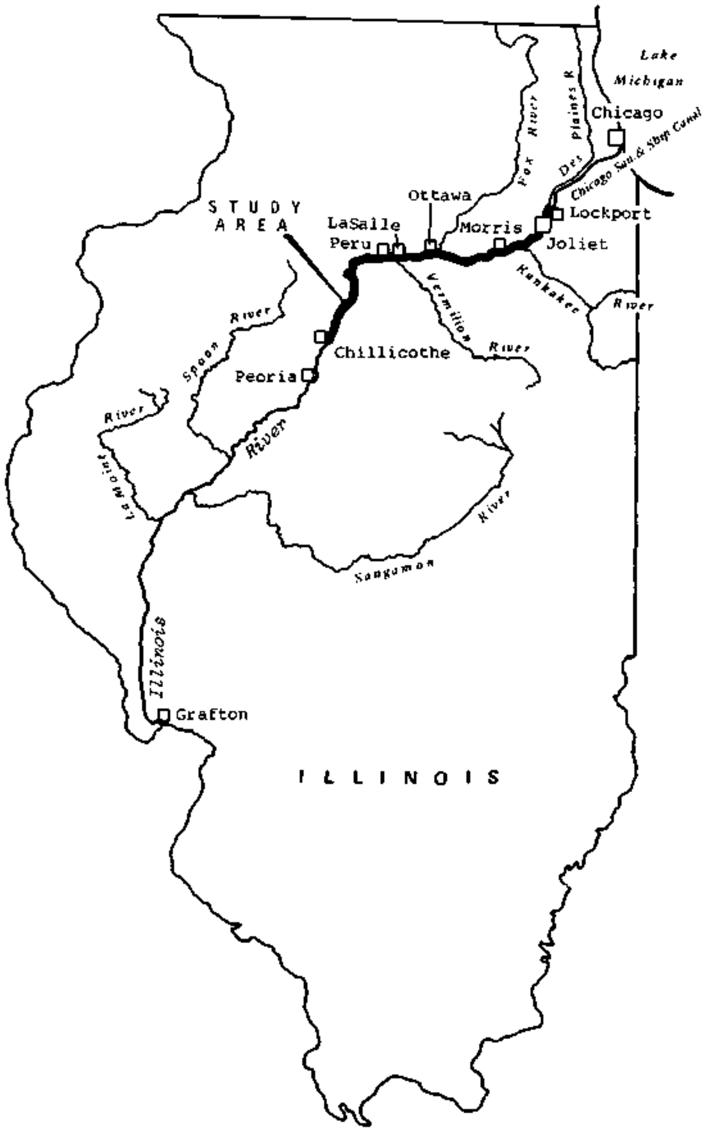

Figure 1. Study area, Upper Illinois Waterway

way from the Chicago area. The wastes are frequently diluted with Lake Michigan water diverted through control structures maintained by the Metropolitan Sanitary District of Greater Chicago (MSDGC). Diversion by MSDGC is limited to an annual average rate not exceeding 1500 cubic feet per second (cfs).

The Illinois Waterway has three distinct sections. The uppermost portion consists of the Chicago Sanitary and Ship Canal and its associated branches which extend from Lake Michigan to MP 289.9, the confluence of the Des Plaines River. The Des Plaines River, from its confluence with the Sanitary and Ship Canal, flows approximately 17 miles to MP 273.0 where it joins the Kankakee River to form the third section, the Illinois River. Besides the Des Plaines and Kankakee Rivers, other major tributaries within the study area are the Du Page (MP 276.9), Fox (MP 239.7), and Vermilion (MP 226.3) Rivers.

Table 1. Illinois Waterway Navigation Pools

Pool	Inclusive milepoints	Length *(miles)*
Lockport	327.2 – 291.0	36.2
Brandon Road	291.0 – 286.0	4.7
Dresden Island	286.0 – 271.5	14.5
Marseilles	271.5 – 247.0	24.5
Starved Rock	247.0 – 231.0	15.4
Peoria	231.0 – 157.6	73.4
La Grange	157.6 – 80.2	77.4
Alton	80.2 – 0	80.2

Table 2. Waste Discharge Loads to Upper Illinois Waterway

		Average waste flow		Ultimate waste loads *(lbs/day)*	
Source	Milepoint	*(mgd)*	*(cfs)*	*Carbonaceous*	*Nitrogenous*
MSDGC Skokie	336.8	352	545	43,629	76,540
MSDGC Calumet	321.4	213	330	33,426	139,848
MSDGC Stickney	315.8	901	1394	91,098	247,292
Grand Calumet R.	325.7		63.10		24,409
Lockport	290.9	2.00	3.10	203	535
Texaco	290.9	5.89	9.10	297	1,345
GAF Corp.	289.9	2.20	3.41	1,281	588
U. S. Steel	288.9	23.00	35.50	2,610	1,443
Joliet	286.2	21.2	32.80	7,502	9,859
Olin-Blockson	284.5	3.0	4.70	1,296	488
Caterpillar	283.6	0.77	1.19	238	35
Amoco Chem.	280.5	0.82	1.26	182	559
Stephen Chem.	280.3	0.84	1.30	1,434	80
Mobil Refinery	278.0	2.40	3.70	1,282	8,660
Rexene Chemical	277.7	0.13	0.21	10	548
Glidden Durkee	276.8	0.22	0.35	1,601	40
Reichhold Chemical	270.5	0.10	0.15	183	25
Northern Pet. Co.	269.5	1.01	1.55	310	176
Federal Paper	264.3	2.70	4.18	1,544	13
Morris	262.8	0.76	1.18	161	78
Du Pont Corp.	254.4	1.63	2.52	93	695
National Phosphate	249.8	1.67	2.58	207	290
Illinois Nitrogen	248.7	16.3	25.20	3,294	15,895
Nabisco	246.8	0.36	0.56	1,317	0
Marseilles	246.0	1.10	1.70	948	620
Marbon Corp.	244.3	0.56	0.85	104	1,265
Ottawa	239.3	2.98	4.62	664	68
LOF Corp.	237.5	3.73	5.78	203	0
Utica	229.6	0.15	0.23	44	26
La Salle	223.2	1.20	1.86	693	467
Peru	222.0	1.84	2.85	161	70
Spring Valley	218.0	0.88	1.88	183	100
De Pue	210.8	0.20	0.31	28	32
Jones & Laughlin	208.2	3.60	5.50	624	0
Hennepin	208.2	0.15	0.23	7	0
B. F. Goodrich	197.8	1.00	1.55	228	878
Lacon	188.8	0.28	0.44	137	64
Chillicothe	179.0	0.46	0.71	139	93

Waste Sources

The MSDGC operates three major sewage treatment plants that discharge directly into the waterway above Lockport but have a significant influence on the water quality below the Lockport dam. In addition, 13 other municipalities or sanitary districts and 21 industries discharge effluents between Lockport and Chillicothe. The names, locations, flows, and estimated waste loads are listed in table 2. Included in the table is the estimated nitrogenous biochemical oxygen demand load originating from the Grand Calumet River which has been found to be a significant source of ammonia. The flow and load data for the listed plants are as reported to the Illinois Environmental Protection Agency from plant operating reports. Approximately 98 percent of the total municipal flow originates from the MSDGC facilities. In addition, the MSDGC flows make up over 93 percent of all waste flows directly entering the Upper Illinois Waterway. The municipal, industrial, and MSDGC average flows are 33.2, 71.9, and 1466 mgd, respectively.

Two hydroelectric power plants exist in the study area. At times they significantly affect the dissolved oxygen (DO) resources of the waterway immediately downstream of the dams. One plant is located at the Lockport dam and is operated by the MSDGC, and the other is located at the Marseilles dam and is operated by the Illinois Power Company.

Acknowledgments

This study was conducted as part of the work of the Water Quality Section of the Illinois State Water Survey, Dr. William C. Ackermann, Chief. All members of Section's staff participated in the study in one capacity or another. Donald Schnepper, Veerasamy Kothandaraman, Wun-Cheng Wang, and John Thiel performed much of the field work and William Sullivan made most of the chemical determinations. Davis Beuscher identified and enumerated most of the bacteria and algae. Illustrations were prepared by the Graphic Arts Section under the supervision of John W. Brother, Jr; Miss Katherine Shemas typed the original manuscript; Mrs. J. L. Ivensand Miss Nancy Scott edited the final report; and Mrs. Suzi S. O'Connor typed the camera-copy.

FIELD SAMPLING METHODS AND PROCEDURES

Data used in this study can be categorized into three groupings: 1) field measurements of water quality parameters, 2) field measurements of sediment characteristics, and 3) laboratory analyses of water and sediment samples collected in the field. Group one includes temperature and dissolved oxygen observations. Group two includes benthic organism counts and changes in dissolved oxygen usage and temperature observed within a specially designed bottom sediment oxygen demand sampler. Group three includes analyses of total, carbonaceous, and nitrogenous biochemical oxygen demand, ammonia (NH -N), nitrite (NO -N), nitrate (NO -N), algae identification and enumeration, total and fecal coliform counts, and percent solids and percent volatile solids of bottom sediments.

Dissolved Oxygen and Temperature

During 1971, dissolved oxygen (DO) and temperature measurements were made at 45 stations on the waterway. Five were sampled from bridges — three in the Brandon Road pool, and one each in the Lockport and Dresden Island pools. All other stations were sampled from boats. Measurements were made on 24 separate days; however, on only 17 days were all 45 stations sampled. On four days, only the upper 22 stations were sampled, and on three other days, the lower 23 stations were sampled. The discontinuity in measurements resulted from equipment breakdowns and unfavorable weather conditions.

During 1972, four days of sampling were completed through the study area. Two stations were added to the 45 monitored during 1971. Sampling stations were added immediately above the Brandon Road dam (sampled from the dam) and immediately below the Marseilles dam (sampled from a bridge).

During both years, DO and temperature measurements were taken on the Des Plaines, Du Page, Fox, and Vermilion Rivers from bridges near their confluences with the Waterway. During 1971 the Kankakee River was sampled from a bridge; however, during 1972 it was sampled from a boat approximately a half mile above the Dresden Island Nuclear Power Plant cooling water intake. In addition, the power plant cooling water discharge was monitored for both DO and temperature.

All DO measurements at the bridge locations were made by the Winkler method, and temperature measurements were made with bimetallic thermometers. DO analyzers equipped with probes and thermistors were used in the boats. These instruments were calibrated by the Winkler method and were periodically checked for variance. All measurements used for simulations and analyses were taken at 3-foot depths in the centerline of the main channel. A limited number of horizontal and vertical profiles were taken.

Overall, more than 1100 DO and temperature measurements were recorded from the boat in approximately 3000 river miles.

Biochemical Oxygen Demand

Twenty waterway stations were selected as locations for determining biochemical oxygen demand (BOD) during 1971. (No successful BOD analyses were performed in 1972.) Samples were collected on seven days. A complete data record for all stations was achieved on six days; the other day's sampling was limited to the upper 12 stations. Analyses were performed for nitrogenous as well as carbonaceous demand, and sequential analyses either in the order of 1, 2, 5, and 9 days (all samples collected up to August 25) or 2, 3, 4, 5, 7, and 9 days (all samples collected from August 25 through September 28) were performed.

In addition, a special study of the upper four stations was made on four separate days during October and November; BOD analyses for these stations included sequential demand determinations on day 2 through and including day 18. All BOD analyses were made by modifications of the procedure suggested by Elmore[1] commonly known as the 'jug technique.' The carbonaceous and nitrogenous BOD fractions were separated by use of the nitrogenous inhibitor N-Serve as outlined by Young.[2] Approximately 1775 BOD analyses were made during this study.

Ammonia, Nitrite, and Nitrate Nitrogen

On five days during 1971, ammonia and nitrate analyses were run on samples collected at 20 stations through the waterway. On three additional days ammonia and nitrate samples were not collected at some of the 20 stations because of equipment failures. During 1972, ammonia, nitrite, and nitrate analyses were run on samples collected at 21 stations on four days. The station added was one located immediately above the Brandon Road dam.

Ammonia samples were preserved by using a 100-cc plastic syringe to force water through a 0.45-micron filter contained in a 37-mm plastic field monitor. Ammonia stability tests of filtered samples showed no measurable changes in ammonia concentrations in more than 48 hours under field conditions. The advantages of this methodology are that handling of acid is eliminated in the field, and the chemical properties of the original sample are unaltered. A disadvantage is that a filtered sample may become contaminated by carelessness or by an undetectable filter break. This happened only once in over 240 samples preserved in this manner.

Algae

Algae were collected at the water surface at 18 waterway stations in 1971. All the stations were sampled on seven days. In addition, partial collections were made on two other days. In all, 144 algae samples were collected for identification and enumeration. All samples were preserved with Lugol's solution.

Coliform Bacteria

Samples for coliform bacteria analyses were collected at 19 waterway stations in 1971. Collections were made on nine separate days and samples were obtained from all stations on seven days. Partial records were obtained from the upper and lower stations on the other two days. All samples were examined in triplicate according to *Standard Methods.*[3] Over 900 bacterial determinations were performed during the period of study.

Samples were collected at a few inches from the surface of the navigational channels in sterile glass bottles and placed in ice immediately. The bacterial analyses were performed within 24 hours of collection.

Sediments and Sediment Oxygen Demand

Benthic Organisms. Benthic organism samples were collected at 13 locations for use in conjunction with the 1972 study of the sediment oxygen demand characteristics of the waterway. A 6-inch Ekman dredge was used for obtaining the samples which were washed through a 30-mesh sieve and picked in the field. Organisms were counted and identified in the laboratory. Formalin was used for preservation.

Sediment Oxygen Demand (SOD). A special bottom sediment oxygen demand sampler was designed to measure the oxygen consuming potential of benthal deposits in the study area. The details of the design features and methodology developed are explained in detail by Butts.[4]

Basically the SOD sampler consisted of a 24-inch long half section of a 14-inch diameter steel pipe to which 2×2 angles were welded to act as cutting edges and seating flanges. A split collar plate was welded to the inside to hold the DO and temperature probe. Intake and outlet hose attachments were provided to circulate the water in the sampler system past the DO probe. Circulation was obtained by an electric pump powered by a generator on the boat.

Dissolved oxygen and temperature changes with elapsed time were recorded. Measurements were made at 22 locations within the study area.

Sediment Characteristics. The physical characteristics of the benthic deposits were well documented throughout the study area. Sediment samples for laboratory analysis of liquid and volatile content were collected with a 9-inch ponar dredge at three locations in a cross section, i.e., in the centerline of the main channel and at points right and left of the channel looking upstream.

Approximately 65 to 75 grams of sediment was retained and stored in 125-ml wide-mouth plastic bottles. The bottles were stored overnight in a refrigerator for analysis the next day. About 25 to 30 grams of sample was used for determining the percent volatile and dried solids. The percent dried solids parameter is a somewhat general indicator of constituency, i.e., the degree of solidity or liquidity of the sediment material. It was determined by decanting the supernatant from the top of the refrigerated samples that had been stored in the 125-ml bottles for approximately 16 hours. The residue was then thoroughly mixed, and a portion was oven dried at 103 C. The weight of the oven dried residue divided by the weight of the decanted wet residue times 100 was defined as the percent dried solids for use in this report. The percent volatile solids was determined according to *Standard Methods.*[3] A physical description of the raw and incinerated samples was recorded.[4]

HYDRAULIC AND HYDROLOGIC DATA

The water quality and waste assimilative capacity of a watercourse are dependent upon its flow regime and hydraulic characteristics such as flow, velocity, depth, and cross-sectional area. Discharge records of the MSDGC Lockport gage (MP 291.0) and the U. S. Geological Survey (USGS) gages at Marseilles (MP 246.3), Kingston Mines (MP 145.4), and on 14 tributaries were used for estimating streamflow rates. A special flow rating curve was developed by the USGS for determining flows in the lower Des Plaines River above Lockport.

Data for use in developing cross sections of the Upper Illinois Waterway at 0.1 mile intervals throughout its 113-mile reach were obtained from the Peoria and Joliet offices of the U. S. Army Corps of Engineers and the Illinois Division of Waterways. This information was used to develop a hydraulic-hydrologic model for predicting streamflows, widths, depths, volumes, and time-of-travel values during intermediate to low flows for any location within the study reach.

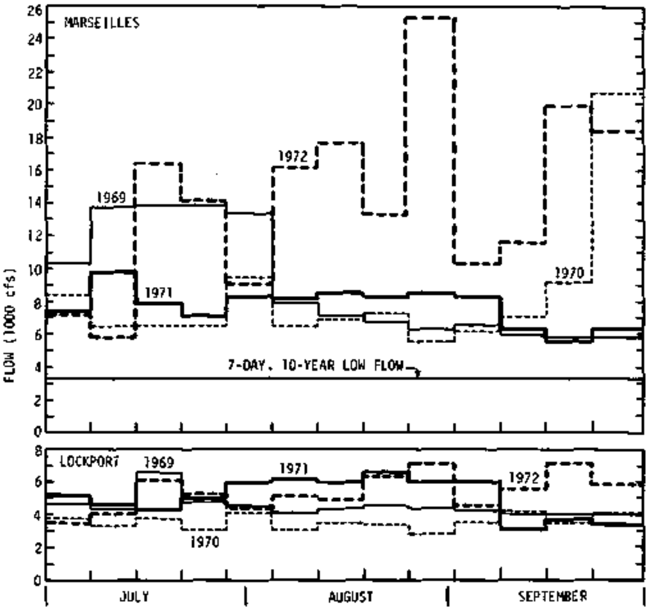

Figure 2. Weekly average flow hydrographs

Flow Characteristics

Because streamflows are regulated, the stage of the waterway can fluctuate rapidly and significantly. The effects of Lake Michigan diversion and water release at the Lockport dam, managed by the MSDGC, were demonstrated during a sampling day on July 22, 1971. Minimum 0.5-hour flows at the Lockport dam were about 1670 cfs, maximum 0.5-hour flows were an estimated 8467 cfs, and the average daily flow was 4208 cfs. On another sampling day, September 20, 1971, flows in the Dresden pool dropped to 2400 cfs from about 17,000 cfs on the preceding day. The drop in water stage elevation in a short period of time was readily noticeable in the pool. It is probable that such large fluctuations in flow occur when precipitation in the Chicago watershed appears imminent. Presumably storage within the channel system must be made available for anticipated runoff in an effort to minimize flooding within the drainage system.

Weekly average streamflows recorded during July, August, and September for 1969, 1970, 1971, and 1972, at Lockport and Marseilles are shown in figure 2. These depictions reflect the uncertainties involved in planning a water quality study during low flow and high temperature periods. In general, the flows were higher at Lockport during 1971 and 1972 study periods than during similar periods in 1969 and 1970. At Marseilles, 1971 flows were fairly stable and in line with those of 1969 and 1970. However, the flows during 1972 at Marseilles were very high throughout the study period, and at times were near or at flood stage. These conditions prevented meaningful sampling for DO and BOD except for a brief period in July. During the 1972 study period, the maximum daily flows at Lockport and Marseilles were 17,377 and 39,100 cfs, respectively, whereas during 1971 the maximum values were only 12,112 and 12,200 cfs, respectively. The yearly average flow at Lockport for 71 years of record is 5536 cfs, and the yearly average flow at Marseilles for 52 years of record is 10,630 cfs.

Flow Duration

The water quality standards for Illinois surface waters are predicated upon design flows of 7-day duration at 10-year recurrence intervals. Estimates of these flows have been made for all the nonintermittent streams in the state by Singh and Stall.[5] The flows for the Lockport, Marseilles, and Kingston Mines gages on the main stem and for the principal tributaries at their confluence with the main stem are given in table 3. All of the lowest 7-day flows occur in late summer or early fall except those at Lockport and the Kankakee River which occur in winter. Both seasonally matched flows and 7-day low flows are given for these two stations.

Flow duration curves for Marseilles and Kingston Mines are depicted in figure 3. The maximum flow at Marseilles during a 1971 sampling day was 11,500 cfs; the minimum was 5150 cfs. As shown by the Marseilles curve in figure 3, these flows are likely to be exceeded 21.0 and 75.5 percent of the time, respectively. Similarly for 1972, the maximum and minimum flows at Marseilles during a sampling day were 21,000 and 6680 cfs, respectively, and corresponding duration percentages are 5.5 and 50.0. Comparison of the values for the two years indicates that the flows during 1972 were much higher. Flow durations, i.e., the percent of time a flow is likely to be exceeded, are tabulated in table 4 for all sampling days.

A comparison of the 7-day 10-year low flows in table 3 with flows observed on the 28 sampling days given in table 4 indicates that the 1971 and 1972 sampling periods did not coincide with the design flows that are used to assess water quality measurements. This suggests that during design flows the values of certain water quality parameters, principally DO, may be lower than those observed in this study. Lower values are likely because the average flows (2269 cfs) from sewage treatment facilities discharging into the canals upstream of Lockport are nearly the same as the 7-day 10-year low flow at Lockport.

RESULTS AND DISCUSSION

This section deals primarily with the factors affecting the dissolved oxygen resources and the waste assimilative capacity of the study area. The interrelationships between such parameters as dissolved oxygen, water temperature, biochemical oxygen demand, ammonia nitrogen, and sediment oxygen demand are discussed. In addition, the results of the algal and bacterial determinations are reviewed.

Dissolved Oxygen

DO observations made at all the stations on all dates are tabulated in appendix A. A summary of the DO concentrations observed at each of the 45 stations during 1971 is given in table 5; the mean DO values for each station along with 99 percent confidence intervals are plotted in figure 4. For conditions similar to those which occurred during sampling a 99 percent chance exists that the true mean DO values fall between the confidence limits. A summary of the DO concentrations observed for the four days sampled at 47 stations during 1972 is given in table 6, and the DO profiles are plotted in figure 5. A confidence interval for the 1972 profile was not computed because it would have little meaning with only four samples.

Figure 4 shows that DO degradation occurs in all the pools except the Starved Rock pool. A smooth transition in DO appears to be occurring between pools at the Marseilles dam in contrast to the other dam sites where significant reaeration takes place causing abrupt increases in DO below the structures. In other words, the DO profile for the Starved Rock pool appears to be merely an extension of the Marseilles pool DO profile. The reason for this is that when Illinois River flows are approximately 8500 cfs or less, all the river flow is diverted through the Illinois Power Company hydroelectric plant at Marseilles. This water is not subjected to reaeration as it would be if left to flow over the dam. Except for one date (see table 4) the flows for the four 1972 sampling days were much greater than 8500 cfs. Consequently, a considerable percentage of the flow was subjected to aeration at the dam and this is reflected in the 1972 DO profile for the Starved Rock pool (figure 5). A sharp jump in DO occurs below the Marseilles dam, and a DO sag curve, similar to those in the other pools, develops. Although the flows during 1972 were quite high, pronounced and well-defined DO sag curves developed for all the pools.

The MSDGC operation of the hydroelectric station at Lockport also reduces reaeration at the Lockport dam, although not to the degree that was observed at Marseilles. Only on two occasions during the study period did the upstream and downstream DO concentrations essentially remain unchanged. However, on most other days, the downstream DO was less than it would have been if the hydroelectric plant had not been operating. Since the MSDGC keeps excellent records of its operations, it was possible to develop an empirical formula for predicting the downstream DO concentration. This formula is:

$$DO = 0.03655\,P + 0.000455\,Q + 0.67 \qquad (1)$$

where

DO = dissolved oxygen concentration, in mg/l, below the Lockport dam
P = percentage of flow over dam
Q = total flow in Sanitary and Ship Canal, in cfs

The multiple correlation coefficient between P, Q and DO for the observed data is 0.95, a high value. The equation in-

Table 3. 7-Day 10-Year Low Flows, Main Stem and Principal Tributaries

Stream or gaging station	7-da 10-yr flow *(cfs)*
Sanitary & Ship Canal at Lockport	2320 (1700)*
Des Plaines at Canal Junction	29
Hickory Creek	20
Du Page River	46
Kankakee River	635 (455)*
Mazon	0
Illinois River at Marseilles	3240
Fox River	208
Vermilion River	8
Bureau Creek	18
Kickapoo Creek	1
Mackinaw River	47
Illinois River at Kingston Mines	3000

* *Winter values in parentheses, all others are summer or early fall values*

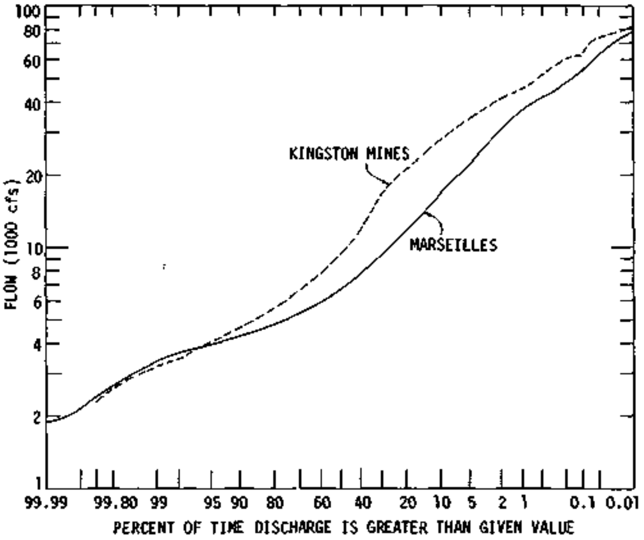

Figure 3. Flow duration curves for Marseilles and Kingston Mines

Table 4. Time-of-Travel, Flow, and Flow Duration for Sampling Dates

Date	t* *(days)*	Flow *(cfs)* Lock.	Flow *(cfs)* *Mar.*	Flow *(cfs)* *K.M.*	Duration** *(%)* *Mar.*	Duration** *(%)* *K.M.*	Major tributaries Flow *(cfs)* *Kank.*	Major tributaries Flow *(cfs)* *Fox*	Major tributaries Duration *(%)* *Kank.*	Major tributaries Duration *(%)* *Fox*
1971										
7/14	6.54	4590	11,500	14,100	21.0	34.5	4820	609	23.5	63.0
7/15	6.82	4126	9,760	15,000	25.2	33.0	3820	525	30.0	69.0
7/19	8.74	3731	6,530	12,300	52.5	39.0	1520	540	62.5	70.0
7/22	8.88	4208	6,440	10,000	53.0	43.5	1150	463	74.0	75.0
7/23	8.75	5384	6,330	9,000	57.5	54.0	1130	356	75.5	85.5
7/28	7.59	5937	8,550	7,860	34.5	56.5	1150	403	74.0	80.5
7/29	7.79	5819	8,070	8,070	38.0	54.5	1280	371	69.5	84.0
8/4	7.28	5955	8,020	10,700	38.5	43.0	1060	410	77.5	80.0
8/5	7.15	5962	8,100	11,100	38.0	42.5	970	379	80.5	83.0
8/10	7.18	7172	8,060	9,370	38.0	48.5	761	323	89.0	88.5
8/11	7.11	6056	8,990	8,830	32.5	49.0	829	291	86.0	91.5
8/17	6.56	6388	9,800	9,010	28.0	49.5	778	393	87.5	82.0
8/18	7.69	5874	7,540	9,410	42.5	50.0	727	370	90.0	84.0
8/25	5.90	7698	11,000	9,160	22.5	51.0	812	928	86.5	48.5
8/26	6.85	6184	8,810	9,220	53.5	47.0	1130	1210	75.5	40.0
8/31	7.27	5907	8,040	9,400	59.0	50.5	952	420	80.5	79.5
9/1	7.60	6163	7,810	9,000	40.5	51.5	846	428	85.5	79.5
9/2	7.60	5965	7,940	9,000	39.0	52.0	761	440	88.5	77.0
9/3	7.59	6014	7,810	9,000	40.5	52.5	710	427	91.0	79.5
9/20	10.94	2766	5,330	7,090	69.5	62.0	1200	467	73.0	74.5
9/21	10.50	3203	5,690	7,630	64.0	46.0	1280	430	70.0	79.5
9/22	10.96	3178	5,150	7,620	75.5	60.5	1500	370	64.0	84.0
9/28	10.02	3081	6,650	6,940	51.0	65.5	2520	362	45.5	84.0
9/30	11.15	2999	5,560	6,960	66.0	64.5	2610	328	44.0	88.5
1972										
7/11	9.11	3378	6,680	8,900	50.0	52.5	1730	636	59.0	61.5
7/18	3.76	8728	21,000	13,800	5.5	35.0	6830	965	15.0	47.0
7/24	4.18	5605	15,300	25,200	14.0	12.5	4890	852	24.0	51.0
7/26	4.90	5604	13,800	23,700	18.0	15.5	5160	825	23.0	52.0

* *t = time-of-travel between MP 291.0 and 179.0*
** *Percent of time flow is greater than listed value; not available for Lockport*

Table 5. Summary of DO Concentrations, 1971 Sampling Dates

Station MP	Number of samples	DO concentration *(mg/l)*		
		Average	*Minimum*	*Maximum*
292.1	23	1.18	0	3.00
290.0	23	5.00	2.30	6.30
288.4	23	3.91	1.90	5.80
287.3	23	3.74	0.60	5.90
285.8	23	6.47	5.50	7.90
284.0	22	6.31	5.20	8.20
281.0	22	5.16	3.10	7.15
278.0	22	4.42	2.60	6.50
276.1	21	3.99	2.10	6.10
273.5	21	3.85	2.70	5.25
272.4	21	3.96	2.80	5.30
271.6	21	5.14	3.30	5.40
270.6	21	6.85	5.60	8.10
267.2	21	6.33	5.20	7.60
265.0	21	6.21	5.00	7.50
263.7	21	6.03	4.90	7.25
261.6	21	5.64	4.60	6.90
258.0	21	5.34	4.20	6.35
256.0	21	5.17	4.00	6.20
253.0	21	5.05	4.00	6.10
250.0	21	4.91	3.90	6.50
247.0	21	4.77	3.70	6.20
246.±	22	4.63	2.90	7.05
243.7	22	4.62	3.60	6.10
242.9	17	4.37	3.45	6.30
240.0	21	4.45	3.40	6.00
239.0	21	4.52	3.55	5.70
236.8	21	4.60	3.70	5.70
234.5	20	4.74	3.85	5.90
231.0	20	4.90	3.60	6.10
229.6	20	6.54	5.30	7.60
226.9	20	6.49	5.50	7.40
224.7	20	6.75	5.30	7.40
222.6	20	6.01	5.25	7.50
219.8	19	5.80	4.80	6.90
217.1	20	5.84	5.10	7.30
213.4	20	5.79	5.00	7.10
209.4	20	5.45	4.50	7.00
205.0	20	5.27	4.40	6.90
200.4	20	4.97	4.30	6.80
196.9	20	4.56	4.00	6.50
190.0	20	4.34	3.60	5.90
188.0	20	3.92	3.20	5.60
183.2	20	3.94	2.80	5.60
179.0	20	3.58	2.75	5.90

Table 6. Summary of DO Concentrations, Four 1972 Dates

Station MP	DO concentration *(mg/l)*		
	Average	*Minimum*	*Maximum*
292.1	1.28	0	2.40
290.0	1.95	1.10	2.70
288.4	2.20	0.70	2.90
287.3	1.75	1.10	3.00
286.3	1.10	0.60	1.50
285.4	5.93	5.40	6.60
284.0	5.39	4.90	5.60
281.0	4.44	4.05	5.10
278.0	3.86	3.30	4.75
276.1	3.38	3.10	4.50
273.5	3.46	2.85	4.05
272.4	3.75	3.15	4.50
271.6	5.29	4.20	7.30
270.6	6.33	5.75	6.70
267.2	5.79	5.30	6.30
265.0	5.66	5.20	6.20
263.7	5.55	5.10	6.15
261.6	5.48	5.00	6.00
258.0	5.19	4.70	5.70
256.0	5.08	4.75	5.40
253.0	4.99	4.60	5.30
250.0	4.63	4.35	5.05
247.0	4.46	4.20	4.90
246.9	6.20	6.00	6.70
246.0	5.53	5.10	6.20
243.7	5.54	4.90	6.20
242.9	5.36	4.80	6.10
240.0	5.24	4.80	5.80
239.0	5.56	5.00	6.20
236.8	5.62	4.95	6.70
234.5	5.30	4.70	6.10
231.0	5.30	4.70	5.70
229.6	5.71	5.30	6.20
226.9	5.94	5.25	7.20
224.7	5.80	5.10	7.00
222.6	5.51	4.90	6.70
219.8	5.41	4.85	6.40
217.1	5.09	4.80	5.60
213.4	4.95	4.55	5.70
209.4	4.60	4.40	5.00
205.0	4.30	3.60	5.10
200.4	3.99	3.15	5.00
196.9	3.75	3.15	4.25
190.0	3.45	2.70	3.80
188.0	3.25	2.40	3.60
183.0	3.28	2.30	3.80
179.0	3.35	2.70	3.60

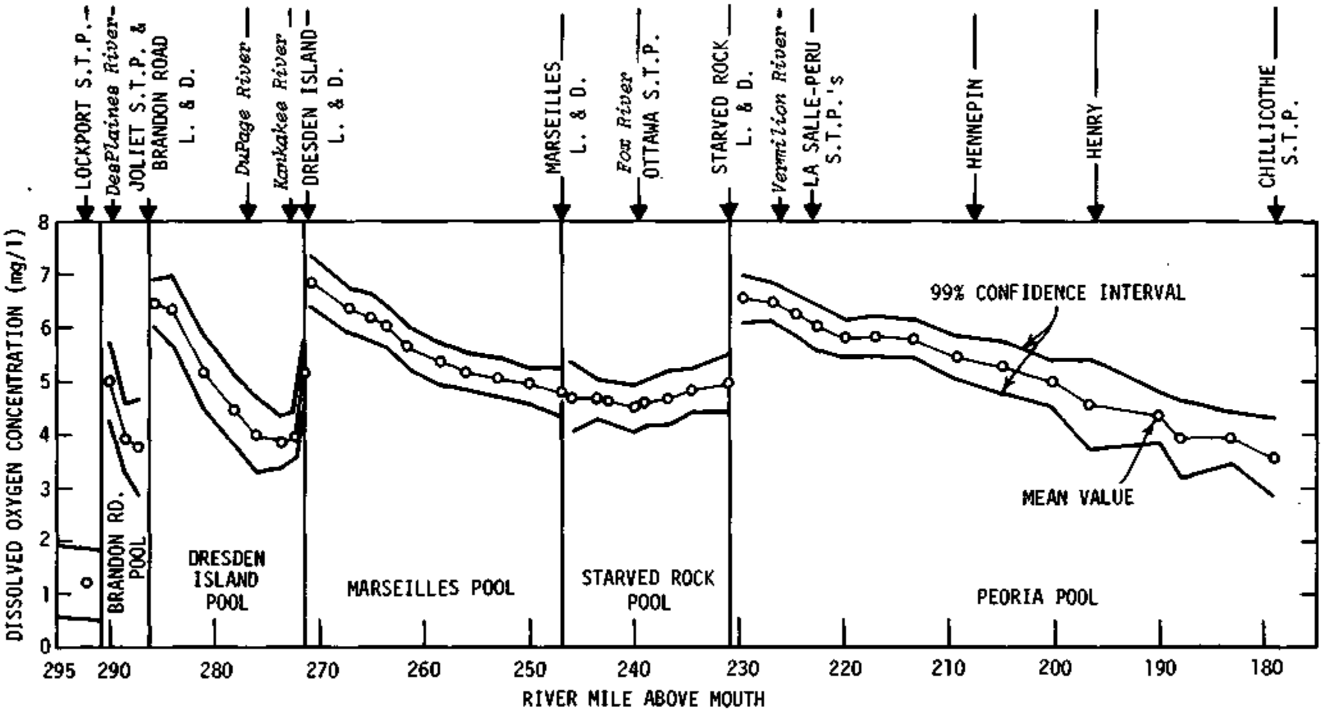

Figure 4. Mean dissolved oxygen profile, 1971 dates

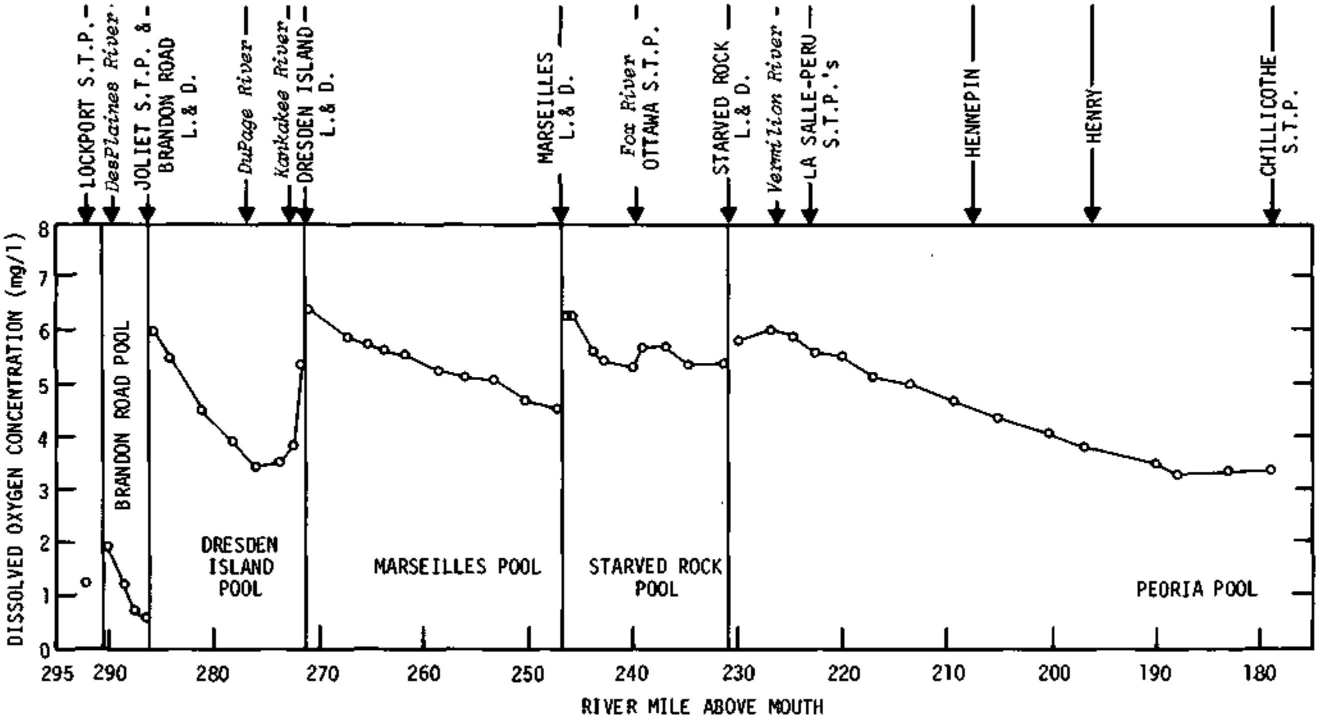

Figure 5. Mean dissolved oxygen profile, July 11, 18, 24, 26, 1972

Table 7. Summary of 1971 Upstream and Downstream DO Values at Dam Locations

	DO concentration *(mg/l)*					
	Upstream of dam			Downstream of dam		
Dam location	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*
Lockport	3.0	1.2	0	6.3	5.0	2.3
Brandon Road	5.9	3.7	0.6	7.9	6.5	5.5
Dresden Island	5.4	5.1	3.3	8.1	6.8	5.6
Marseilles	6.2	4.8	3.7	7.0	4.6	2.9
Starved Rock	6.1	4.9	3.6	7.6	6.5	5.3

Table 8. Summary of 1972 Upstream and Downstream DO Values at Dam Locations

	DO concentration *(mg/l)*					
	Upstream of dam			Downstream of dam		
Dam location	*Max*	*Avg*	*Min*	*Max*	*Avg*	*Min*
Lockport	2.4	1.3	0	2.7	2.0	1.1
Brandon Road	1.5	1.1	0.6	6.6	5.9	5.4
Dresden Island	7.3	5.3	4.2	6.7	6.3	5.8
Marseilles	4.9	4.5	4.2	6.2	5.5	5.1
Starved Rock	5.7	5.3	4.7	6.2	5.7	5.3

dicates that for a flow in the canal of 2800 cfs (approximately three-fourths of the average MSDGC waste discharge) and $P = 100$ (no power generation), the estimated downstream DO would be 5.6 mg/l. However, if 100 percent of this flow were used for power generation, the estimated downstream DO would be only 1.9 mg/l. This demonstrates that a detrimental effect on the downstream water quality can occur when a large fraction of the flow is used for power generation. In this case, however, only a short reach is affected since the Brandon Road Dam, a highly efficient aerator, is less than 5 miles downstream.

Summaries of the upstream and downstream DO concentrations for all the dam locations are given in tables 7 and 8. The data indicate that during intermediate to low flows, such as those during 1971, DOs above 5.0 mg/1 can be readily maintained immediately below the Brandon Road, Dresden Island, and Starved Rock dams even though the upstream values were considerably lower than 5.0 mg/1. During 1972 when the flows at Marseilles were high, DOs of 5.0 mg/l or greater were maintained downstream of the dam. However, the downstream DO levels at Lockport showed a marked deterioration over those observed in 1971, though the DO levels upstream of the dam were similar in both years. The overall effect this had on DO resources of the Brandon Road pool is demonstrated by the great difference in levels of the 1971 and 1972 DO profiles depicted in figures 4 and 5.

The dams are significant reaeration sources for waters overflowing them. The extent of the aeration establishes the bases for the configurations of the DO sag curves. However, the dams should not be considered wholly beneficial. On the contrary, their existence lessens the capability of the waterway to assimilate organic waste by:

1) Increasing the time-of-travel and thus lengthening incubation periods in each pool
2) Increasing the depth of flow and decreasing stream velocities thus lowering the reaeration capability of the pooled water
3) Encouraging deposition and accumulation of solids on the pool bottom thereby creating benthic biochemical oxygen demands.

The hydraulic features for each pool are summarized in table 9. Although the average pool DO is influenced by the biological rate of organic degradation, it is also influenced by the waste assimilative capacity which is directly related to hydraulic characteristics. Table 9 indicates that the pools possessing the lowest capabilities for assimilating wastes are Brandon Road, Dresden Island, and Peoria, principally because of their lower velocities and deeper water depths. A summary of pool DOs given in table 10 supports this classification. Therefore, any measures undertaken to deepen the pools would be detrimental to the water quality of the pools.

In general, the average pool DO values given in table 10 appear highest for the Marseilles pool. This was particularly true during the period August 4-25, 1971, when lake diversion was substantially increased.

The DO content of several tributary streams can significantly influence the DO in the waterway under certain circumstances. To have a significant positive effect both the DO concentrations and flows of the tributary must be relatively high in comparison with Illinois Waterway values. The DO and flows are summarized in table 11 for the five major tributaries; the DO values for each individual date are tabulated in appendix A. The 1971 data represent up to 24 dates and are therefore more representative of conditions over a wider but lower flow range.

Table 9. Summary of Hydraulic Features for Pools, 1971 Sampling Dates

	Depth *(feet)*			Flow *(cfs)*			Velocity *(fps)*			Time-of-travel *(days)*		
Pool	*Avg*	*Max*	*Min*	*Avg*	*Max*	*Min*	*Avg*	*Max*	*Min*	*Avg*	*Max*	*Min*
Brandon Road	16.3	16.6	15.9	5314	8,090	2888	0.75	1.13	0.40	0.42	0.71	0.25
Dresden Island	10.4	10.7	10.2	5746	8,788	3301	0.68	1.00	0.39	1.54	2.29	0.88
Marseilles	11.3	12.6	10.8	7485	10,758	4910	1.11	1.40	0.77	1.41	1.94	0.99
Starved Rock	8.4	8.9	8.1	8127	11,556	5518	0.74	1.02	0.51	1.33	1.86	0.93
Peoria	11.3	12.6	10.7	8770	11,813	6457	0.92	1.11	0.70	3.51	4.54	2.79

Table 10. Average DO for Pools

(A verage DO in milligrams per liter)

Date	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria
1971					
7/14	4.13	3.31	5.51	5.24	5.23
7/15	2.67	3.84	5.22		
7/19				5.36	5.11
7/22	4.03	4.47	6.47	5.34	5.25
7/23	4.70	4.55	5.51	4.42	5.45
7/28	5.20			4.89	5.68
7/29	4.90	5.49	5.96		
8/4	5.07	6.73	6.80	5.11	6.11
8/5	5.30	5.69	6.42	5.45	4.90
8/10	5.56	6.16	6.10	4.44	4.93
8/11	5.47	5.82	6.47	4.34	4.62
8/17	5,83	5.86	5.65	3.80	4.44
8/18	5.37			5.05	4.68
8/25	3.00	5.38	5.69	3.85	4.77
8/26	3.37	4.94	5.42	4.49	4.64
8/31	5.37	4.95	4.60		
9/1	4.97	4.87	5.56		
9/2	4.87	4.48	4.61	5.91	5.39
9/3	4.80	4.49	5.13	4.54	4.98
9/20	1.77	4.09	4.61	4.60	6.11
9/21	2.27	3.85	5.25	3.72	5.46
9/22	2.57	4.13	5.48	4.57	6.60
9/28	2.97	4.57	5.68	4.18	4.72
9/30	2.83	4.43	5.56	3.92	5.09
1972					
7/11	1.52	4.36	5.31	5.98	5.25
7/18	0.88	5.17	5.32	5.02	4.05
7/24	2.12	3.87	4.90	4.62	4.38
7/26	2.48	4.47	5.77	5.90	4.60

The Kankakee and Fox are the only two rivers of sufficient size to continuously affect the DO in the waterway. These influences are reflected in the average DO profiles of figures 4 and 5. The Fox River effect on the waterway represents a fraction of a milligram per liter increase, whereas the apparent effect of the Kankakee is well over 1 mg/l. The Kankakee effect is called 'apparent' because the ambient DO in the Kankakee is not in itself great enough to cause a 1 or 2 mg/l DO increase downstream in the waterway. The dramatic reversal of the Dresden Island pool DO profiles of figures 4 and 5 is due principally to the highly oxygenated cooling water effluent discharged at the Dresden Island Nuclear Power Station located at the mouth of the Kankakee. During the four 1972 sampling days, the average DO of the cooling water intake (located on the Kankakee River) was 5.6 mg/1, whereas that of the discharge (located on the waterway) was 6.8 mg/1. Because the discharge DO is high and at times the power plant uses practically all the Kankakee River flow for cooling purposes, a large increase in the waterway DO below the power station is to be expected. However, the benefit of this influx of highly oxygenated water is not fully utilized because the Dresden Island dam, located less than 1 mile downstream, reaerates the stream to high DO levels as previously discussed.

All the tributaries listed in table 11, except the Kankakee River, show wide fluctuations in DO; supersaturation commonly occurs. This indicates these tributaries are enriched, and they commonly experience algal blooms. During this study the Du Page, Fox, and Vermilion Rivers were frequently observed to be 'pea soup' green, and the Des Plaines River was observed to be in this condition infrequently.

Temperature

Cooling water is withdrawn and returned as heated discharges by 11 steam electrical generating plants along the Illinois Waterway. Four of these plants, along with numerous industrial operations, discharge heated cooling water within the study area. The temperatures observed at each sampling station for each date are tabulated in appendix B.

A summary of water temperatures observed during 1971 is shown in table 12. The stations at MPs 284.0, 271.6, 222.6, and 209.4 are the first ones-downstream of power plants. Station 284.0 had the maximum rise in temperature of 5.5°C (9.9°F), the highest average rise of 4.0°C (7.2°F),

Table 11. Summary of Tributary Flows and DO Concentrations near Confluences with Waterway

	Des Plaines R.		Du Page R.		Kankakee R.		Fox R.		Vermilion R.	
	1971	*1972*	*1971*	*1972*	*1971*	*1972*	*1971*	*1972*	*1971*	*1972*
Flow *(cfs)*										
Maximum	415	5200	187	1010	4820	6830	1210	965	794	3270
Average	149	2310	66	401	1430	4653	546	820	89	1223
Minimum	78	700	44	128	710	1730	291	636	10	259
DO *(mg/l)*										
Maximum	16.7	16.1	14.1	6.6	10.2	7.5	18.1	14.4	13.9	
Average	9.9	6.9	7.9	5.1	8.0	6.4	8.9	9.3	8.9	
Minimum	8.0	2.1	2.9	1.3	5.3	5.8	4.1	6.4	4.8	

Table 12. Summary of Station Temperatures, 1971 Sampling Dates

Station MP	Number of samples	Temperature (°C) *Average*	*Minimum*	*Maximum*
292.1	22	24.9	22.1	28.0
290.0	22	24.3	20.8	28.0
288.4	22	24.5	21.2	28.0
287.3	22	24.1	21.5	27.5
285.8	21	24.4	21.7	26.9
284.0	22	28.4	23.5	32.0
281.0	22	27.2	23.5	30.0
278.0	22	27.1	24.0	29.5
276.1	22	26.9	24.0	29.5
273.5	21	26.7	24.0	29.0
272.4	21	26.6	23.5	29.0
271.6	21	27.6	24.9	31.2
270.6	21	26.9	24.0	30.0
267.2	21	26.9	24.0	30.0
265.0	21	26.9	23.8	29.8
263.7	21	26.8	23.2	29.6
261.6	21	26.7	23.0	29.2
258.0	21	26.5	23.1	29.2
256.0	21	26.4	23.2	29.0
253.0	21	26.5	23.1	29.2
250.0	21	26.5	23.0	29.2
247.0	21	26.4	22.9	29.0
246.±	22	26.5	23.0	29.2
243.7	21	26.5	23.0	29.1
242.9	17	26.4	23.0	29.0
240.0	21	26.3	22.9	28.6
239.0	21	26.1	22.8	28.2
236.8	21	26.2	22.8	28.3
234.5	20	25.9	22.6	28.2
231.0	20	25.7	22.1	28.0
229.6	20	25.3	21.4	28.0
226.9	20	25.1	21.0	27.5
224.7	20	25.3	20.9	27.5
222.6	20	25.4	20.9	27.5
219.6	19	25.3	21.0	27.6
217.1	20	25.4	21.0	27.8
213.4	20	25.2	20.1	27.7
209.4	20	25.4	21.5	27.8
205.0	20	25.4	21.5	27.9
200.4	20	25.5	21.5	28.1
196.9	20	25.1	21.4	28.5
190.0	20	25.1	21.5	28.1
188.0	20	25.1	21.4	27.8
183.0	20	24.8	20.8	27.4
179.0	20	24.8	20.4	27.1

and a maximum temperature of 32.0 C (89.5 F). At station 271.6 the average rise in water temperature was 1 C (1.8 F) with a maximum rise of 3.2 C (5.8 F) and a maximum temperature of 31.2°C (88.0°F). Very slight increases occurred at 222.6 and 209.4. All measurements were made at 3-foot depths on the centerline of the navigational channel; no effort was made to define the thermal plume at each station.

A mean temperature profile, with 99 percent confidence intervals, is depicted in figure 6. This shows the significant rise in water temperature at MP 284.0 which in effect raises the whole temperature profile of the waterway.

The average temperatures for each pool on each sampling date are shown in table 13. The average temperatures for the Dresden Island pool were the highest, equaling or exceeding 29 C (84.3 F) on five occasions. This average temperature was exceeded in the Marseilles pool twice. On September 2, 1971, and July 24, 1972, the average pool temperatures were uniformly high throughout the study area below the Brandon Road dam.

Table 13. Average Temperatures for Pools on Sampling Dates

(Temperature in degrees Centigrade)

Date	Brandon Road	Dresden Island	Marseilles	Starved Rock	Peoria
1971					
7/14		28.6	27.5	27.3	27.2
7/15	27.8	29.5	27.3		
7/19				27.2	26.5
7/22	26.2	28.7	28.1	27.3	25.9
7/23	25.8	29.0	28.1	26.6	26.2
7/28	23.1			26.5	25.1
7/29	23.1	26.4	26.4		
8/4	21.3	24.1	24.9	24.5	24.6
8/5	21.2	23.8	24.9	25.1	24.0
8/10	25.5	27.4	27.9	27.3	27.0
8/11	24.6	26.8	27.8	27.6	26.3
8/17	23.6	26.6	26.8	26.6	26.7
8/18	24.2			27.9	26.8
8/25	25.3	28.3	28.2	27.8	27.8
8/26	24.8	26.7	27.0	26.6	26.6
8/31	24.7	28.2	27.3		
9/1	25.6	27.7	27.9		
9/2	26.1	29.0	28.6	28.0	28.0
9/3	26.3	29.3	29.4	28.5	26.9
9/20	22.1	24.8	24.2	23.1	21.5
9/21	21.9	25.1	23.5	23.3	20.4
9/22	23.7	24.7	23.5	22.8	21.4
9/28	23.7	25.9	25.1	24.3	22.2
9/30	23.8	27.8	25.1	24.9	24.4
1972					
7/11	26.7	29.5	28.5	28.8	26.7
7/18	24.9	25.6	26.3	27.2	26.6
7/24	26.8	28.8	29.3	28.6	29.0
7/26	25.0	27.0	27.1	26.6	26.7

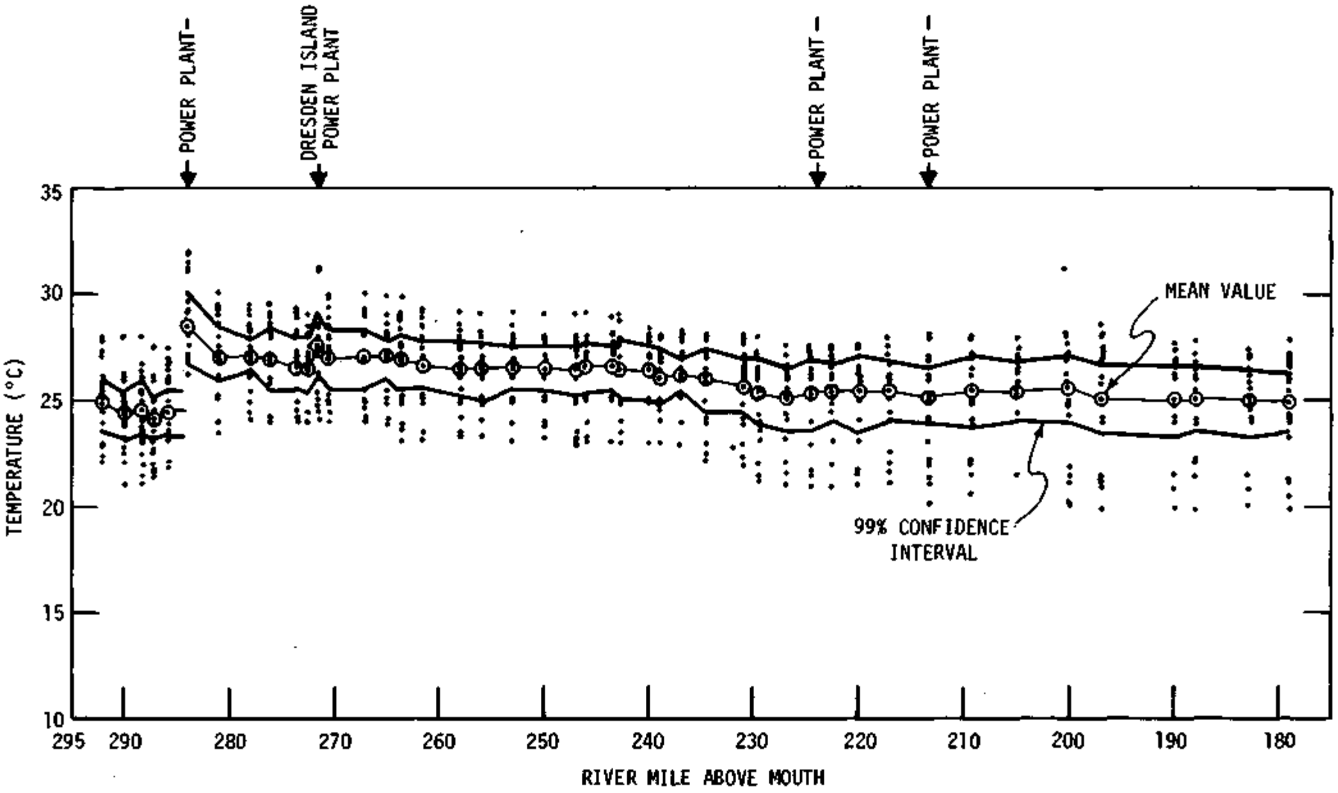

Figure 6. Mean temperature profile, 1971 sampling dates

Biochemical Oxygen Demand

Previous studies in the La Grange pool[6] of the waterway demonstrated the need for assessing both the carbonaceous oxygen demand and the nitrogenous oxygen demand, i.e., the microbial oxidation of ammonia-N and nitrite-N. For this study, the sum of these demands was considered the total dissolved biochemical oxygen demand upon the dissolved oxygen resources in the waterway. The bottom sediments also exert an oxygen demand and will be discussed later.

Frequently the oxygen demand of liquid wastes or substances subject to biochemical oxidation in water is characterized by the 5-day biochemical oxygen demand (BOD) test. In essence, the test results are interpreted as the demand for oxygen of the substance being tested or as the measure of the biodegradable material available for microbial oxidation. Just as important but less understood is the fact that the test reflects the activity and population of the microbes available in the tested media.

The carbonaceous or nitrogenous demand is dependent upon the number of cooperating bacteria present in a sample, if an unlimited supply of food is available. In the case of carbonaceous oxidation, the heterotrophs are capable of using an organic carbon source for energy and producing, as a byproduct, carbon dioxide. For nitrogenous oxidation, the autotroph *Nitrosomonas* utilizes ammonia as an energy source converting it to nitrites while the autotroph *Nitrobacter* utilizes nitrites as an energy source converting it to nitrates.

The oxygen requirements for these fundamental oxidation processes are very different. For satisfying the carbonaceous demand one part of oxygen is required for each part of the substance oxidized; for the nitrogenous demand 4.57 parts of oxygen is required for one part ammonia-N oxidized. In effect, 1 mg/l NH -N has a potential oxygen demand equivalent to 4.57 mg/l.

A limiting aspect of the BOD test is that frequently five days is not sufficient time to develop a dynamic nitrifying bacteria population. Thus a BOD_5 result may not include the effects of nitrogenous oxidation.

With these basic concepts in mind, it is also important to realize that the ultimate BOD, not the BOD_5, is the parameter used to assess waste degradation in stream waters. The ultimate demand (L_a) is a function of the rate of deoxygenation (K_1), and the basis for determining these values is either BODs performed at varying periods of time, as mentioned earlier in this report, or determinations of actual DO usage between selected points on a stream.

The mean 5-day total, carbonaceous, and nitrogenous oxygen demands observed at 20 locations in the study area are listed in table 14. Also given are the 1971 mean ammonia-N and nitrate-N loads. The 1971 residual ammonia-N and nitrate-N loads and the 1972 residual ammonia-N, nitrite-N, and nitrate-N loads are shown in figures 7 and 8, respectively. The 1971 and 1972 data show similar patterns that basically dictate the downstream BOD characteristics. Between Lockport and Marseilles the am-

Table 14. Mean Oxygen Demand and Residual Ammonia and Nitrate-Nitrogen Loads, 1971 Sampling Dates

Station	Oxygen demand, BOD_5 (10^4 lbs/day)			Nitrogen loads (10^4 lbs/day)	
MP	*Total*	*Carbonaceous*	*Nitrogenous*	*Ammonia-N*	*Nitrate-N*
292.1	15.2	8.3	6.9	10.7	0.8
290.0	21.6	7.6	14.0	11.1	0.7
287.3	19.0	7.9	11.1	11.1	0.8
285.8	24.2	9.4	14.8	10.9	1.1
278.0	27.3	9.4	18.3	11.4	1.6
273.5	25.3	9.5	15.8	12.2	1.9
271.6	26.7	11.2	15.5	10.5	2.6
270.6	32.2	11.8	20.4	10.9	2.7
265.0	32.5	10.3	22.2	11.1	3.2
261.6	39.4	10.2	29.2	11.4	3.1
253.0	34.6	9.6	25.0	10.7	3.8
247.0	40.0	11.5	28.9	10.6	4.1
243.7	47.9	10.3	37.7	9.7	5.0
236.8	45.0	13.0	32.0	8.2	5.8
231.0	50.1	14.0	36.1	8.9	5.6
226.9	45.6	13.0	32.6	8.6	6.1
222.6	45.4	12.5	32.9	8.0	6.4
213.4	46.8	12.9	32.9	8.0	6.8
196.9	44.1	15.2	28.9	5.4	7.9
179.0	34.8	16.5	18.3	3.3	9.2

monia-N load appears relatively constant although some localized influences are evident. The sampling station at the confluence of the Kankakee and Des Plaines Rivers shows an apparent additive effect in 1971 and a diluting effect in 1972. A significant increase in ammonia-N occurred through the Brandon Road pool during 1972. The biochemical oxidation of ammonia-N commences around Marseilles and continues to Chillicothe, the head of Upper Lake Peoria.

The average ammonia-N loads at Lockport during 1971 and 1972 were 107,000 and 149,000 lbs/day, respectively. The estimated average upstream ammonia-N contributions from the three MSDGC treatment plants and from the Grand Calumet River total 106,800 lbs/day, a figure almost identical to the 1971 observed load. The somewhat higher 1972 values could be the result of possible increased combined sewer overflow because of the wet conditions that persisted during 1972. The theoretical ultimate BOD of the 1971 and 1972 ammonia-N loads at Lockport were approximately 489,000 and 681,000 lbs/day, respectively. Both constitute a tremendous potential demand on the DO resources of the upper waterway.

Figures 7 and 8 show an inverse relationship between ammonia-N and nitrate-N in a downstream direction. This is expected since the final product of nitrification is nitrate. However, the increase in nitrate-N is out of proportion to the decrease in ammonia-N; the reason for this is that the Kankakee and Fox Rivers contribute heavily to the nitrate-N load. This was particularly true during 1972 when the tributary flows were unusually high for summer. The sharp drop in the ammonia-N load at Marseilles during both years may be partially due to the Fox River discharge. The Fox River low flows are made up principally of well treated domestic sewage, and by the time these discharges reach the Illinois River they are partially or fully nitrified. Consequently, the Fox River discharge should be populated with viable nitrifying bacteria capable of immediately utilizing Illinois River ammonia-N as an energy source.

Nitrite, an intermediate oxidation product, usually occurs only in small quantities in an aquatic environment. As shown in figure 8, the nitrite-N load was relatively small in the upper waterway above Marseilles. Below Marseilles the nitrite-N load increases and appears to be correlated to the sharp decrease in ammonia-N load in this area.

The observed nitrogen concentrations and loads are tabulated in appendix C. Ammonia-N and nitrate-N concentrations were found to be significantly influenced by streamflow. For example, during 1971 concentrations of NH -N ranged from 2.45 to 6.12 mg/l at the uppermost station and from 0.45 to 0.86 mg/l at the lowermost station. Similarly NO-N concentrations varied from 0.08 to 0.46 mg/l at the upper end and from 1.42 to 2.66 mg/l at the lower end. The higher concentrations occurred at the lower flows.

The inverse relationship of the NH -N loadings to the NO_3-N loadings along the course of the waterway, as depicted in figures 7 and 8 and summarized in table 14, demonstrate some aspects of nitrification. However, figure 9 clearly shows the relative importance of the nitrogenous demand to the carbonaceous demand for DO in the Upper Illinois Waterway.

The carbonaceous demand curve suggests a slight upward trend in the downstream direction with some additions in the vicinity of the Kankakee River confluence and the Ottawa area. The carbonaceous demand is not, however, the primary load. The significance of the nitrogenous demand is reflected by the configuration of the total demand curve. That the maximum demand occurs at approximately the midpoint of the study area creates an illusion that the Chicago Metropolitan area is not the principal source of the demand load. This is indeed an illusion and is not supported, in fact, by the data depicted in figures 7 and 8 or knowledge of community and industrial sources along the reach (see table 2). The total demand curve, governed principally by the nitrogenous demand, reflects bacteria growth rather than organic waste additions along the watercourse.

The autotrophic nitrifying bacteria required for ammonia reduction have a generation time of 30 to 40 hours; the heterotrophs, which utilize carbonaceous organic matter, have a generation time in terms of minutes. Thus the nitrifiers require 5 to 6 days to generate a bacteria population sufficient to use the potential nitrogenous load. The 45-

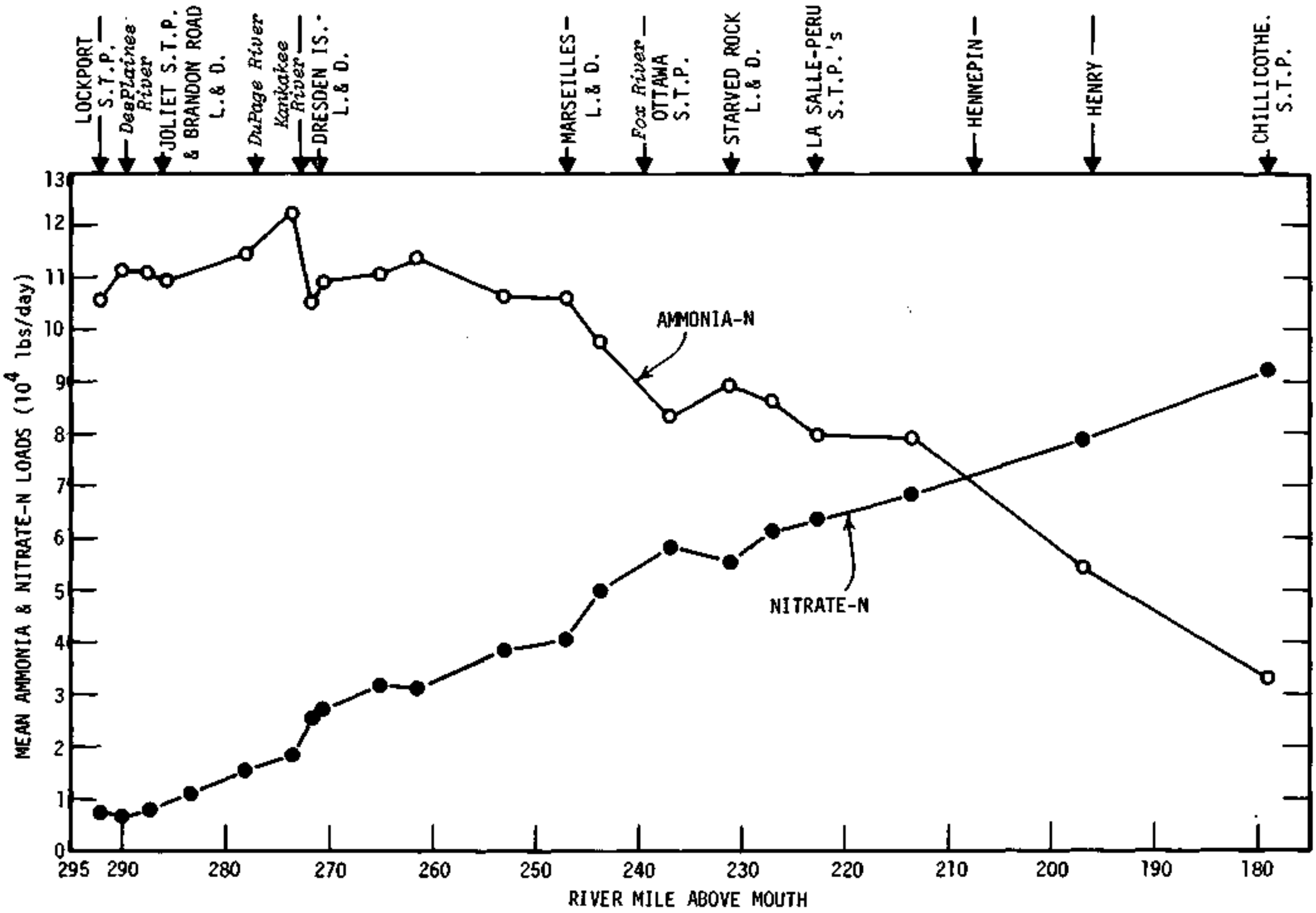

Figure 7. Mean ammonia—N and nitrate—N loads through study reach, 1971

mile distance between Lockport and the area of maximum demand load (near Marseilles) is equivalent to a time-of-travel of 5 to 6 days during moderately low flows. Consequently, in the lower reaches, the nitrifying bacteria have attained the high metabolic activity required for utilizing the ammonia originating in the Chicago area. These are the underlying reasons for the configuration of the total and nitrogenous demand loads depicted in figure 9.

In support of this reasoning, water samples were collected at MP 290.0, and long term BODs, up to 18 days, were observed. Results were similar for four samples and a representative finding is depicted in figure 10. The configuration of the nitrogenous demand curve indicates that nitrogenous bacteria do not become active for several days (lag period) whereas carbonaceous bacterial activity starts almost immediately. However, after a buildup of nitrifiers in about 5 days, an increasing rate of oxidation occurs up to 10 days from the time of incubation; thereafter, the rate of demand decreases. This curve supports the view that the waterway will be required to satisfy a nitrogenous demand somewhere along its downstream course, and further that any BOD curve developed for downstream stations will likely be a truncated portion of the whole curve shown in figure 10.

As an example of this, three BOD curves for three stations are shown in figure 11. The stations are MP 243.7, 213.4, and 179.0, and zero times for the curves represent 5—6 days, 6—7 days, and 11—12 days, respectively, travel time from Lockport. In other words, when these samples were collected they had already gone through the in-river incubation times noted. The BOD curves (a) and (b) represent that portion of figure 10 commencing after about 6 and 8 days, respectively, and curve (c) represents the uppermost portion of figure 10.

The demand loads depicted in figure 9 are the *mean* loads observed during the period of study. For this condition, the peak of the nitrogenous demand occurred in the vicinity of Marseilles. However, the apex of the demand load, being a function of the bacterial activity and thus dependent on time, will shift with streamflows. For higher streamflows (shorter time-of-travel between points) the shift of the maximum demand for oxygen will be downstream. Figure 12 demonstrates this phenomenon for moderately high flows (August 4, 1971), and shows the apex of the demand load near Chillicothe about 110 miles downstream of Lockport. For lower streamflows (longer time-of-travel between points) the shift of the maximum demand will be upstream. Figure 13, for September 20, 1971, represents

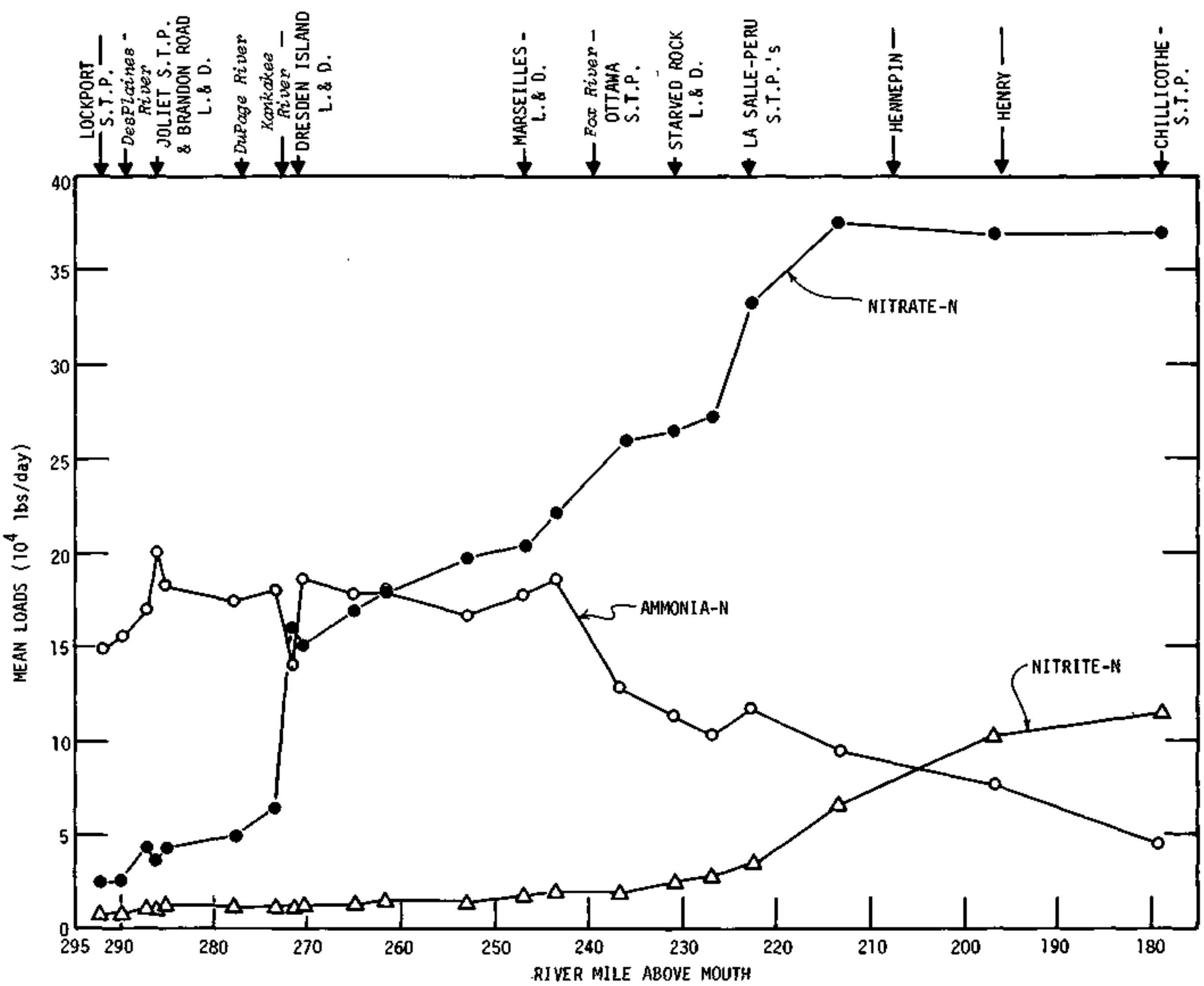

Figure 8. Mean ammonia-N, nitrite—N, and nitrate—N loads through study reach, 1972

this condition. In general, the maximum nitrogenous demand for oxygen in the Upper Illinois Waterway commences within 5 to 7 days flow time downstream of Lockport.

The rates of oxidation (K_1) were not successfully determined during this study because the maximum selected incubation period of 9 days was subsequently found to be too short. This realization prompted the long term incubation periods for samples collected from stations 292.1, 290.0, 287.3, and 285.8. The results from 18-day incubations of these samples *(see example in figure 10)* were substantial proof that the preconceived 9-day incubation period was unsatisfactory. Therefore, the samples from each station would have required incubation from 10 to 18 days for defining the rate of biochemical oxidation along the waterway.

To assess the reliability of the long term progression curves (figure 10) as applied to actual observations for total BOD_5 in the waterway, two of the progression curves for MP 290.0 were restructured into 5-day increments and plotted against time. The total BOD_5 observed at each station on September 20 was similarly plotted. As shown in figure 14, the similarity in configuration and magnitude is quite good considering the artificiality of the BOD tests. The results suggest that BOD progression curves for a station can be of value in predicting the shape and magnitude of 5-day BOD curves at some point downstream of that station. By the same reasoning a single 5-day BOD at some point along the Upper Illinois Waterway is meaningless and not worthy as a measure of water quality.

Benthic Oxygen Demand

Oxygen depletion as a result of benthic activity is influenced by two factors in the study area: 1) biological extraction of dissolved BOD by attached zoological growths, and 2) biological stabilization of deposited sediments, re-

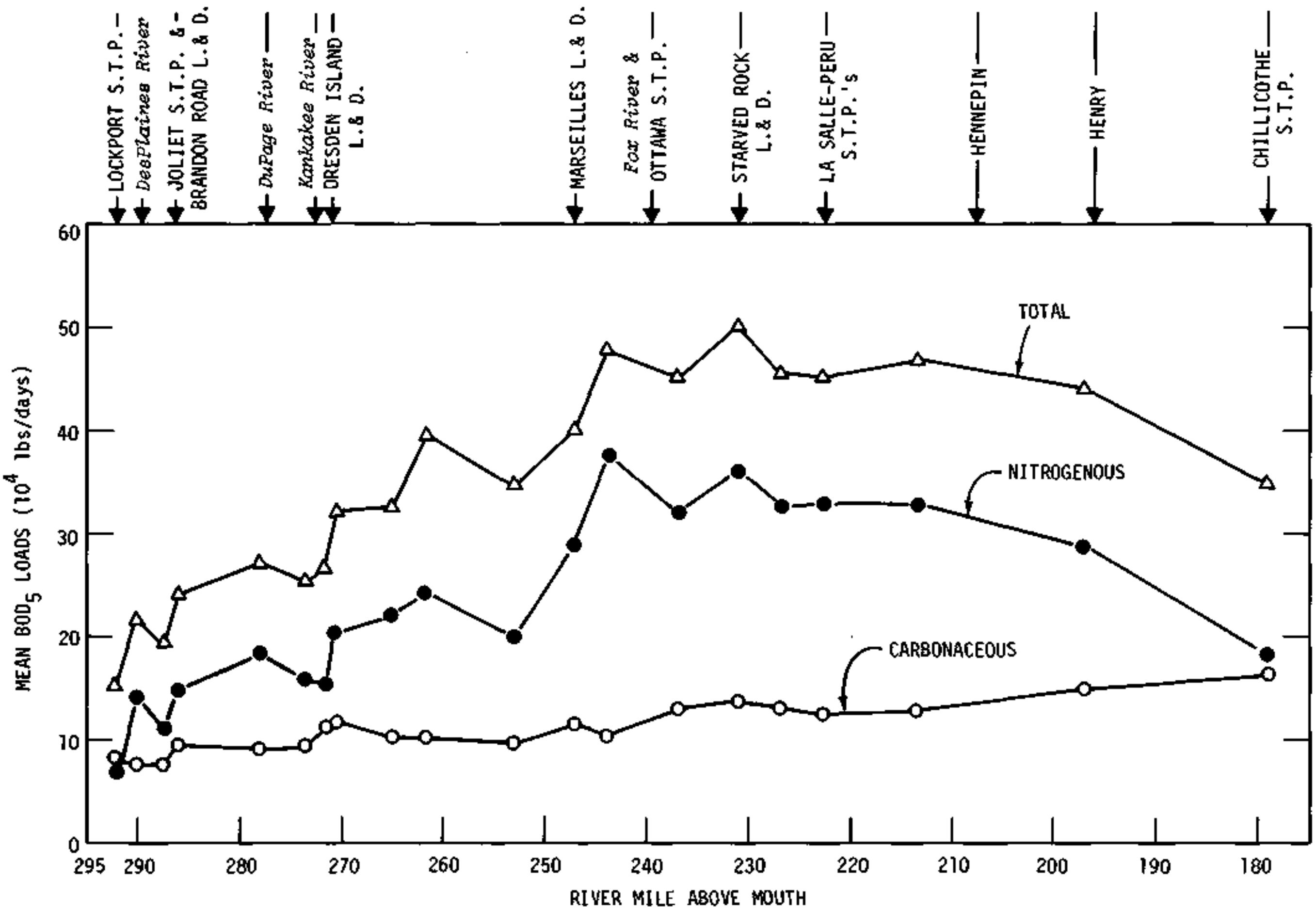

Figure 9. Mean BOD_5 loads per station through study area

ferred to as sediment oxygen demand (SOD). The SOD was measured directly in the field as briefly outlined in the section on sampling methods in this report. The influence of biological extraction was computed. For details of this investigation see Butts.[4]

Measured SODs are tabulated in table 15 and computed benthal extraction values are given in table 16. Areas within all pools except the Marseilles pool exhibited significant SOD rates. Values within the Marseilles pool are estimated to be less than 1 $g/m^2/day$ principally because the bottom sediments are mostly sand and gravel. On the basis of sediment composition and the volatile solids content, SOD extrapolations were made for the bottoms throughout the study area.

Benthal extraction generally occurs in rocky, shallow areas below the navigation dams, within the dam locks, and along riprap shore lines. The rates listed in table 16 are for areas immediately downstream of the dams, and the rates decrease markedly in the downstream direction. The values immediately below the Lockport dam in the Brandon Road pool are very high reflecting the large organic waste and nutrient loads being imposed upon the waterway at this point. The shore line consists of limestone riprap covered by a dense healthy zoological mass similar to that which occurs on the stone of a trickling filter treatment plant. Similar growth occurs on all the walls of the navigation locks; the fill and draw operation of locking promotes this growth in conjunction with dissolved BOD in the river water.

During low flow conditions, benthal oxygen usage is significant. When the SOD rate is given in terms of grams per square meter per day ($g/m^2/day$), the usage in terms of milligrams per liter per day (mg/l) within a reach can be computed by:

$$G' = (3.28\,Gt)/H \qquad (2)$$

where

G' = oxygen usage per reach, mg/l
G = sediment or benthal oxygen demand rate, $g/m^2/day$
t = time-of-travel in reach, days
H = average depth in reach, feet

The equation shows that, for a given SOD rate and time-of-travel value, wide shallow reaches will show greater DO depletions than will narrow deep reaches. Table 17 sum-

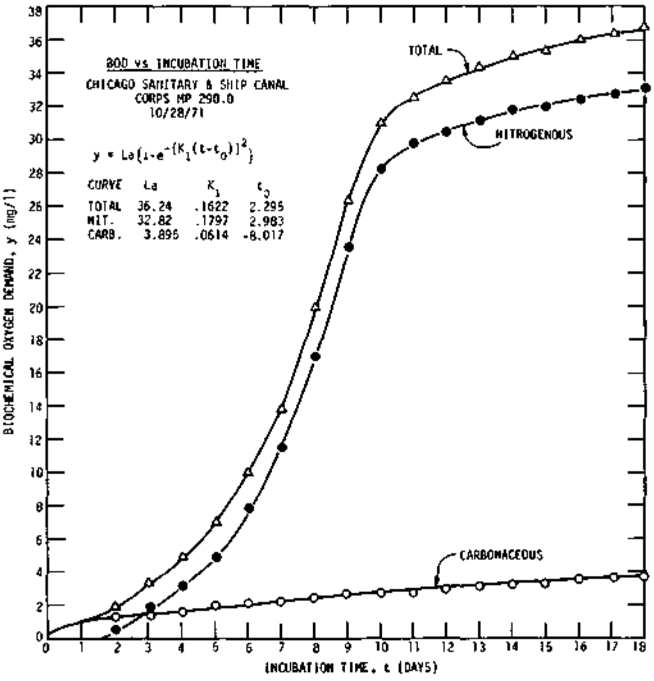

Figure 10. BOD progression curves, Brandon Road pool

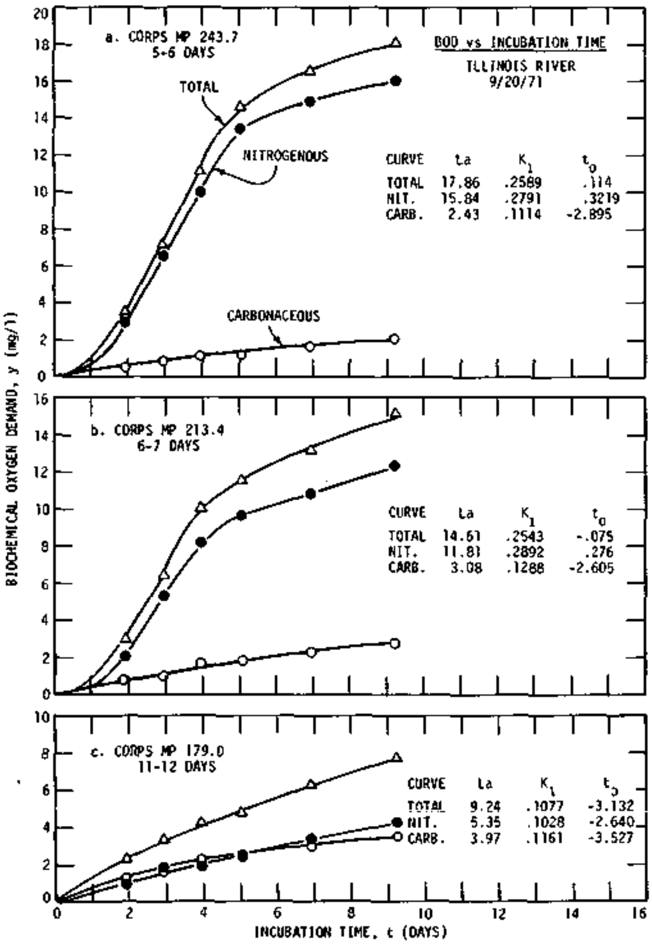

Figure 11. BOD progression curves, lower section

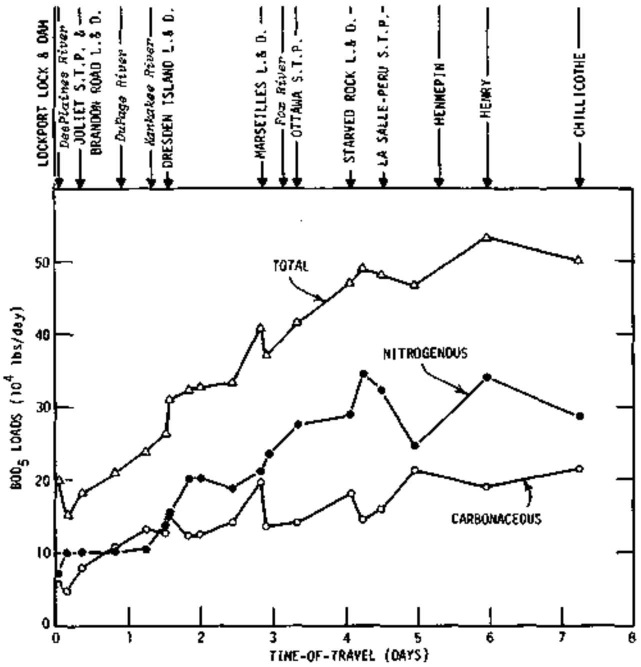

Figure 12. BOD versus time-of-travel for moderately high flow, August 4, 1971

marizes the effects of benthal oxygen demands within the pool areas under several flow conditions. DO usage is considerably greater for the 7-day 10-year low flow condition than for the two higher flow conditions.

Benthic Organisms

At 13 of the 22 stations sampled for SOD, bottom samples were examined for macroorganisms. The only organisms found were sludgeworms *(Tubifix)* and bloodworms *(Chironomus* larvae). The former occurred in massive quantities in the Brandon Road and Dresden Island pools. Table 18 lists the total number of invertebrates found at the 13 stations examined. The number of worms in the samples above mile 281.4 was so great that field picking and counting was impossible (they existed in terms of hundreds of thousands per square meter). The reason for making the counts was principally to determine where macroinvertebrates were present and in what numbers, since several researchers have found a high correlation between macroinvertebrate numbers and SOD rates.

Algae

Many factors affect the distribution, density, and species composition of algae in natural waters. These include the physical characteristics of the water, length of storage, temperature and chemical composition, *in situ* reproduction and elimination, floods, nutrients, human activities, trace elements, and seasonal cycles. Consequently, any

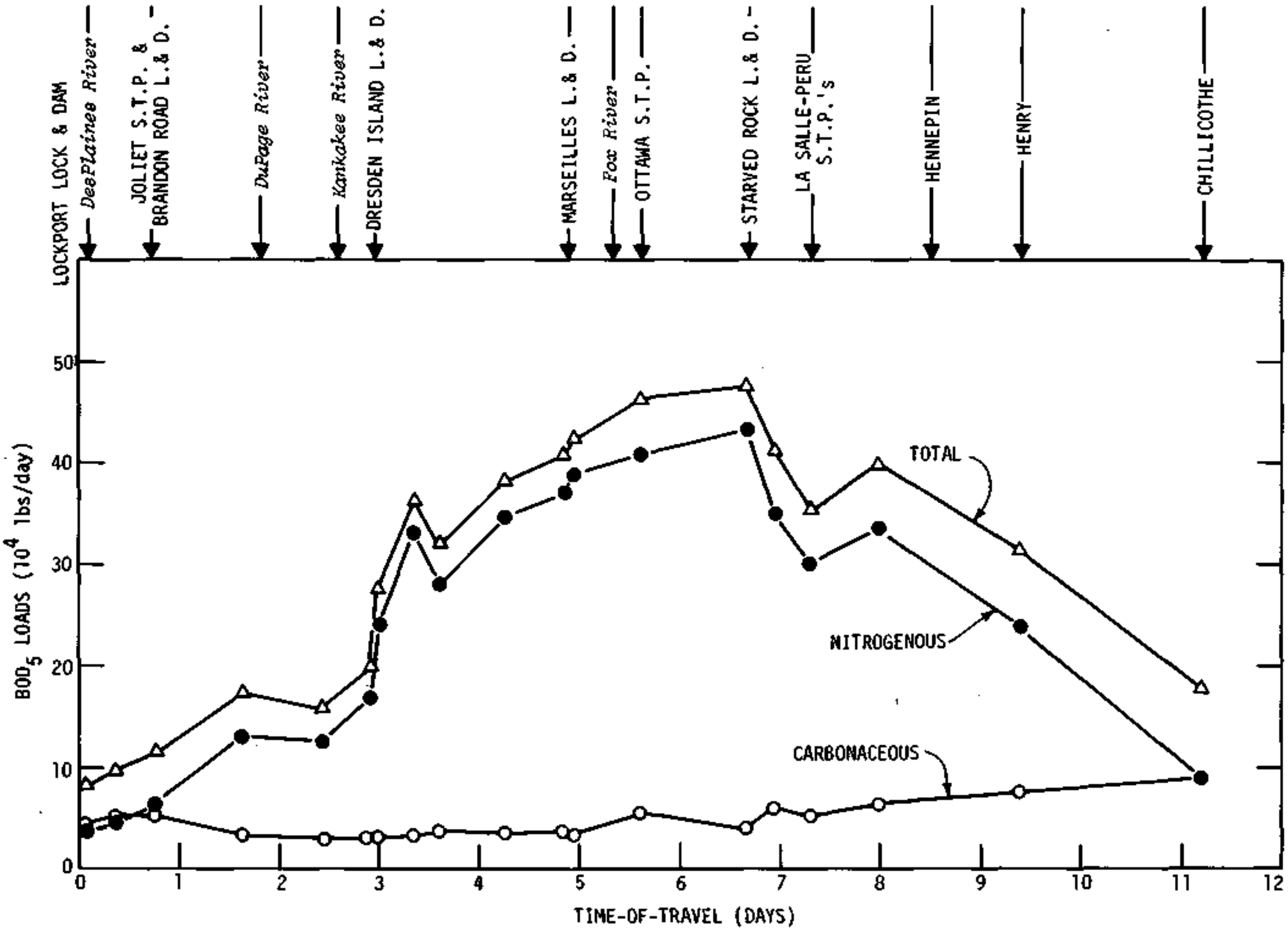

Figure 13. BOD versus time-of-travel for low flow date, September 20, 1971

definitive study of algae populations in a natural water must be of long term duration. There is, nevertheless, some merit in performing short term studies, particularly during periods of high temperature and low flow, if the interest in algal productivity is related to water-based recreation. The objectives of the algal phase of the study were threefold:

1) To determine and compare the densities, composition, and distribution of algae at various locations along the waterway.
2) To assess the relationship, if any, of algal densities to selected water quality indices (temperature, DO, BOD_5, coliform bacteria, and streamflow).
3) To ascertain the evaluation techniques best suited for detecting significant changes in the density, composition, and distribution of the algal community.

The 18 waterway stations selected for algae collections and their relationship to each pool are shown in figure 15, and algal densities for days of collection at each station are tabulated in appendix D. During the days of collection, streamflows ranged from 2766 to 7698 cfs at Lockport and

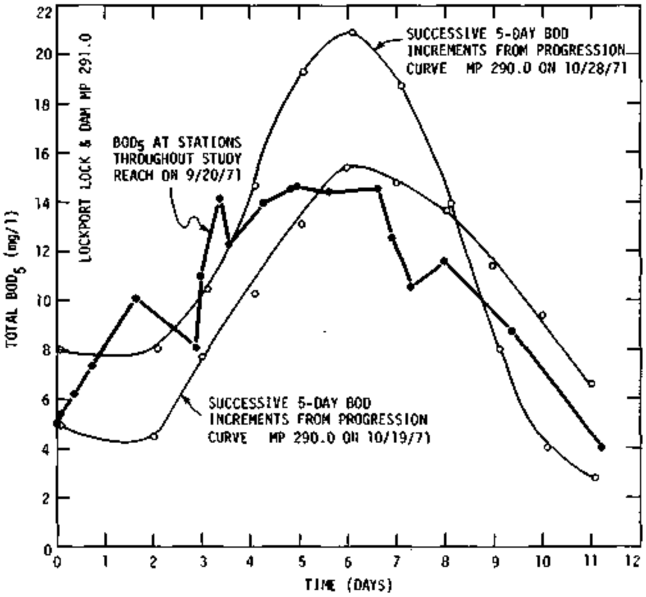

Figure 14. Comparison of station BOD_5 plots and 5-day BOD incremental plots for MP 290.0

Table 15. Summary of Sediment and SOD Characteristics

Station*	Percent dried solids	Percent vol. solids	Avg. water temp. (°C)	Sediment composition		SOD†
				silt-clay	*sand-gravel*	
(In Peoria Pool)						
179.0 L	43.6	9.5	27.8	x		1.37
179.0 R	55.7	9.4	27.1		x	0.96
183.0 R	49.6	8.8	27.0	x		3.07
187.5 L	68.4	4.6	26.8		x	1.38
193.0 L	63.2	5.5	28.0		x	0.56
198.8 L	53.8	7.6	28.0	x		2.82
204.6 L	75.5	3.3	26.2	x		1.52
208.2 L	75.3	3.8	26.0		x	1.03
(In Starved Rock Pool)						
231.7 R	60.6	5.0	22.3		x	1.44
234.2 R	76.4	3.0	22.5		x	1.49
(In Dresden Island Pool)						
271.7 C	56.2	7.5	19.6	x		1.25
275.5 L	43.6	15.4	22.3	x		4.13
276.9 R	56.3	9.0	24.0	x		8.08
277.4 L	76.8	2.6	23.9		x	6.45
278.0 L	43.0	14.7	26.9	x		2.80
278.9 R	77.0	2.5	28.3		x	2.18
280.6 L	59.2	11.4	25.7	x		2.42
281.4 C	25.1	25.7	26.7	x		4.69
282.3 L	57.5	19.7	25.6	x		2.57
282.3 C	76.6	5.8	25.4		x	2.11
282.8 R	51.8	10.6	25.1	x		4.58
283.6 R	33.9	13.5	25.0	x		5.00

* *Corps of Engineers milepoint, L and R indicate left side and right side of channel looking upstream, C indicates channel*

† *SOD in grams per square meter per day*

Table 16. Computed Benthal Extraction Rates

Pool	Reach	SOD (g/m²/day)
Brandon Road	290.1 – 290.0	44.8
Brandon Road	290.0 – 289.3	50.5
Brandon Road	289.3 – 289.2	50.1
Brandon Road	289.2 – 287.9	40.0
Dresden Island	285.4 – 285.1	1.1
Dresden Island	285.1 – 283.3	2.7
Marseilles	270.9 – 270.8	0.6
Marseilles	270.8 – 270.1	4.1
Starved Rock	246.4 – 246.3	0.3
Starved Rock	246.3 – 245.5	0.8
Peoria	230.9 – 229.6	0.1

Table 17. Computed DO Usage in Pools Due to SOD and Benthic Extraction

Pool		DO depletion *(mg/l)* for flow conditions at given periods		
		7-day 10-year	8/25/71	9/30/71
	Flow duration*	*M 99%*	*22.5%*	*66.0%*
		K 99+%	51.0%	64.5%
Brandon Road		3.1	0.9	2.4
Dresden Island		2.0	0.6	1.5
Marseilles		1.5	0.4	0.8
Starved Rock		1.6	0.5	0.9
Peoria		4.5	1.5	2.3

* *Percent of time a given flow is equaled or exceeded at Marseilles (M) or Kingston Mines (K) gages.*

Table 18. Invertebrate Populations at 13 SOD Sampling Stations

Station	Invertebrates *(number/m²)*
179.0 L*	800
179.0 R	600
183.0 R	650
187.5 L	350
193.0 L	650
198.8 L	450
204.6 L	900
231.7 R	210
234.2 R	130
277.4 L	400
278.9 R	11,000
280.6 L	4,000
281.4 R	30,000

* *L and R indicate left and right of channel looking upstream*

from 5330 to 10,990 cfs at Marseilles. Temperatures ranged from 20.4 to 31.0 C and were generally lower as the waters progressed downstream. Algal densities ranged from a minimum of 310 counts per milliliter (cts/ml) at MP 292.1 (Lockport pool) on July 28 to a maximum of 13,600 cts/ml at MP 222.6 (Peoria pool) on August 4. Algal densities exceeded 3900 cts/ml 25 percent of the time.

In Lackey's study[7] on plankton production on certain lakes in southeastern Wisconsin he arbitrarily selected 500 cts/ml as representative of an algal bloom for the purpose of his work. His definition has been perpetuated in such a manner as to suggest that algal densities in excess of 500 cts/ml are in all cases undesirable and of nuisance proportion. Most algal densities observed during the study period were in excess of 500 cts/ml, yet algal blooms of nuisance proportions did not exist on the waterway. The principal reason for this is that most of the plankters are diatoms; similar algal densities with blue-green as the predominant type would create different results. It is, therefore, inappropriate and misleading to characterize the environmental desirability of water solely on the basis of algal density without regard to the types of predominant plankters and the use to be made of the water.

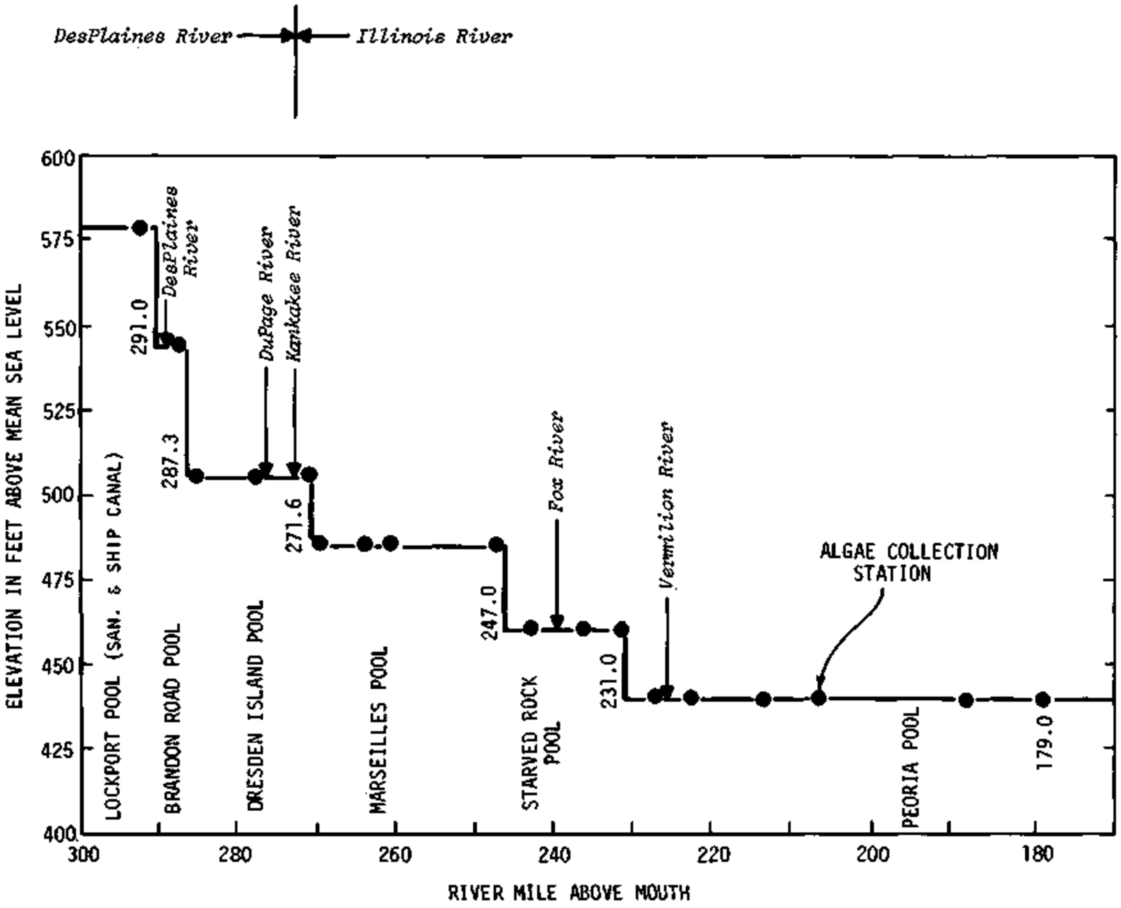

Figure 15. Profile of waterway with location of algae collection sites

Observations for four representative stations plotted on logarithmic probability paper formed a geometrically normal distribution pattern (straight line), as shown in figure 16. It seemed appropriate, therefore, to express central tendencies and the dispersion of the algal density data in geometric terms. The geometric mean (M_g) and dispersion characteristics for algal densities at each station are summarized in table 19. The geometric mean ranges from 1340 cts/ml at MP 292.1, the uppermost station, to 3790 cts/ml at MP 196.9, in the lower reach.

Comparing the geometric mean of a station with that at other stations by Duncan's multiple range test failed to reveal a clear-cut pattern of distribution. Cell counts for all stations within a pool were then combined and considered as representative of that pool. The distribution of 'pool means' was found to be geometrically normal and the geometric mean for each pool was plotted as shown in figure 17. The figure shows a trend of increasing algal population with progressive water movement downstream.

Other investigators have found water temperature to be the single most important factor affecting river plankton densities. Within the temperature ranges experienced in this work, there was no detectable correlation between algal den-

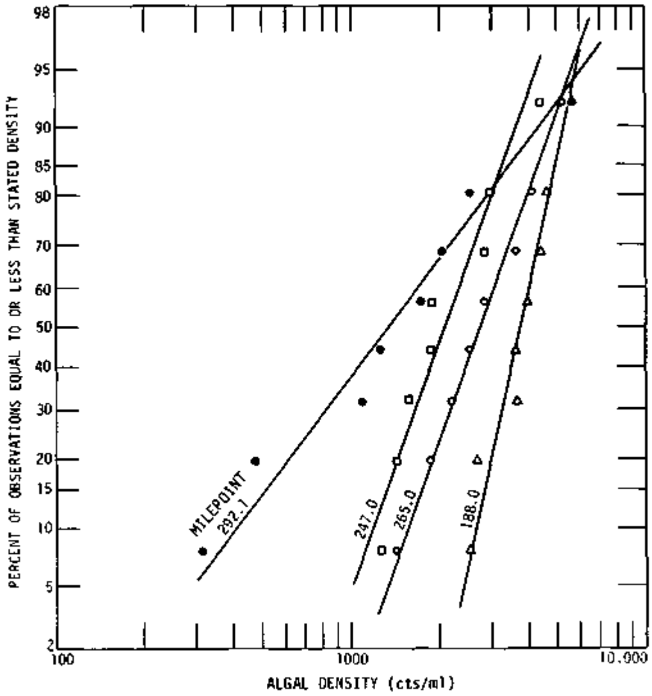

Figure 16. Probability of algal densities at selected stations

Table 19. Range, Mean, and Standard Deviation of Algal Densities, 1971 Sampling Dates

Station	Algal density per milliliter			Geometric standard deviation, σ_g
	Maximum	Minimum	Geometric mean, M_g	
292.1	5,650	314	1340	2.51
287.3	5,960	628	2110	2.01
285.8	4,870	1100	2240	1.61
278.0	5,020	785	2750	1.79
271.6	5,020	1100	2940	1.60
270.6	4,550	1100	2430	1.59
265.0	5,180	1410	2730	1.53
261.6	5,710	1410	2980	1.57
247.0	4,400	1260	2090	1.54
243.7	7,850	2200	3510	1.51
236.8	5,020	1100	2150	1.60
231.0	3,530	1730	3230	1.44
226.9	10,000	2040	3700	1.72
222.6	13,700	1880	3680	1.90
213.4	4,080	1730	2690	1.45
196.9	8,470	1880	3790	1.62
188.0	5,650	2510	3750	1.31
179.0	4,710	1730	2880	1.43

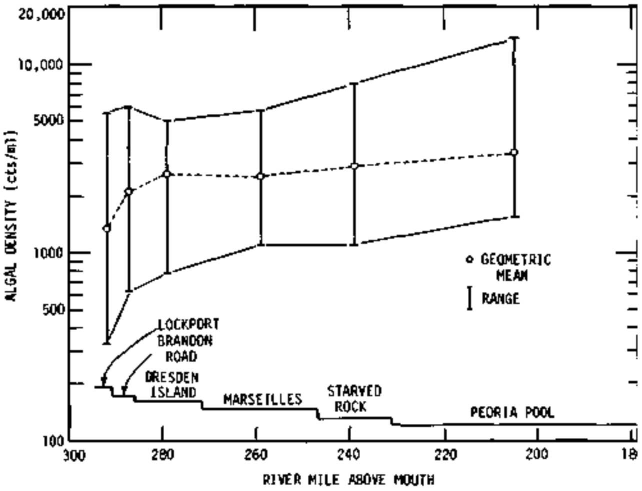

Figure 17. Distribution of algae in pools

sities and water temperature. Further, no correlation existed for algal densities with DO, BOD_5, coliform bacteria, and streamflow. It is conceivable that any attempt to define relationships of a gross plankton population with significant environmental factors is likely to be unfruitful. A more meaningful correlation might be gained by comparing specific genera with changes in environment, but since the composition of the algal population in the waterway was not diverse, this did not appear worthwhile.

The genera richness of the waterway is reflected by the tabulation in table 20. In the 144 collections, 23 algal genera were identified. During an earlier study in Peoria Lake, 38 genera were detected. Of the 23 genera, 1 was blue-green, 8 were greens, 13 were diatoms, and 2 were pigmented flagellates.

The dominant genera were the diatoms *Cyclotella, Nivacula* and *Melosira;* the green algae *Scenedesmus;* and the pigmented flagellate *Euglena.* These plankters occurred at all 18 collection stations with the exception of *Melosira* which was not detected at MP 292.1.

Diatoms were the predominant genera making up about 85 percent of the total algal density with *Cyclotella* accounting for 61 percent of the total density. There was no evidence, on the basis of occurrence, to suggest that any preferential habitat existed for algal production in the 113-mile reach.

The number of genera per sample as a function of total occurrence was found to be distributed in an arithmetically normal pattern. As shown in figure 18 the number of genera per sample ranged from 1 to 9 with a mean of 4.2; about 95 percent of the time the range was 3 to 6 genera per sample.

Of the many methods suggested for defining the structure of a biological community, the most widely used procedure has been the diversity index. Although different formulas have been used, the one determined by the information theory formula was chosen for this study, as follows:

$$D = -\sum_{i=1}^{m} p_i \log_2 p_i \qquad (3)$$

where p. = N_i/N_5 is the probability of the occurrence of the ith genera, N_i is the density of the *i* genera, N_5 is the total algal density of the sample, and *m* is the number of genera per sample. For convenience $\log_2 p_i$. may be expressed as 1.44 In p_i

The index *D* has a minimum value when $m = 1$ and a maximum value when $m = N_5$. The computed diversity indices for the waterway are summarized in table 21. The mean values observed for each navigational pool suggest the upper two pools have the least diversity in algal genera as well as the least mean algal density (see figure 17). Interestingly, the next downstream pool (Dresden Island) was the most diverse in algal genera as measured by the index. Although there was a wide range in the diversity index per station, 95 percent of the samples had indices between 1.0 and 2.0.

Wilhm and Dorris[8] proposed the use of the diversity index as a means for assessing degrees of water pollution. They suggest that an index of less than 1.0 is indicative of 'heavy' pollution, and from 1.0 to 3.0 representative of moderately polluted to reasonably clean water. Solely on the basis of these criteria the water quality of the Upper Illinois Waterway could be classified as moderately polluted.

There have been claims that the diversity index is the best parameter for assessing the effects of various chemicals and wastewater on an algal population. However, the use of the index here does not appear any more rewarding in evaluating algae communities in the Upper Illinois Waterway than the use of algal densities and algal richness.

Table 20. Algae Genera and Occurrence, 1971 Sampling Dates

Algal genus	MP 292.1	287.3	285.8	278.0	271.6	270.6	265.0	261.6	247.0	243.7	236.8
Blue-green algae											
Aphanizomenon			1	1	1	1	1	2	1		
Green algae											
Actinastrum	1	1			2		3	2	1	1	1
Ankistrodesmus									1		
Chlorella	1			2				1		1	
Coelastrum											
Oocystis			1							1	
Pediastrum		1	2	2	1	2	2		1		1
Scenedesmus	4	1	3	5	5	3	4	4	4	6	4
Ulothrix			1		1			1			1
Diatoms											
Caloneis		1		1							1
Cyclotella	8	8	8	8	8	8	8	8	8	8	7
Diatoma						1					
Fragilaria		1	1							2	1
Gyrosigma	4	3	1	2	2	4	1	2		2	
Melosira		2	1	1	1	2	1	5	2	2	1
Navicula	5	6	5	7	6	4	7	7	7	6	7
Nitzschia	1		1	1		1					
Stephanodiscus					2		1				
Surirella		1	1	3	3	1	1				2
Synedra	1	1	1	1			1	1	1		
Tabellaria	1	2	3	5	1	1	3				3
Pigmented flagellates											
Chlanydomonas											
Euglena	1	1	2	1	4	5	3	3	5	2	3
Number of genera at station	10	13	15	14	13	12	13	11	10	10	12

Algal genus	MP 231.0	226.9	222.6	213.4	196.9	188.0	179.0	Total occur-rence	No. of stations occurred	Average occur. per station
Blue-green algae										
Aphanizomenon		1	1		1	2	2	15	12	1.3
Green algae										
Actinastrum	2	3	3	1	1		1	23	14	1.7
Ankistrodesmus						1		2	2	1.0
Chlorella				1	1	1		8	7	1.1
Coelastrum	1							1	1	1.0
Oocystis	1		1		1	1		6	6	1.0
Pediastrum	1	1		3	3	1	1	22	14	1.6
Scenedesmus	4	4	6	3	5	5	5	75	18	4.2
Ulothrix		2				1		7	6	1.2
Diatoms										
Caloneis			1			1	3	8	6	1.3
Cyclotella	8	8	8	8	8	8	8	143	18	8.0
Diatoma		1						2	2	1.0
Fragilaria								6	5	1.2
Gyrosigma	2	2	1		1	1		28	14	2.0
Melosira	5	3	1	4	2	4	4	41	17	2.4
Navicula	6	7	8	6	7	7	6	114	18	6.3
Nitzschia								4	4	1.0
Stephanodiscus								3	2	1.5
Surirella	1	1	1	1		1		17	12	1.4
Synedra		1						8	8	1.0
Tabellaria		1	2	2	2	1		27	13	2.1
Pigmented flagellates										
Chlanydomonas				1				1	1	1.0
Euglena	3	3	2	2	4	2	2	48	18	2.7
Number of genera at station	11	14	12	11	12	15	10	218		

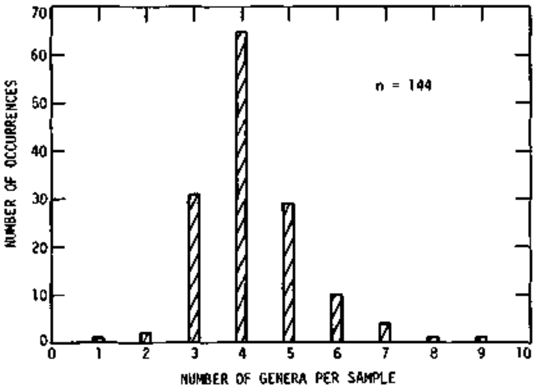

Figure 18. Frequency of occurrence of algae genera

Table 21. Algae Diversity Indices, 1971 Sampling Dates

	Run								Mean	
Station	1	2	3	4	5	6	7	8	Station	Pool
292.1	1.00	1.94	0.00	1.07	1.19	1.62	1.30	1.38	1.19	1.19
287.3	1.90	1.21	1.50	1.40	1.06	1.06	1.39	1.63	1.39	1.39
285.8	1.78	2.18	1.70	1.45	1.69	1.24	1.66	1.56	1.66	
278.0	2.34	1.43	1.19	2.34	1.98	1.29	1.34	1.44	1.67	1.65
271.6	1.00	1.87	1.67	1.37	1.91	2.06	1.01	1.95	1.61	
270.6	1.63	1.84	1.15	0.96	1.32	1.88	1.23	1.61	1.45	
265.0	1.75	1.26	1.61	2.48	1.42	1.43	1.21	1.61	1.60	1.52
261.6	2.47	1.19	1.28	1.67	1.45	1.32	1.82	1.50	1.59	
247.0	1.73	1.16	1.88	1.61	1.23	1.70	0.81	1.21	1.42	
243.7	2.23	0.79	1.05	1.53	1.24	1.30	1.64	0.98	1.34	
236.8	1.63	1.29	0.88	1.78	1.84	1.50	1.99	1.91	1.60	1.47
231.0	1.79	1.48	1.69	1.07	1.63	1.68	0.64	1.69	1.46	
226.9	1.29	1.18	1.76	1.83	1.89	1.61	1.63	1.64	1.61	
222.6	2.31	0.88	1.10	1.60	1.34	1.43	1.17	2.22	1.51	
213.4	1.10	2.16	1.69	1.24	1.46	1.36	1.24	2.01	1.53	1.57
196.9	2.12	0.91	1.10	2.01	1.65	1.91	1.61	1.70	1.62	
188.0	1.61	1.31	1.02	2.23	1.80	1.58	1.09	2.54	1.65	
179.0	2.12	1.26	1.35	1.67	0.95	1.62	1.26	1.91	1.52	
Mean	1.77	1.41	1.31	1.63	1.50	1.53	1.34	1.69	1.52	

In summary, the total number of algae at each station, and in each navigational pool, showed a logarithmically normal frequency distribution. Therefore, the central tendency and dispersion of algal densities are characterized by geometric terms. Algal densities ranged from a minimum of 310 cts/ml to a maximum of 13,600 cts/ml. The geometric means ranged from 1340 cts/ml at the uppermost station to 3790 cts/ml in the lower reach. Assessing algal densities on a pool by pool basis suggests an increase in algal densities progressively downstream. There was no visible evidence of a nuisance algal bloom during the study.

Efforts to correlate algal densities with water temperature, DO, BOD_5, coliform bacteria, and streamflows were not successful. Diatoms were the dominant algal group making up 85 percent of the total density, and the number of genera per sample collection, though ranging from 1 to 9, averaged 4.2. Solely on the basis of criteria suggested by some investigators in applying the diversity index for quantifying water quality, the waters of the Upper Illinois Waterway can be classified as moderately polluted. However, since no correlation existed between other factors related to water quality and algae, it would not seem prudent to define the degree of pollution and purity of the waterway solely from diversity indices.

In general, there does not appear to be any advantage in using a single technique, i.e., algal density, genera richness, or diversity index, over another in assessing algal community structures in the waterway. From the measurements employed it can be concluded that 1) the use of the waterway for recreation is not impaired by algae; 2) there is likely to be some filter clogging problems at water treatment plants if *Melosira* predominate; and 3) there does not appear to be a selective habitat conducive to extraordinary propagation of algae in the waterway.

Coliform Bacteria

Coliform bacteria have been used as the indicator tool to measure the occurrence and intensity of fecal contamination in natural waters for over 50 years. Until recently the total coliform group, a heterogenous collection of bacterial species, was the indicator of bacterial pollution. Since these bacteria are always present in the normal intestinal tract of humans and other warm-blooded animals, the absence of total coliform (TC) bacteria is evidence of bacteriologically safe waters. There are, however, several strains included in the total coliform group that are not common to fecal matter — some of soil origin — which introduce complications in assessing stream water quality. More recently the fecal coliform (FC) subgroup of the total coliform bacteria has been used to detect evidence of fecal pollution, and it is the bacteria indicator chosen by the Illinois Pollution Control Board for assessing water quality of Illinois surface waters.

The Illinois Pollution Control Board[9] (IPCB) has two rules regarding maximum permissible fecal coliform densities applicable to the Upper Illinois Waterway. One is a general standard for most Illinois streams and the other is for 'Restricted Use Water.' [Restricted use means certain designated waters which are not protected for aquatic life. In this study area, the restricted water extends from the uppermost station to MP 278.0 in the vicinity of the I-55 bridge.] The general standard is:

203(g) Based on a minimum of five samples taken over not more than a 30-day period, fecal coliform shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10% of the samples during any 30-day period, exceed 400 per 100 ml.

The 'restricted use' standard is:

205(d) Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms shall not exceed a geometric mean of 1000 per 100 ml, nor shall more than 10% of the samples during any 30-day period, exceed 2000 per 100 ml.

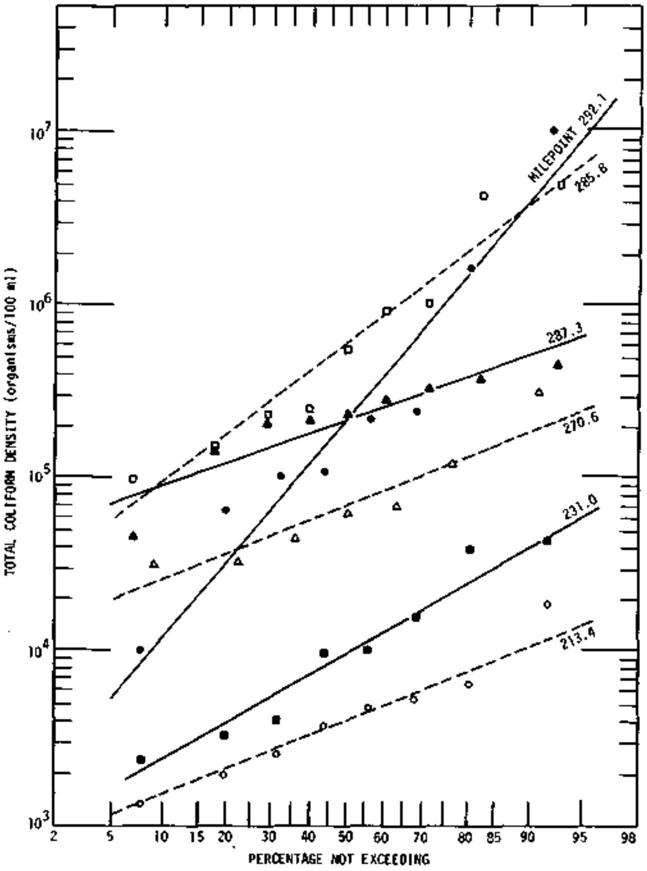

Figure 19. Probability of TC densities at selected stations

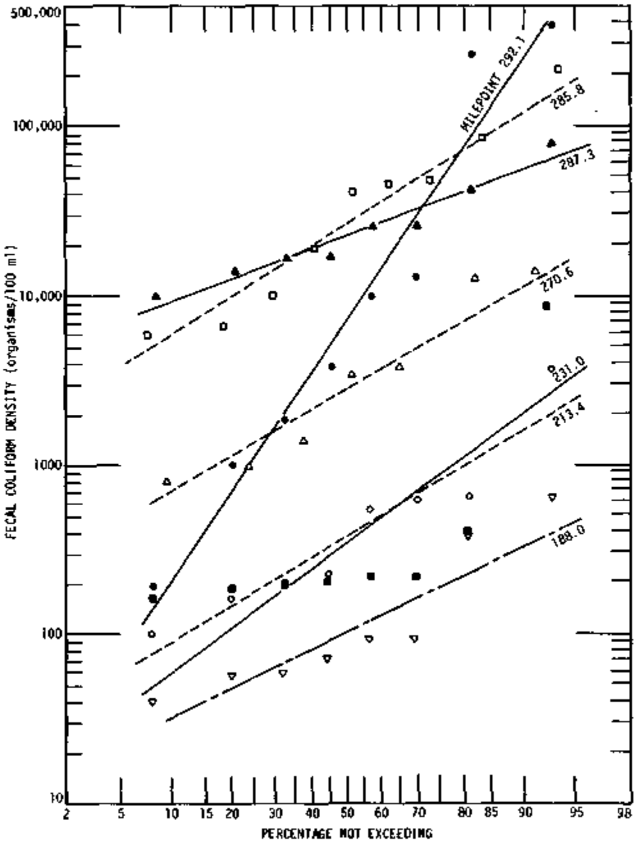

Figure 20. Probability of FC densities at selected stations

The bacteria sampling stations were the same as those used to collect algal samples (figure 15) except one station was added at MP 290.0. As in the case of the algal data, the bacterial densities were determined to be distributed in a geometrically normal pattern. Plots of total coliform and fecal coliform data on log probability paper are shown in figures 19 and 20, respectively. From the slopes of the distribution lines it appears that bacterial densities at MP 292.1 are likely to be considerably more variable than at the other stations shown.

The bacterial densities at each station for each collection are included in appendix E, and the ranges and geometric means for total and fecal coliform densities are summarized in tables 22 and 23, respectively. That bacteria densities, as measured by geometric means, progressively decrease with downstream water movement is illustrated in figures 21 and 22. The influence of waste treatment plants at Joliet, Morris, Marseilles, Ottawa, and La Salle-Peru is marked by pulses along the density curves.

Total and fecal coliform densities were quite variable and presumably a function of sampling days and downstream water movement. Total coliform densities ranged from a maximum of 9,900,000/100 ml at MP 292.1 to a minimum of 200/100 ml at MP 188.0 and 179.0. Similarly, fecal coliform densities varied from a maximum of 400,000/100 ml at MP 292.1 and 278.0 to a minimum of 4/100 ml at MP 179.0. Fecal coliform densities observed during July and August 1971 were evaluated in terms of the IPCB standards.

Five samples collected during August 4-31, 1971, were used for each of the upper stations from MP 292.1 to 247.0. Five samples obtained during July 28 to August 25 were used for the lower series of stations from MP 243.7 to 179.0. The observed data are depicted in figure 23 which also shows the 'limit lines' for fecal coliform of 200/100 ml and 1000/100 ml. Figure 23 shows that only three stations met IPCB rule 203(g): MP 226.9, 188.0, and 179.0. All but one station in the Peoria pool had geometric means less than 200/100 ml. All other pools had geometric means exceeding the IPCB bacteria standard by excessive margins.

Since the historical record of bacteriological examinations on the waterway is based principally on total coliform densities, determinations for FC:TC ratios were made to assess the historical bacterial data in terms of FC.

A summary of the FC:TC ratios for all stations and each navigation pool is given in table 24. The ratios vary from 0.002 to 0.38 with an overall average of 0.088. The overall average was lower than the 0.14 ratio found for the Ohio River.[10] Strobel[11] reported that the relationship between fecal coliforms and total coliforms varied with the source of

Table 22. Ranges and Means of Total Coliform Densities, 1971

Station or pool	Number of samples	Organisms per 100 milliliter			Geom. std. deviation, σ_g	Standard error	
		Minimum	Maximum	Geometric mean, M_g		log M_g	log σ_g
292.1	8	10,000	9,900,000	220,000	8.08	0.3209	0.2269
290.0	8	10,000	9,500,000	280,000	6.50	0.2874	0.2032
287.3	9	45,000	440,000	210,000	1.96	0.0977	0.0691
285.8	9	95,000	5,800,000	610,000	4.37	0.2133	0.1509
278.0	8	43,000	1,300,000	270,000	2.82	0.1592	0.2251
271.6	8	15,000	540,000	79,000	3.15	0.1761	0.1245
270.6	7	32,000	260,000	67,000	2.13	0.1244	0.0880
265.0	8	8,000	1,000,000	33,000	4.28	0.2232	0.1579
261.6	8	15,000	1,300,000	57,000	4.79	0.2042	0.1700
247.0	8	2,000	120,000	12,000	3.81	0.2052	0.1451
243.7	8	6,000	71,000	18,000	2.19	0.1202	0.0850
236.8	7	4,000	280,000	18,000	4.42	0.2338	0.1724
231.0	8	2,400	43,000	9,600	2.95	0.1658	0.1173
226.9	8	1,100	21,000	4,800	2.85	0.1607	0.1136
222.6	7	1,500	44,000	6,900	4.90	0.1795	0.1269
213.4	8	1,300	18,000	4,000	2.26	0.1250	0.0884
196.9	8	600	86,000	3,000	5.06	0.2489	0.1760
188.0	8	200	7,700	1,000	3.74	0.2025	0.1432
179.0	7	200	2,400	590	2.43	0.1460	0.2302
Lockport	8	10,000	9,900,000	220,000	8.08	0.3209	0.2269
Brandon Road	17	10,000	9,500,000	240,000	3.79	0.1404	0.0993
Dresden Island	25	15,000	5,800,000	240,000	4.70	0.1345	0.0951
Marseilles	31	2,000	1,300,000	34,000	4.21	0.1121	0.0793
Starved Rock	23	2,400	280,000	14,000	3.07	0.1014	0.0717
Peoria	46	200	86,000	2,500	4.08	0.0900	0.0623

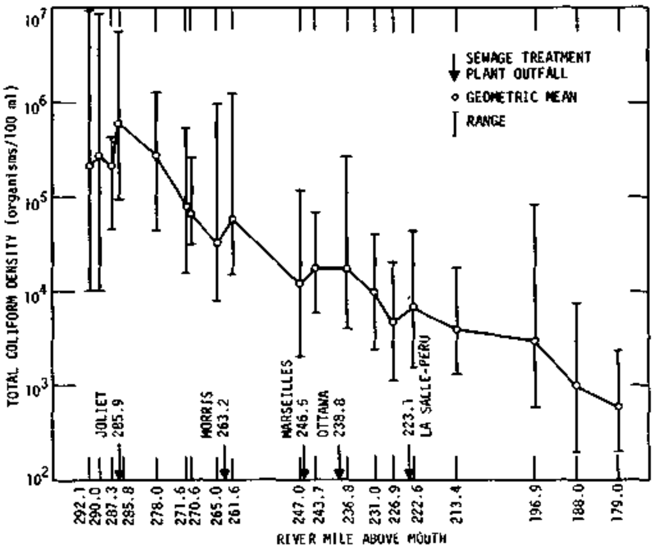

Figure 21. Density progression curve for total coliform

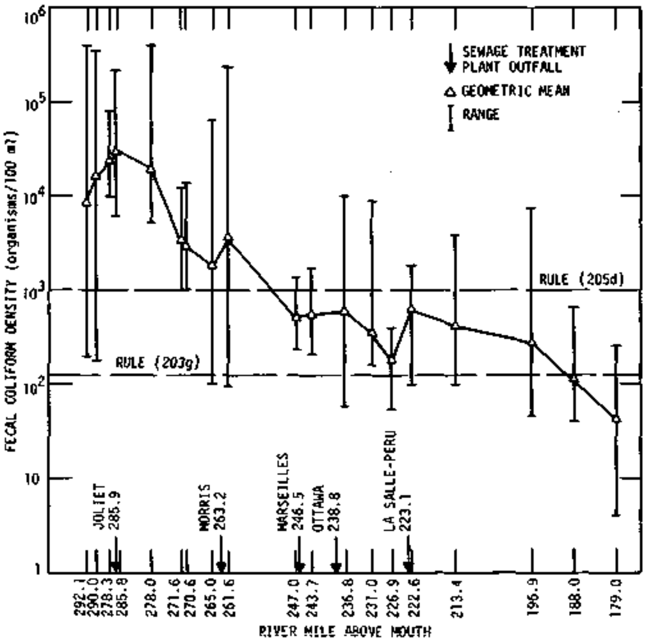

Figure 22. Density progression curve for fecal coliform

Table 23. Ranges and Means of Fecal Coliform Densities, 1971

Station or pool	Number of samples	Organisms per 100 milliliter Minimum	Maximum	Geometric mean, M_g	Geom. std. deviation, σ_g	Standard error log M_g	log σ_g
292.1	8	200	400,000	8,200	14.09	0.4062	0.2873
290.0	8	4,900	350,000	16,000	5.18	0.2526	0.1786
287.3	8	10,000	80,000	23,000	1.96	0.1029	0.0728
285.8	9	6,000	220,000	28,000	3.40	0.2170	0.1251
278.0	8	9,500	400,000	19,000	4.11	0.2170	0.1534
271.6	8	1,000	13,000	3,300	2.56	0.1442	0.1020
270.6	7	800	14,000	3,000	3.04	0.1823	0.1289
265.0	8	100	68,000	1,800	7.07	0.3004	0.2124
261.6	8	600	240,000	3,600	6.31	0.2829	0.2000
247.0	8	230	1,400	510	1.62	0.0744	0.0526
243.7	8	210	1,800	540	1.87	0.0957	0.0677
236.8	8	60	10,000	570	4.23	0.2216	0.1567
231.0	8	160	9,000	350	4.13	0.2179	0.1540
226.9	8	84	400	180	2.09	0.1131	0.0800
222.6	7	100	5,500	600	4.47	0.2458	0.1738
213.4	8	100	3,800	400	3.14	0.1758	0.1243
196.9	8	46	7,000	272	6.15	0.2790	0.1973
188.0	8	40	650	110	2.68	0.1514	0.1071
179.0	7	4	260	42	3.04	0.2193	0.1551
Lockport	8	200	400,000	8,200	14.09	0.4062	0.2873
Brandon Road	16	4,900	350,000	19,000	3.42	0.1335	0.0944
Dresden Island	25	1,000	400,000	12,000	4.86	0.1372	0.0970
Marseilles	31	100	240,000	1,700	5.41	0.1317	0.0931
Starved Rock	24	60	10,000	470	3.20	0.1030	0.0728
Peoria	46	4	7,000	200	4.44	0.0955	0.0661

pollution, level of treatment provided, characteristics of the receiving waters, and precipitation on the watershed. The ORSANCO committee[10] felt that high FC:TC ratios might indicate the proximity of inefficient waste treatment plants; low ratios are most likely caused by aftergrowths of *Aerobacter aerogenes* which produce abnormally high TC counts.

There have been many studies[12-22] concerning the die-off rates of bacteria in streams and most of the work suggests that Chick's law, one of the first mathematical formulations for describing die-off curves, remains quite applicable for estimating the survival of pathogens and nonpathogens of special interest in stream sanitation investigations. The law is:

$$N = N_0 \, 10^{-kt} \tag{4}$$

or

$$\log N/N_0 = -kt \tag{5}$$

where N_0 and N are bacterial densities at time 0 and t days, respectively, and k is the die-off or death rate.

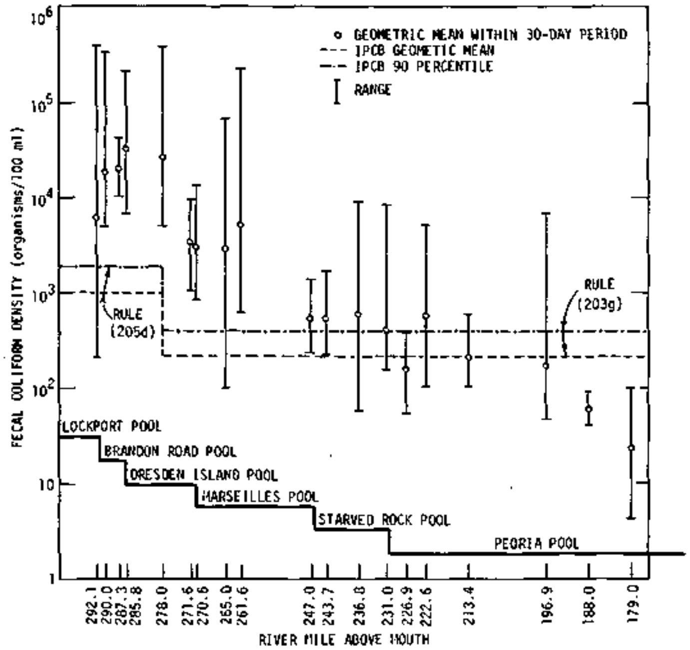

Figure 23. Evaluation of FC data with IPCB rules

Table 24. The FC:TC Ratio for the Upper Illinois Waterway

Station or pool	Number of samples	FC:TC ratio *Minimum*	*Average*	*Maximum*
292.1	8	0.003	0.064	0.17
290.0	8	0.025	0.072	0.18
287.3	8	0.043	0.106	0.20
285.8	9	0.007	0.084	0.22
278.0	8	0.018	0.123	0.33
271.6	8	0.017	0.065	0.20
270.6	7	0.019	0.055	0.15
265.0	8	0.013	0.070	0.19
261.6	8	0.024	0.078	0.18
247.0	8	0.012	0.067	0.18
243.7	8	0.007	0.044	0.09
236.8	7	0.022	0.052	0.12
231.0	8	0.006	0.059	0.21
226.9	8	0.002	0.044	0.09
222.6	7	0.002	0.106	0.27
213.4	8	0.042	0.109	0.21
196.9	8	0.013	0.137	0.38
188.0	8	0.012	0.170	0.36
179.0	7	0.007	0.148	0.30
Lockport	8	0.003	0.064	0.17
Brandon Road	16	0.025	0.089	0.20
Dresden Island	25	0.007	0.090	0.33
Marseilles	31	0.012	0.068	0.19
Starved Rock	22	0.006	0.054	0.21
Peoria	46	0.002	0.118	0.38
Overall	148	0.002	0.088	0.38

Fair and Geyer[19] proposed a similar model to describe the decreasing phase of the curve, as follows:

$$N/N_0 = (1 - nkt)^{-1/n} \qquad (6)$$

where n is a coefficient of nonuniformity. When $n = 0$ equations 6 and 4 are the same.

The work of Frost and Streeter[17] and more recently that of Klock[20] have led to similar mathematical expressions. However, the probable errors in stream sampling, bacterial enumeration, temperature changes, and other limitations in field work would suggest the use of a simple mathematical expression. For that reason Chick's formulation was chosen.

Before Chick's law was applied to the data they were transformed to bacterial population equivalents (BPE) in the manner proposed by Kittrell.[12] The following expressions were used for TC and FC data:

$$BPE = Q(\text{cfs}) \times TC/100\text{ ml} \times 6.1 \times 10^{-5} \qquad (7)$$

$$BPE = Q(\text{cfs}) \times FC/100\text{ ml} \times 6.1 \times 0.964 \times 10^{-5} \qquad (8)$$

Here the FC:TC ratio was assumed to be 0.964 as reported by Geldreich.[21]

Average streamflows and geometric means were used for BPE calculations. Plots of BPE versus time-of-travel on semilog paper are shown in figures 24 and 25 for TC and FC data. Reasonably good straight lines of fit were developed. It was determined that the decline in the bacteria population could best be characterized by considering the study area in two sectors, that is, an upper portion extending from MP 285.8 to 246.9 (Dresden Island and Marseilles pools), and a lower portion extending from MP 246.9 to 179.0 (Starved Rock and Peoria pools). The estimated decay or

Table 25. Coliform Death Rates

(Death rare k *per day)*

Sampling period 1971	Coliform type	Upper pools	Lower pools
July 28 – Aug 31	TC	0.79	0.52
	FC	1.17	0.47
Sep 20-28	TC	0.43	0.27
	FC	0.36	0.36
July 28 – Sep 28	TC	0.62	0.33
	FC	0.77	0.42

Table 26. Coliform Death Rates Observed in Rivers

River	Death rate $k(day^{-1})$ Warm weather	Cool weather	Authority for data	Remarks
Upper Illinois	0.90	0.32	Hoskins	1-day decline
	0.67	0.29	et al.	2-day decline
Ohio	0.50	0.45	Frost, Streeter et al.	Generalized results of analysis of extensive data
Scioto	0.96	0.46	Kehr et al.	
Hudson	0.80		Hall, Reddick, Phelps	Freshwater reach below Albany
Upper Miami	0.80		Velz, Gannon, Kinney	Mean through reach above Dayton
Tennessee	0.46		Kittrell	1- and 2-day declines, below Knoxville
Tennessee	0.60		Kittrell	1-day decline
	0.57			2-day decline, below Knoxville
Sacramento	0.77		Kittrell	1-day decline
	0.65			2-day decline, below Sacramento
Missouri		0.30	Kittrell	1-day decline
		0.26		2-day decline, below Kansas City

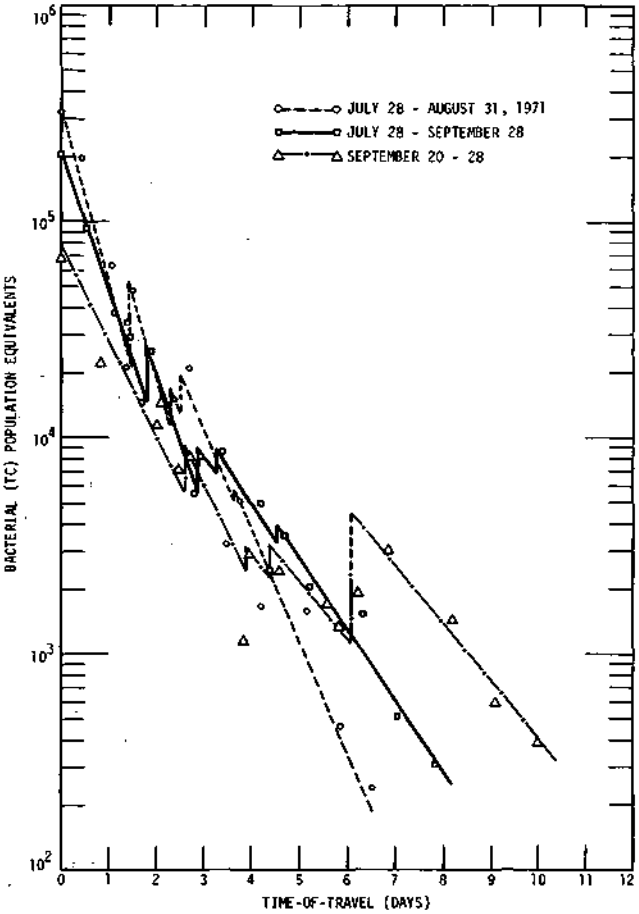

Figure 24. Integration of TC data in relation to time-of-travel from zone of maximum density (MP 285.8)

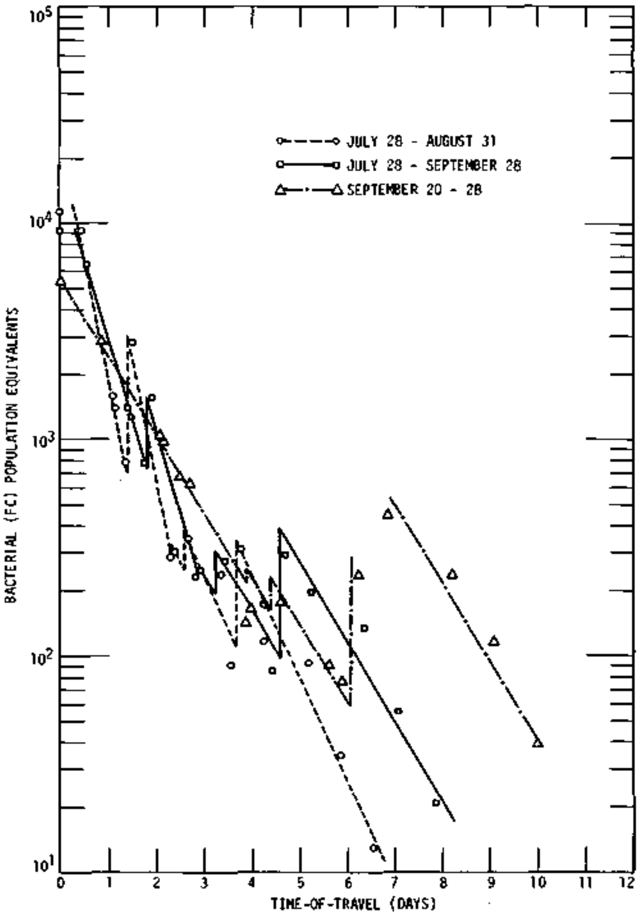

Figure 25. Integration of FC data in relation to time-of-travel from zone of maximum density (MP 285.8)

death rates for TC and FC in the two sectors for different sampling periods are summarized in table 25.

In general, bacterial death rates were higher in early summer than in late summer, and the rates were higher in the upper pools than in the lower pools. For reference as well as comparison, a summary from Velz[13] is included in table 26. Here it is shown that work by Hoskins et al.,[22] reported in 1927, produced a death rate for the Illinois River of 0.67 during warm weather after 2 days of travel compared with a rate of 0.62 developed from this study during warm weather on the upper pools.

In summary, total coliform and fecal coliform bacteria, like algal populations, showed a logarithmic normal frequency distribution. Total coliform densities ranged from 9,900,000/100 ml to 200/100 ml; fecal coliform densities ranged from 400,000/100 ml to 4/100 ml. Only 3 of 19 stream sampling stations met the bacterial quality required by IPCB standards. Fecal coliforms, on the average, represented about 9 percent of the total coliform population which was somewhat lower than the average of 14 percent observed on the Ohio River. Bacterial densities decreased with downstream movement at overall death rates for FC of 0.77 in the upper pools of the study area and 0.42 in the lower pools.

BOD AND DO MODELING

The acceptability of dissolved oxygen levels in the Upper Illinois Waterway is governed by two rules of the Illinois Pollution Control Board. One applies to all waters except those designated as 'Restricted Use Water' and is:

203(d) Dissolved oxygen shall not be less than 6.0 mg/l during at least 16 hours of any 24 hour period, nor less than 5.0 mg/l at any time.

The rule applicable to 'restricted use' water is:

205(c) Dissolved oxygen shall not be less than 3.0 mg/l during at least 16 hours of any 24 hour period, nor less than 2.0 mg/l at any time.

Within the Upper Illinois Waterway study area, one portion has been designated as 'Restricted Use Water.' It is "The Des Plaines River from its confluence with the Chicago

Sanitary and Ship Canal to Interstate 55 bridge."

This expanse of water, for all practical purposes, extends from Lockport (MP 291.0) downstream to about MP 278.0 and includes all of the Brandon Road pool and the upper 8 miles of the 14.5-mile long Dresden Island pool.

To determine the waste load reductions needed to meet these dissolved oxygen objectives mathematical modeling of the BOD—DO characteristics of the waterway was attempted. The procedures and methods used are outlined in Illinois State Water Survey Circular 110.[23] Only the most basic formulations from which the models were developed are given here; Circular 110 should be referred to for more detailed information.

BOD Model

Generally the long term BOD or DO usage in a stream is modeled as a first order exponential reaction, i.e., the rate of biological oxidation of organic matter is directly proportional to the remaining concentration of unoxidized material. The integrated mathematical expression representing this reaction is:

$$L = L_a(1 - e^{-K_1 t}) \tag{9}$$

where

L = oxygen demand exerted up to time t
L_a = ultimate oxygen demand
K_1 = reaction rate, per day
t = incubation time, days

When a delay occurs in oxygen uptake at the onset of a BOD test, a lag time factor, t is included and equation 9 becomes:

$$L = L_a[1 - e^{-K_1(t - t_o)}] \tag{10}$$

For the Upper Illinois Waterway, equation 10 was at times found to fit observed BOD progression curves poorly, because most of the BOD in the upper reaches of the upper waterway consists of second stage or nitrogenous oxygen demand. Many of the total and nitrogenous BOD curves have an S—shape configuration similar to that shown in figure 10. The general mathematical model used to simulate the S—shape curve is:

$$L = L_a(1 - e^{-[K_1(t-t_o)]^x}) \tag{11}$$

where x is a power factor and the other terms are the same as previously defined. Experimental data were analyzed to determine the value of x for which consistently good fits were achieved. The power factor was arbitrarily assigned values of 1.0, 1.9, 2.0, and 2.1, and the best fits with these factors were achieved by the method of steepest descent programmed on a digital computer. Table 27 shows the results of the analyses for station 292.1 for four sampling dates. The data for the other three stations are tabulated in appendix F.

The standard errors of estimate (indicators of goodness-of-fit) indicate that a power factor in the vicinity of 2.0 provides a much better fit to the total and nitrogenous data than does the first power formula described by equation 10. For the total BOD data for station 292.1 on October 21, 1971, the power factor was increased in various increments up to 3.5. The standard error of estimate was reduced to 0.96 compared with a value of 1.14 for the 2.0 factor. This slight increase in accuracy did not appear to warrant the use of a factor greater than 2.0. Consequently, the following equation was used to represent S—shaped total and nitrogenous BOD progression curves similar to those illustrated in figure 10.

$$L = L_a(1 - e^{-[K_1(t-t_o)]^2}) \tag{12}$$

The carbonaceous data in table 27 show that the first stage BOD is readily described by first order kinetics, and that equation 10 is appropriate for modeling the carbonaceous BOD in the Upper Illinois Waterway. Note that first order equation lag time is negative but to a lesser degree than for the power equations. The negative time lag can be interpreted as an indicator that the carbonaceous BOD commences immediately upon incubation, and when translated to stream conditions, the carbonaceous BOD is already progressing rapidly at the point in the stream where the sample was taken.

On all four days, the nitrogenous BOD appeared to commence in slightly more than three days. A three day time-of-travel below Lockport appears to be a good estimate for the location at which nitrogenous BOD starts to progress rapidly in the waterway. The exact location will depend upon hydraulic conditions within the waterway. As an example for 7-day 10-year low flow conditions, nitrification will start in the Dresden Island pool a short distance above the confluence of the Kankakee River at MP 273.0. However, for relatively high flow conditions, such as occurred on July 18, 1972, nitrification would not start until approximately MP 196.0, in the vicinity of Henry in the Peoria pool.

Because of the instantaneous carbonaceous BOD reaction and the delayed nitrogenous BOD reaction, low flow DO usage in the Brandon Road and Dresden Island pools will be primarily due to dissolved carbonaceous BOD, benthic extraction, and sediment oxygen demand. However, oxygen usage below the Dresden Island dam will be primarily due to nitrification as demonstrated by the model. The model data support the observed ammonia degradation curves shown in figures 7 and 8.

The bottle BODs represent only potential usage of oxygen during stabilization of dissolved and/or colloidal matter by microorganisms. Consequently, bottle BODs when used alone to simulate DO sag curves give DO values considerably above observed profiles because a significant amount of oxygen usage may result from benthic extraction and sediment oxygen demand. A method for incorporating all these factors into one function with the use of observed river DOs and aeration theory is outlined in Circular 110.[23] Within

Table 27. BOD Curve Fitting Summary, Station 292.1

Power factor	K_1 *(1/day)*	L_a *(mg/l)*	t_o *(days)*	Standard error	Power factor	K_1 *(1/day)*	L_a *(mg/l)*	t_o *(days)*	Standard error
		10/19/1971					**10/28/1971**		
Total BOD					*Total BOD*				
1.0	.08512	44.33	2.750	3.02	1.0	.10473	42.14	2.877	2.82
1.9	.12593	33.66	2.334	1.48	1.9	.15643	32.64	2.776	1.09
2.0	.12071	33.51	1.971	1.43	2.0	.15113	32.52	2.540	1.07
2.1	.11608	33.44	1.639	1.37	2.1	.14557	32.43	2.277	1.04
Carbonaceous BOD					*Carbonaceous BOD*				
1.0	.08581	5.22	−1.299	0.15	1.0	.14568	3.31	−0.332	0.07
1.9	.07256	4.43	−6.041	0.15	1.9	.09799	3.07	−4.322	0.08
2.0	.07024	4.40	−6.560	0.15	2.0	.09362	3.06	−4.810	0.08
2.1	.06771	4.38	−7.131	0.15	2.1	.08988	3.05	−5.268	0.08
Nitrogenous BOD					*Nitrogenous BOD*				
1.0	.08155	39.70	3.017	2.81	1.0	.09817	39.41	3.181	2.88
1.9	.14477	28.70	3.354	1.02	1.9	.16139	29.64	3.220	0.94
2.0	.14367	28.50	3.243	0.97	2.0	.16030	29.44	3.121	0.87
2.1	.14163	28.32	3.095	0.93	2.1	.15830	29.32	3.008	0.83
		10/21/1971					**11/9/1971**		
Total BOD					*Total BOD*				
1.0	.09256	39.35	2.854	2.79	1.0	.10473	52.79	2.418	5.22
1.9	.14359	30.01	2.727	1.16	1.9	.11631	44.38	2.767	2.06
2.0	.13693	29.86	2.374	1.14	2.0	.11432	44.15	2.570	2.00
2.1	.12991	29.91	2.014	1.12	2.1	.11171	43.87	2.315	1.95
Carbonaceous BOD					*Carbonaceous BOD*				
1.0	.22984	2.89	−0.001	0.11	1.0	.06757	12.46	−0.023	0.30
1.9	.13147	2.79	−3.301	0.08	1.9	.07380	9.63	−3.679	0.22
2.0	.12486	2.79	−3.699	0.08	2.0	.07325	9.50	−3.973	0.22
2.1	.11959	2.79	−4.052	0.08	2.1	.07104	9.45	−4.446	0.21
Nitrogenous BOD					*Nitrogenous BOD*				
1.0	.08847	36.87	3.144	2.63	1.0	.07323	44.36	2.994	4.74
1.9	.15096	27.16	3.365	0.81	1.9	.11869	35.41	3.418	1.78
2.0	.15024	26.90	3.259	0.78	2.0	.11819	35.44	3.358	1.61
2.1	.14922	26.68	3.148	0.78	2.1	.12036	34.81	3.338	1.46

a given reach total DO usage, which can be interpreted as an all encompassing BOD, can be schematically formulated as:

$$DO_u = DO_a - DO_n + DO_r + DO_x \qquad (13)$$

where

DO_u = dissolved oxygen consumed biologically within a reach
DO_a = initial dissolved oxygen of a reach
DO_n = dissolved oxygen at the end of a reach
DO_r = dissolved oxygen derived from natural aeration within a reach
DO_x = dissolved oxygen from tributaries

An accumulative sum of the DO_u values versus time-of-travel can be fitted to equations 10 and 12, and ultimate river BOD loads (L'_a) and reaction rates (designated K'_a,) can be determined. Figures 26 and 27 illustrate the results of fitting equations 10 and 12 to data generated by this technique. Generally, a pool was taken as a reach; however, when the plots (figures 26-27) showed a dramatic change in slope, the pool was broken up into two reaches at the deflection point. Also, as shown by figure 4, the Starved Rock pool DO profile often appeared as a continuation of the Marseilles pool profile. When this occurred, the profiles for the two pools were assumed to be an extension of each other and were modeled as one.

Appendix G contains a listing of the results of fitting equations 10 and 12 to all the DO_u versus time-of-travel data for all the pools during the 28 sampling days. The best fit was determined by examining the standard error of estimate. A close examination of these data will reveal that

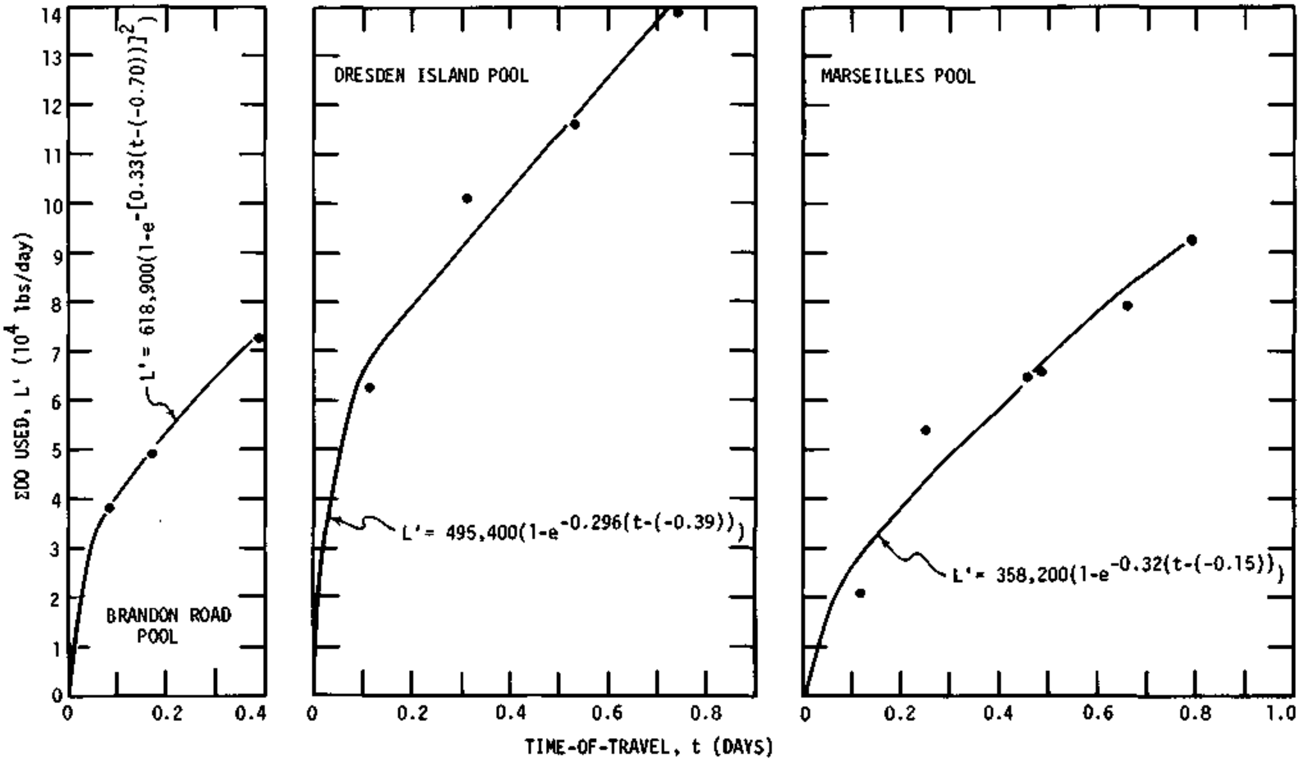

Figure 26. Curve fitting for estimating ultimate loads, L'_a and rates, K'_d

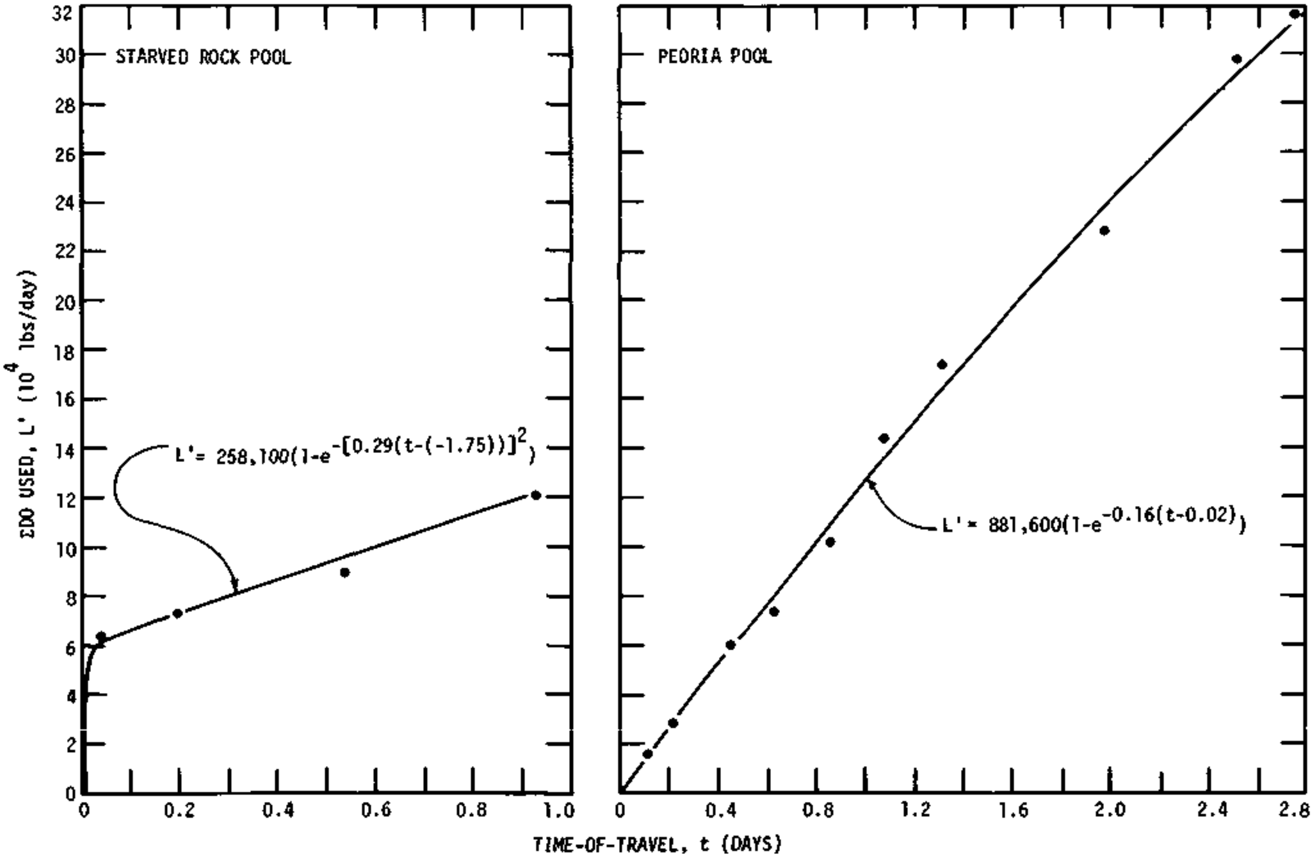

Figure 27. Curve fitting for estimating ultimate loads, L'_a and rates, K'_d

the two models fitted the data equally well most of the time. Some exceptions where either the first or second power model clearly fitted better than the other did exist. The best fitting model parameters were chosen for input into the DO sag model to determine simulation accuracy, and to determine the degree of instream load reduction needed to meet minimum water quality standards.

DO Model

The basic DO model is:

$$DO_n = DO_a - DO_u + DO_r + DO_x \qquad (14)$$

where the terms are the same as defined for equation 13. Details of the methodology for computing aeration and factors influencing DO_x are outlined in Circular 110.[23] Time-of-travel, depths, and other related parameter values were obtained with the SWS volume-displacement hydraulic-hydro logic digital computer program. The DO model was programmed for use on a WANG 720C programmable calculator.

The best fitting data contained in appendix G to define BOD usage in the waterway were used to make DO profile simulations for each sampling day. DO curves were generated on a pool by pool basis, each being independent of the other except when the Marseilles and Starved Rock pool DO curves appeared to be extensions of each other. The initial value assigned for DO_a was the value observed immediately downstream of the dams. After the simulation curve was developed, L was reduced by 35, 50, 75, and 90 percent to determine what instream loads would be allowable per pool to maintain DO standards. On a few occasions the water below the Lockport dam did not meet the 'restricted water' DO standards applicable to this reach of the waterway. When this occurred, even 90 percent instream waste load reductions were not sufficient to bring the downstream values up to the standards because of the low reaeration capacity of the Brandon Road pool.

Overall, the observed DO profiles were described well by this technique. Figure 28 shows the curves for July 14, 1971, simulated by the use of the BOD formulations described by the curves on figures 26-27. The generated curves fit the observed data very well. With few exceptions, similar good fits were achieved for the other sampling days. Figures 29 and 30 show simulated curves for two days during 1971 and two days during 1972 plotted as a function of milepoint as opposed to time-of-travel shown by figure 28. The September 20, 1971, flows were the lowest for any sampling day whereas those for July 18, 1972, were the highest (see table 4). The September 3, 1971, flows were moderately high and stable throughout the study area; the July 11, 1972, flows were low in the upper end of the study area and moderately high in the lower end. The Marseilles and Starved Rock pool profiles appear as one during 1971 because the flows were less than 8500 cfs at Marseilles, and the hydroelectric plant apparently was in operation. For the two 1972 dates two distinct profiles exist for these pools.

Table 28 and tabulations in appendix H have been prepared as a means of summarizing the DO data for 28 days of record. Table 28 gives the minimum calculated and observed DO concentrations. Appendix H summarizes the minimum DO concentrations anticipated at different percentages of waste reduction. The data in table 28 indicate that the minimum calculated DOs agree closely with the observed values for most pools and dates.

Evaluating the results for each individual day showed that the minimum DO standards of 2 mg/l at the Brandon Road pool and the upper half of the Dresden Island pool and 5 mg/l for all other downstream pools were achieved infrequently. Standards were *not* achieved 7 of 27 days in the Brandon Road pool, 23 of 25 days in the Dresden Island pool, 16 of 25 days in the Marseilles pool, 19 of 24 days in the Starved Rock pool, and 22 of 24 days in the Peoria pool. The number of days for which specific percentages of waste reduction are required to achieve minimum DO standards in each pool are shown in figure 31.

Although figure 31 does suggest that certain pools require higher percentages of waste reduction than others (for example, Brandon Road pool compared with Peoria pool), the fact that the major waste load is upstream of all pools means that waste load reduction will have to be considered principally for the uppermost critical stretches. As noted earlier, the DO requirements for Brandon Road and upper Dresden Island pools are less restrictive than those for the lower portion of the Dresden Island pool. Load reductions applied upstream of Brandon Road to meet the lower Dresden Island pool requirements will probably insure DO levels in Brandon Road and upper Dresden Island pools significantly above minimum requirements.

The dual standards now applied to the Dresden Island pool appear unrealistic from a physical standpoint. With aeration at the Brandon Road dam, the probability of achieving high DO levels above the I-55 bridge is much greater than the probability of attaining similar levels below the bridge. This is clearly demonstrated by the average 1971 and 1972 DO profiles shown in figures 4 and 5.

For each pool, no correlation appears to exist between the magnitude of flow and the minimum DO concentrations. The minimum DOs for high flow sampling days were in the same range as those observed for low flow conditions. This phenomenon is illustrated by figure 32. An explanation for this is that during high flows the oxygen consuming loads from nonpoint sources and stormwater overflows increase in direct proportion to the increase in flow. Figure 33 helps support this contention. Shown is a plot of the computed ultimate river BOD versus flow for the Marseilles pool. Excluded from this plot are four values where K'_d was either

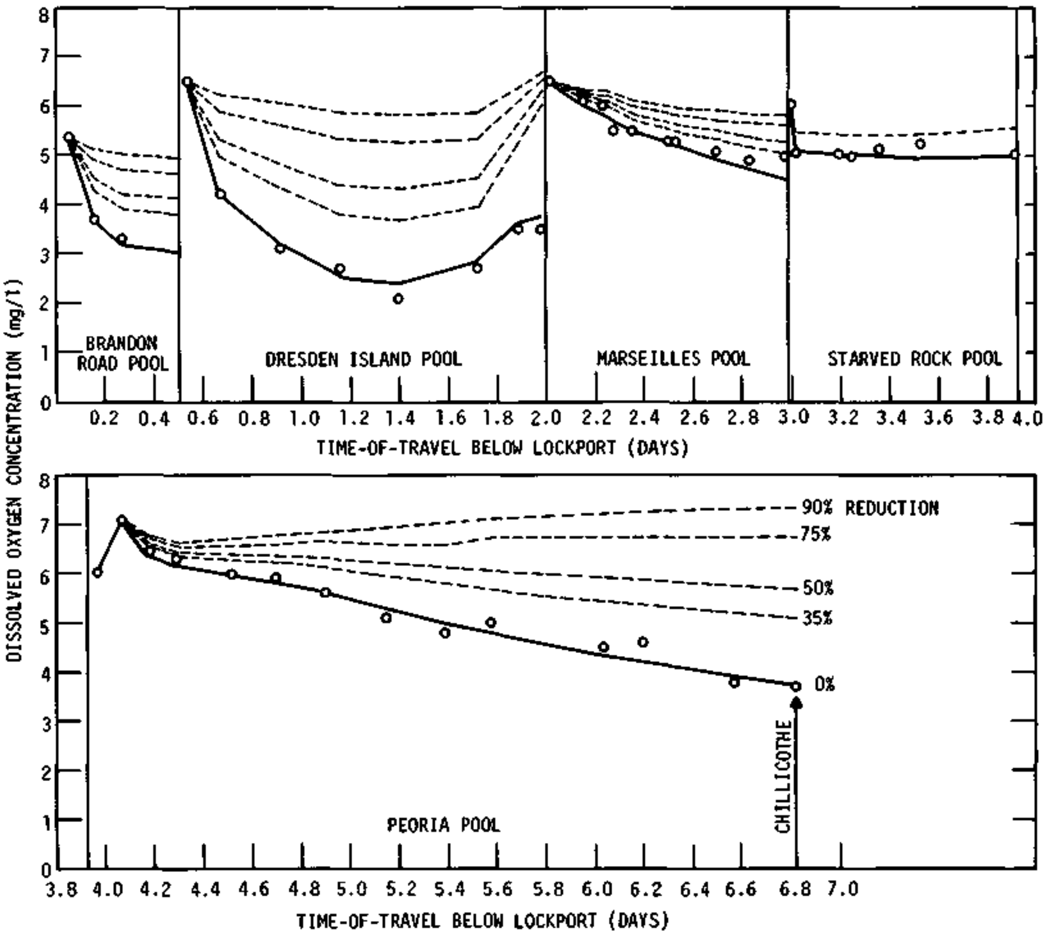

Figure 28. Computed DO sag curve and waste load reduction curves for July 14, 1971

greater than 1.0 or less than 0.1, because such extreme values tend to distort the computed ultimate BOD. The figure shows a definite upward load inflection with increasing flows above 8500 cfs. Generally, at streamflows in excess of 8500 cfs, values above the.line represent loads on the upside or at the peak of the hydrographs, whereas the points below the line represent loads on the downside of the peaks. Note that a first-flush effect appears to occur, i.e., the upside loads tend to be greater than the downside loads. Limited data indicate that during sustained high flows the DO levels recover from the depressed values. During the SOD measurements in the Peoria pool near Chillicothe, very high flows accompanied by unusually low DOs occurred. The high flows persisted for weeks but DOs recovered to reasonable values within a week as indicated by the data in table 29.

The minimum DO versus flow plot for the Brandon Road pool (figure 32a) indicates that the minimum DOs increase in value up to about 7000 cfs and then sharply decrease. The initial upswing in the plot may reflect relatively clean lake diversion water and the downside swing at higher flows may reflect stormwater runoff.

Low Flow DO Simulation

The preceding DO and BOD analyses were made for observed hydrologic and water quality conditions. The basic stream parameters generated were used to predict stream conditions for the Illinois EPA 7-day 10-year design flows included in table 3. The 5-day BOD waste load and flows from various sources were obtained from the Illinois EPA, and the ultimate BODs were estimated by multiplying 5-day BODs by 0.25/0.165, as summarized in table 2. The carbonaceous BOD inputs to the study area from the three major MSDGC plants were estimated residuals remaining in the Sanitary and Ship Canal for design flow conditions. All of the MSDGC ammonia load was passed into the Dresden Island pool with oxidation assumed to commence three days travel time below Lockport.

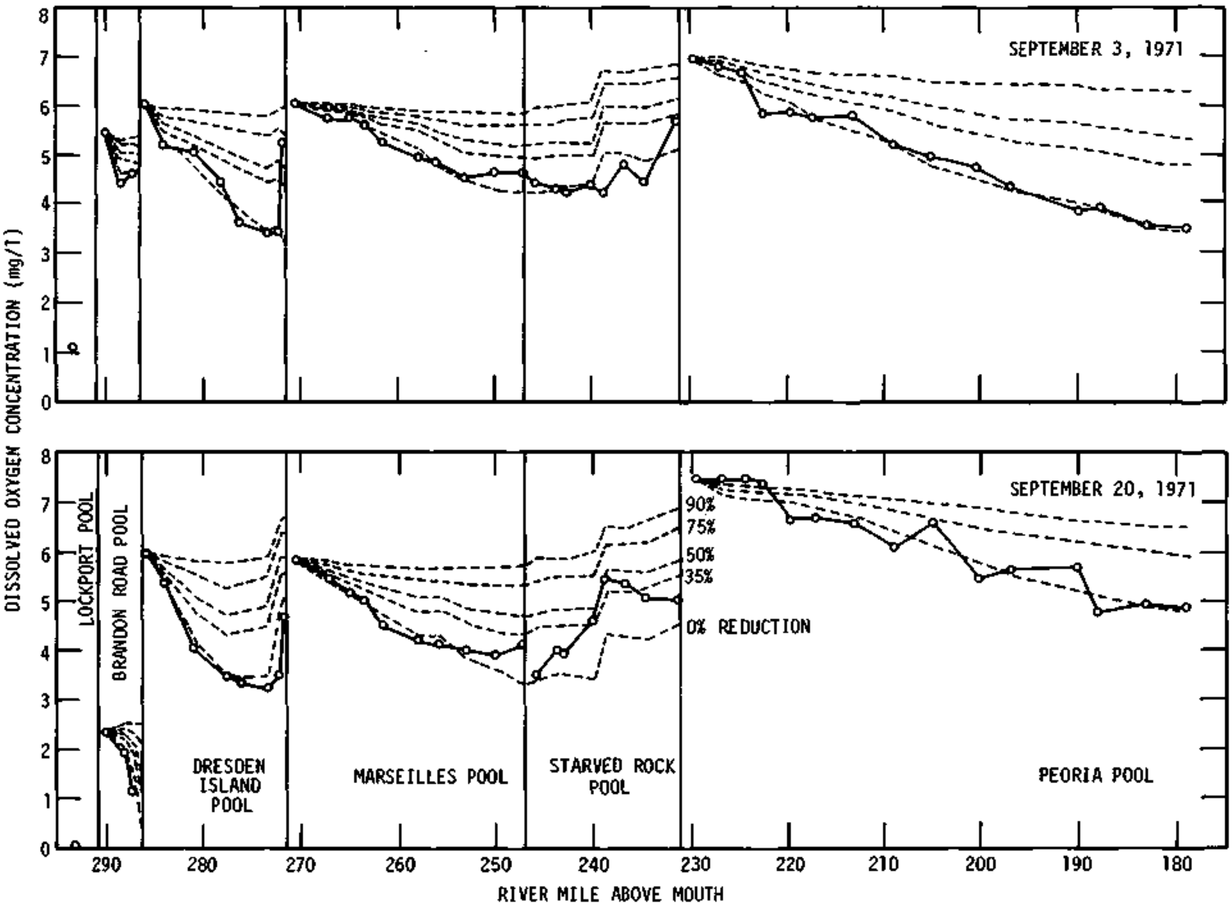

Figure 29. Computed DO sag curves and waste load reduction curves for September 1971 dates

The river BOD reaction rates K'_d for all the navigation pools in the study area were developed by taking the 'best-fit' parameters presented in appendix G and superimposing them upon the 7-day 10-year low flow conditions to generate DO profiles. From the large number of profiles developed, 'mean' DO curves were obtained for each pool. Benthic and sediment oxygen demands were than added to the generated DO_u curves. The resulting curves were used to develop mean *DO* versus time-of-travel plots from which dissolved river BOD reaction rates were obtained. The rate coefficient developed in this way for the Marseilles pool appeared to be high but reasonable for the higher flows for which the input data were derived; however, because nitrification was considered to start above the Marseilles pool, this high rate was considered inappropriate to use with a very large nitrogenous demand. Consequently, from MP 273.0 (three days travel time below Lockport) to the Marseilles dam, the low streamflow K'_d value calculated for September 28, 1971, conditions was utilized. The final deoxygenation rates (K'_d)used for each pool are as follows: Brandon Road, -0.33 per day; Dresden Island to MP 273, -1.53 per day; Dresden Island MP 273 to Marseilles dam, -0.33 per day; Starved Rock, -0.28 per day; Peoria pool, -0.28 per day.

The DO profiles were developed by evaluating the factors in equation 14. The DO curves were generated continuously and not on a pool basis. Reaeration values at the dams were computed by the British weir coefficient formulations outlined by Butts et al.[23] The input parameters needed for using the weir equations were evaluated and are listed in table 30. The free fall of the water *b* is in feet and represents the differences in upstream and downstream flat pool elevations. The water quality factor *q* was arbitrarily assigned a value based on engineering judgment. The weir coefficients *b* were calculated from observed upstream and downstream DO concentrations, and they represent mean values of all the sampling days. Oxygen demands due to benthic extraction and sediments were incorporated into the evaluation.

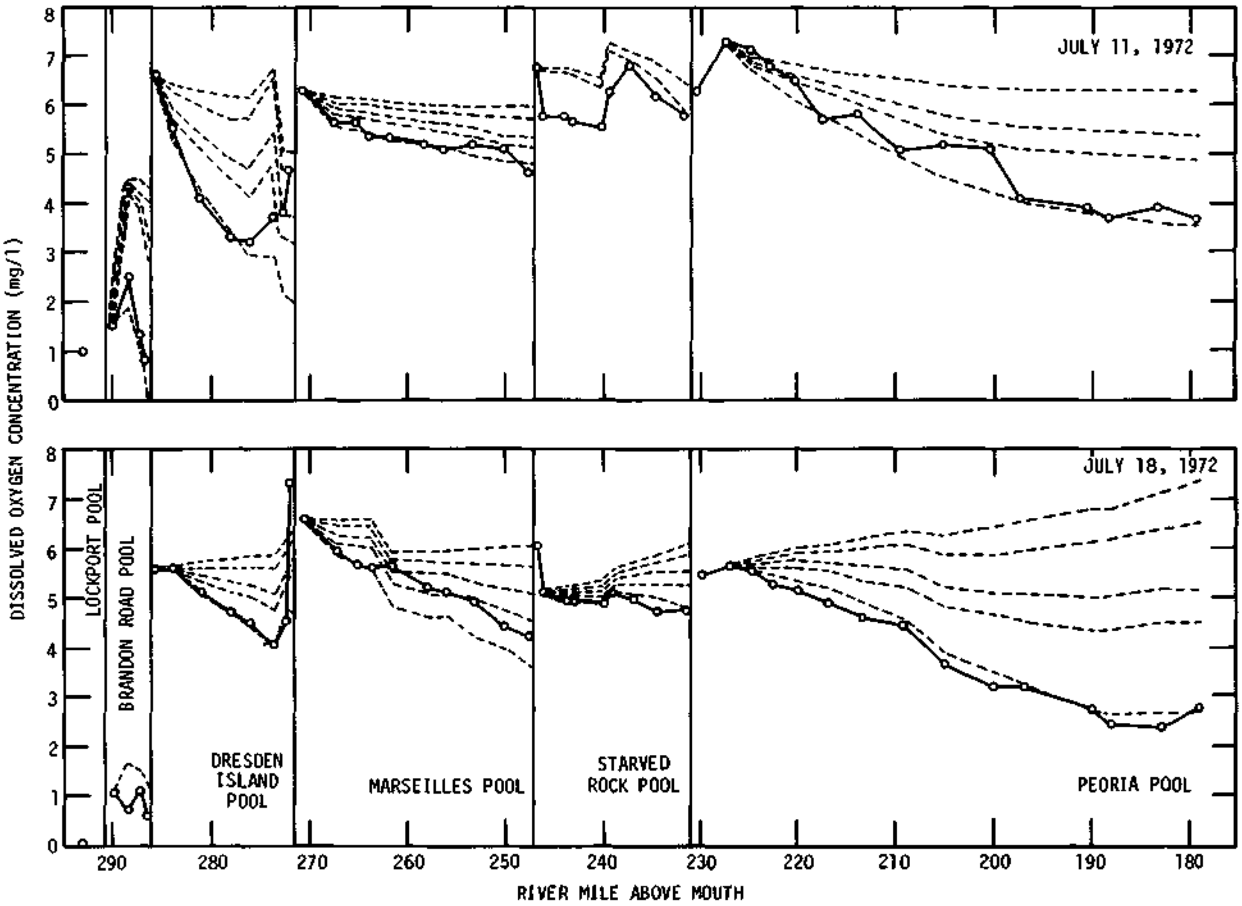

Figure 30. Computed DO sag curves and waste load reduction curves for July 1972 dates

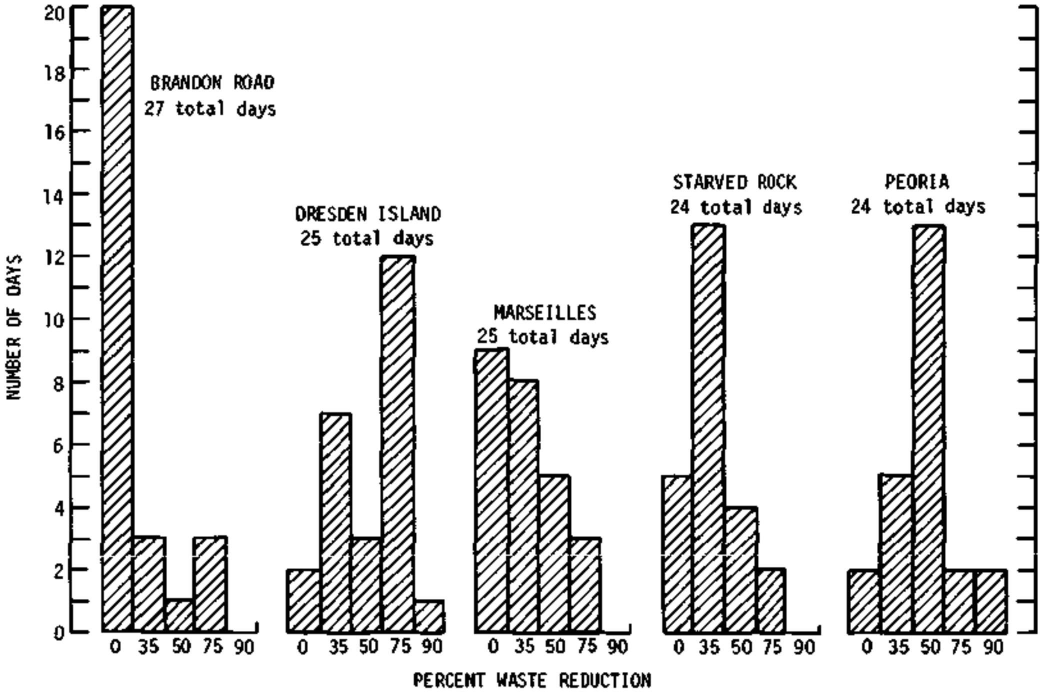

Figure 31. Number of days that designated waste reductions are required

Table 28. Minimum Observed and Calculated DO Concentrations by Pool

	Minimum DO concentrations *(mg/l)*									
	Brandon Road		Dresden Island		Marseilles		Starved Rock		Peoria	
Date	*Obs.*	*Cal.*	*Obs.*	*Cal.*	*Obs.*	*Cal.*	*Obs.*	*Cal.*	*Obs.*	*Cal.*
1971										
7/14	3.30	2.84	2.10	2.40	4.90	4.63	5.00	5.07	3.70	4.02
7/15	0.60	0	2.80	2.94	4.30	3.90				
7/19							4.80	4.65	3.70	3.25
7/22	2.60	3.80	3.30	3.27	5.90	4.83	4.90	4.82	3.60	3.79
7/23	4.00	3.25	3.10	3.05	4.80	4.28	4.20	4.17	4.00	3.65
7/28	4.30	4.31					4.30	4.78	4.90	4.81
7/29	4.80	4.98	4.00	4.35	5.10	5.01				
8/4	4.60	4.33	5.25	5.11	6.00	4.97	4.80	5.08	5.60	5.53
8/5	4.90	4.92	4.30	4.60	5.60	5.44	5.50	6.10	3.80	3.32
8/10	4.80	4.89	4.60	4.92	5.50	4.30	4.10	4.02	3.50	3.42
8/11	4.60	4.70	4.90	4.88	5.35	4.14	4.10	3.53	2.90	3.18
8/17	5.40	4.60	4.30	4.54	4.10	4.15	3.30	4.04	2.70	2.84
8/18	5.00	4.49					4.50	4.54	2.75	2.70
8/25	2.50	2.30	4.70	5.68	4.50	4.19	3.40	3.50	3.20	3.07
8/26	2.10	1.47	3.30	3.44	4.30	4.24	4.10	4.13	2.80	3.11
8/31	4.80	4.83	3.30	3.67	4.50	4.45				
9/1	4.40	4.02	3.90	4.00	4.95	4.93				
9/2	4.40	4.48	3.15	2.93	3.85	3.85	4.00	3.84	3.50	3.42
9/3	4.40	4.49	3.40	3.23	4.50	4.18	4.20	4.17	3.45	3.40
9/20	1.10	0.31	3.20	3.45	3.90	3.44	3.50	3.43	4.70	4.76
9/21	1.40	0.16	2.70	2.64	3.70	3.80	2.80	3.73	4.00	3.90
9/22	2.30	2.45	2.60	2.76	4.00	3.87	3.90	3.15	4.80	4.03
9/28	2.60	1.83	4.10	4.02	4.50	3.89	3.50	3.71	3.50	3.75
9/30	2.50	2.38	3.25	3.24	4.30	4.40	3.45	4.40	3.60	3.39
1972										
7/11	0.80	0.21	3.20	2.93	4.55	4.67	5.50	6.39	3.60	3.54
7/18	0.60	1.19	4.05	4.03	4.20	3.61	4.70	4.75	2.30	2.58
7/24	1.50	1.41	2.85	2.85	4.20	4.18	4.80	4.99	3.50	3.39
7/26	1.50	1.43	3.25	3.19	4.90	4.92	5.30	6.00	3.40	5.23

The results of this evaluation are depicted by the DO profiles shown in figures 34 and 35. The profile for the Peoria pool was carried through the lake area to the Peoria dam. Note that the DO standards are violated in each pool. The principal causes in the Brandon Road and upper Dresden Island pools are carbonaceous BOD and benthic oxygen demand. The peculiar upgrading of the minimum standard from 2.0 to 5.0 mg/l at the I-55 bridge in the Dresden Island pool places a constraint upon the allowable carbonaceous load from the MSDGC West Southwest plant, the city of Joliet, and U. S. Steel. To achieve the minimum DO standard between I-55 and the onset of nitrification near MP 273.0, 75 percent of the existing carbonaceous BOD from the West Southwest plant must be removed. All other discharges between the Lockport dam and MP 273.0, excluding tributary streams, must remove 50 percent of their existing carbonaceous loads. To meet the minimum standards in the portion of the Dresden Island pool below MP

Table 29. Flow and DO Observations near Chillicothe

Date	Flow *(cfs)*	DO *(mg/l)*
1972		
7/17	9,960	
7/18	13,800	
7/19	20,200	
7/20	23,500	1.1
7/21	25,700	2.6
7/22	25,600	
7/23	25,700	
7/24	25,200	4.2
7/25	24,700	
7/26	23,700	
7/27	23,600	
7/28	22,900	
7/29	22,300	
7/30	20,700	
7/31	20,500	5.4

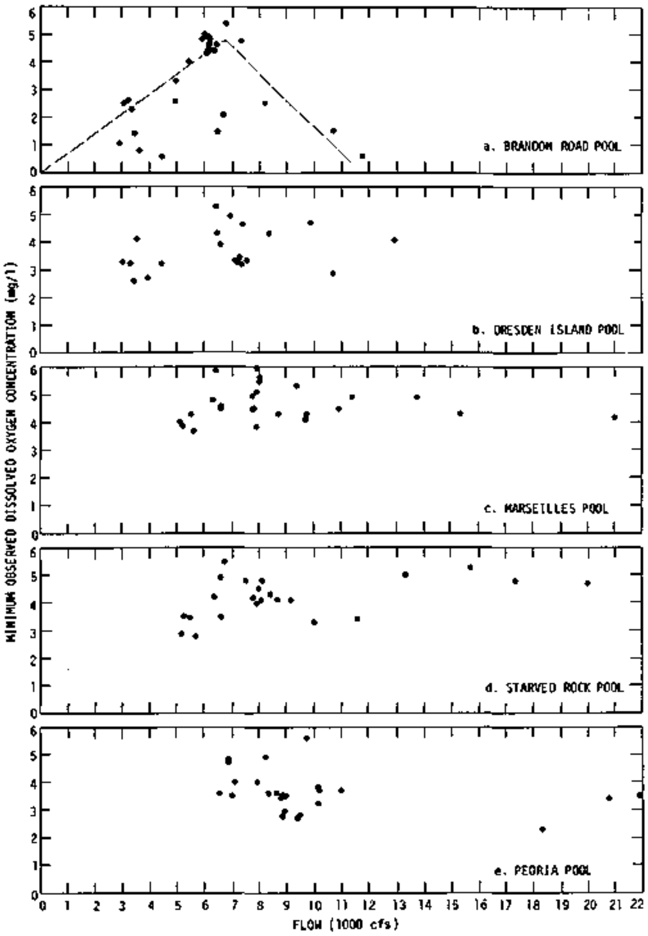

Figure 32. Observed minimum DO concentrations at varying flows

Table 30. British Weir Equation Parameter Input Data

Dam	b	q	b
Lockport	38.0	0.8	0.25
Brandon Road	34.0	0.8	0.30
Dresden Island	21.7	0.8	0.48
Marseilles	13.7	1.0	0.36
Starved Rock	19.0	1.0	0.27

273.0, 98 percent of all upstream nitrogenous BOD must be removed.

If a minimum DO standard of 4.0 mg/l was acceptable throughout the Dresden Island pool, only 50 percent carbonaceous reduction would be needed by the MSDGC West Southwest plant in combination with 95 percent reduction of the NH -N load. However, under these conditions, 50 percent reduction of the NH -N load from the Illinois Nitrogen, Inc., facilities at MP 248.2 would have to be achieved to meet the minimum standard in the Peoria pool.

The reductions of the load inputs as just discussed will insure that the minimum standards will be met in the Marseilles and Starved Rock pools. At the upper end of the Peoria pool most of the nitrogenous and essentially all carbonaceous BOD will be stabilized. All existing waste loads below this point will have little impact upon the dissolved oxygen resources. The principal oxygen depressant in the Peoria pool above MP 179.0, with most of the upstream dissolved load stabilized, is sediment oxygen demand. The sag curve for the Peoria pool depicted on figure 35 is primarily the result of SOD.

SUMMARY AND CONCLUSIONS

1) The dissolved oxygen resources in the Upper Illinois Waterway become highly degraded during warm summer and early fall seasons. The degradation is most persistent during periods of stabilized low streamflows; however, pronounced degradation occurs for short durations at the onset of increased flows because of combined sewer discharges. The lowest DO (1.1 mg/l) observed in the Peoria pool occurred during overbank flow conditions. During persistently high flows the DO concentrations return to acceptable levels.
2) The Marseilles pool had the highest average DOs, with mean pool values ranging from 4.60 to 6.80 mg/l for 25 sampling days. However, even in this best of pools, an average DO of 6.0 mg/l was not regularly achieved.
3) The maintenance of the required DO level of 6.0 mg/l for any 16-hour period will be difficult to achieve in the lower Dresden Island, Marseilles, Starved Rock, and Peoria pools. For 7-day 10-year low flow conditions, the maximum practical limit appears to be 5.0 mg/l. The dual standards for the Dresden Island pool are not manageable and are in conflict with the natural DO profile configurations in the pool. The DO resources in the Brandon Road pool are severely degraded; however, the standards are low and they appear to be achievable under proper management. A maximum standard greater than 3.0 mg/l is not realistically attainable.
4) Significant reaeration occurs at the Brandon Road, Dresden Island, and Starved Rock dams. Reaeration at the Lockport and Marseilles dams is intermittent because flow is diverted for power generation. At flows less than 8500 cfs, the hydroelectric plant at Marseilles diverts the total river flow for power generation. The DO levels in the Starved Rock pool are then adversely

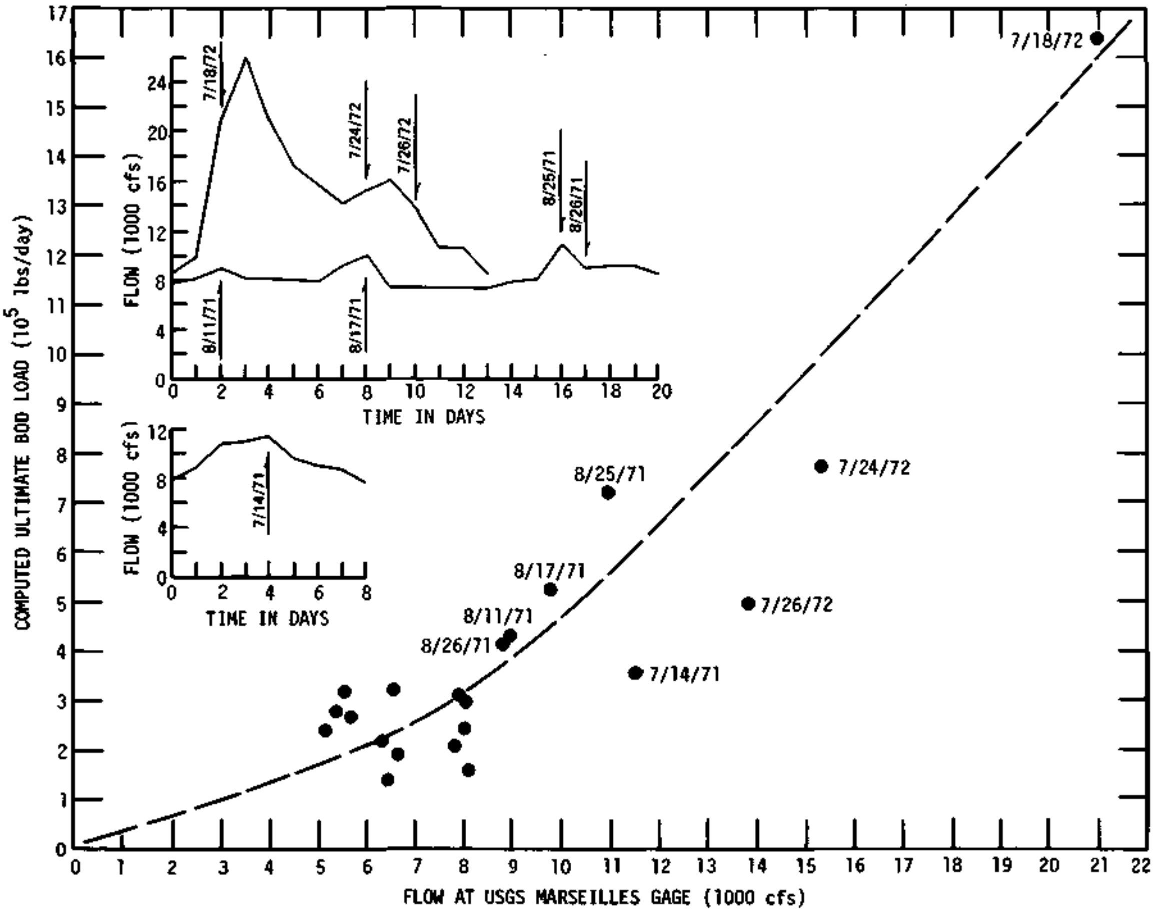

Figure 33. Ultimate BOD versus streamflow in Marseilles pool

affected and the sag curve becomes merely an extension of the Marseilles pool DO profile.

5) Oxygen usage results from four factors: 1) dissolved carbonaceous BOD, 2) dissolved nitrogenous BOD, 3) benthic biological extraction, and 4) sediment oxygen demand. The carbonaceous demand is exerted primarily in the Brandon Road and Dresden Island pools; the nitrogenous demand commences approximately three days time-of-travel below the Lockport dam. The exact location at which ammonia oxidation becomes significant depends on the hydrologic and hydraulic conditions of the waterway. During high flow conditions in 1972, it accelerated significantly in the vicinity of Henry (MP 196) in the Peoria pool. However, during 7-day 10-year low flow conditions significant nitrification probably starts above the confluence of the Kankakee River around MP 273. Biological extraction of oxygen by benthic and attached organisms in the shallow rocky areas below dams appears to be significant. Thick oxygen consuming sludge and sediment deposits exist throughout the Brandon Road, Dresden Island, and the lower portion of the Upper Peoria pools; scattered oxygen demanding sediments exist in the lake area of the Starved Rock pool. The Marseilles pool is essentially free of oxygen demanding sediments.

6) Approximately 98 percent of the total municipal discharges to the study area originate from the three principal MSDGC treatment plants. Also, approximately 93 percent of all waste flows originate from the MSDGC plants. Estimated municipal, industrial, and MSDGC flows are 33.2, 71.9, and 1466 mgd, respectively. The average ammonia load observed at Lockport during 1971 was 107,000 lbs/day; this agrees closely with the 106,800 lbs/day estimated to come from point sources in the Chicago area. During 1972, the observed average ammonia load increased to 149,000 lbs/day. This increase in load may be attributed to increased flows.

7) A continuous DO profile was developed for 7-day 10-year low flow conditions. The reaeration capacities of the dams were mathematically modeled in order to develop the continuous profile. The standards were violated in all pools under existing loads. To meet the standards, the MSDGC West Southwest treatment plant must remove 97.5 percent of its carbonaceous

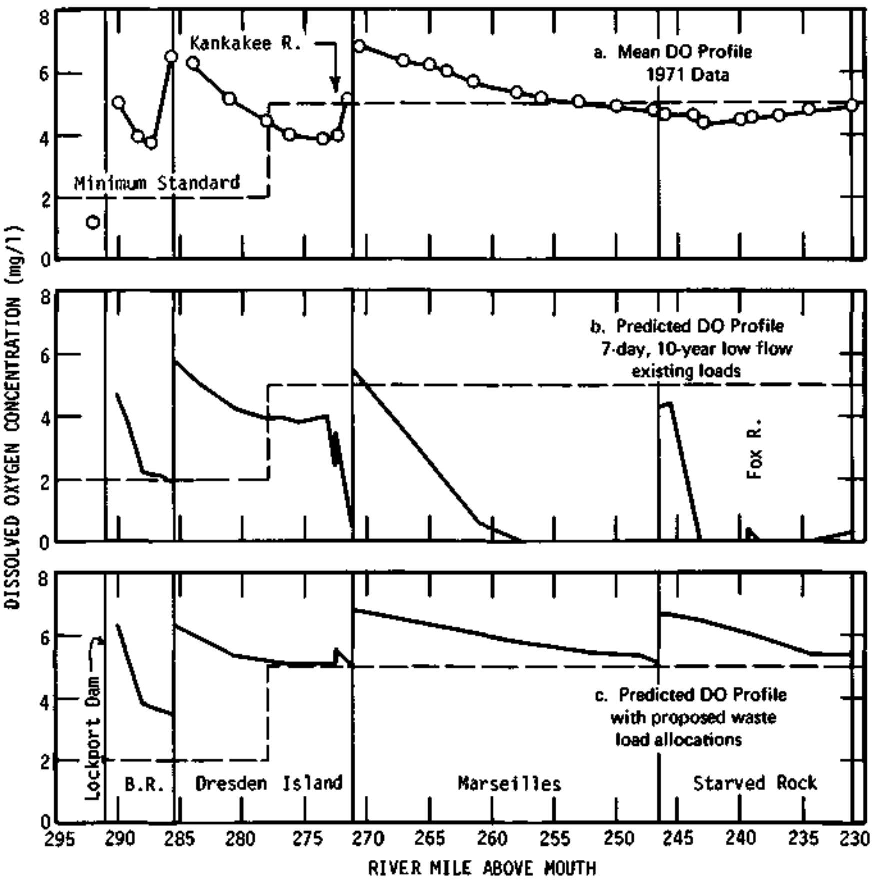

Figure 34. Dissolved oxygen profiles

BOD, and all other carbonaceous discharges between the Lockport dam and the Kankakee River must be reduced 50 percent. Also, 98 percent of all the nitrogenous load above MP 273 must be removed.

8) Thermal waste loads in the vicinity of MP 284.0 appear to affect the temperature profile throughout the reaches of the upper waterway. At this milepoint a maximum temperature of 32.0°C (89.5°F) was observed. The average temperatures for the Dresden Island pool were the highest of all pools.

9) In 144 collections, 23 algal genera were identified. Algal densities ranged from a minimum of 310/ml to 13,600/ml and the geometric means ranged from 1340/ml at the uppermost station to 3790/ml in the lower reach. On a pool by pool basis algal densities increased with downstream movement. Diatoms were the dominant algae group making up about 85 percent of the total densities.

10) Efforts to correlate algal densities with water temperature, DO, BOD_5, coliform bacteria, and streamflow were not successful. However, no selective habitat conducive to extraordinary propagation of algae exists in the waterway, nor is the use of the waterway for recreation impaired by algae concentrations.

11) Total coliform densities ranged from 9,900,000/100 ml at the uppermost station to 200/100 ml at the lowermost station. Fecal coliform densities similarly ranged from 400,000/100 ml to 4/100 ml. Bacterial densities decreased with downstream movement exhibiting an overall death rate of 0.77 per day for fecal coliform in the upper pools (Dresden Island and Marseilles) and 0.42 per day in the lower pools (Starved Rock and Peoria).

12) Only 3 of the 19 stations sampled met the bacterial quality standards required by the IPCB. The 3 stations are located in the Peoria pool.

13) Fecal coliform densities, on the average, represent about 9 percent of the total coliform bacteria population which is somewhat lower than the average of 14 percent reported on the Ohio River.

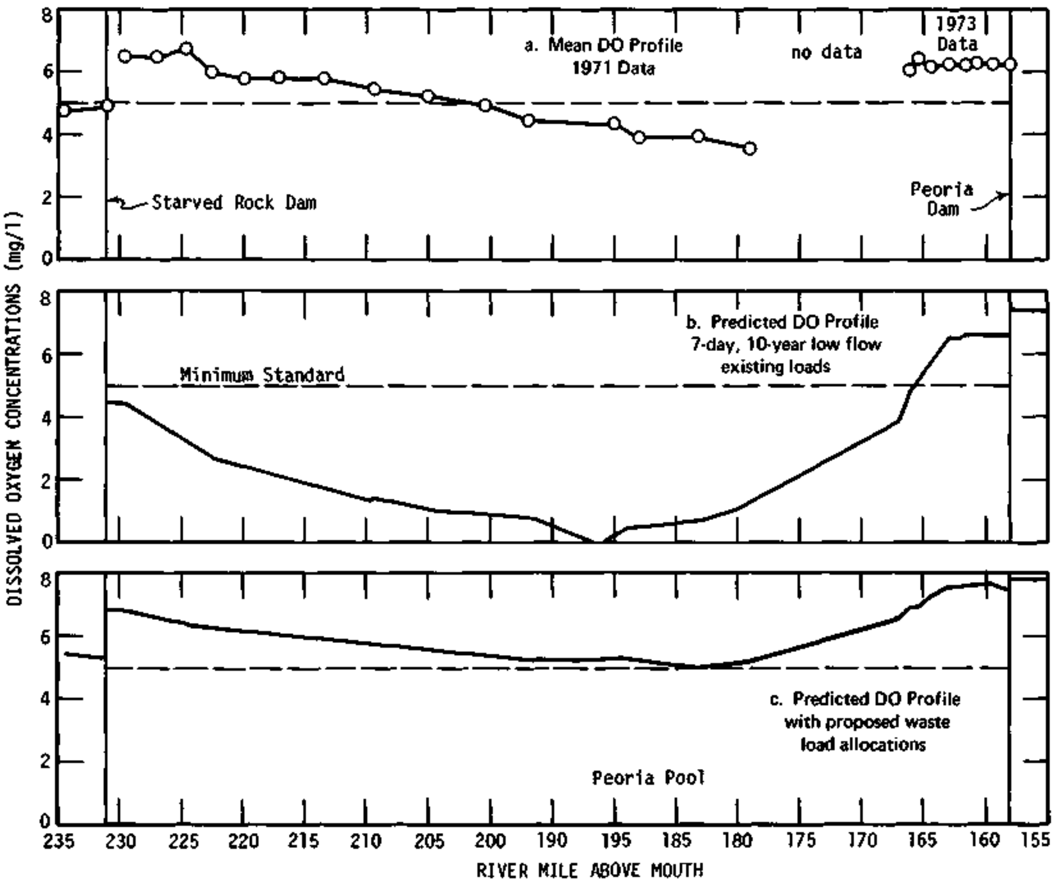

Figure 35. Dissolved oxygen profiles

REFERENCES

1 **Elmore, H. L. 1955.** ***Determinations of BOD by a reaeration technique.*** Sewage and Industrial Wastes v. 27(9):993-1002.

2 **Young, J. C. 1969.** ***Chemical methods for nitrification control.*** Proceedings of the 24th Industrial Waste Conference, Part 2, Purdue University, Lafayette, Indiana, p. 1090-1102.

3 American Public Health Association. 1971. *Standard methods for the examination of water and wastewater.* 13th Edition, New York 874 p.

4 **Butts, T. A. 1974.** ***Sediment oxygen demand in the upper Illinois waterway.*** Illinois State Water Survey Report of Investigation 76.

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

6 Butts, T. A., D. H. Schnepper, and R. L. Evans. 1970. *Dissolved oxygen resources and waste assimilative capacity of the La Grange pool, Illinois River.* Illinois State Water Survey Report of Investigation 64.

7 Lackey, J. B., and C. N. Sawyer. 1945. *Plankton productivity in certain southeastern Wisconsin lakes as related to fertilization.* Sewage Works Journal 17:573, May.

8 Wilhm, J. L., and T. C. Dorris. 1968. *Biological parameters for water quality criteria.* Bioscience 18:477-480.

9 Illinois Environmental Protection Agency. 1972. *Water Pollution Regulations of Illinois.* Adopted by the Illinois Pollution Control Board through March 7, 1972. 36 p.

10 ORSANCO Water Users Committee. 1971. *Total coliform: fecal coliform ratio for evaluation of raw water bacterial quality.* Journal Water Pollution Control Federation v. 43:630.

11 **Strobel, G. A. 1968.** ***Coliform-fecal coliform bacteria in tidal waters.*** Journal Sanitary Engineer Division, ASCE, v. 94(SA4):641.

12 Kittrell, F. W., and S. A. Furfari. 1963. *Observations of coliform bacteria in streams.* Journal Water Pollution Control Federation v. 35:1361.

13 Velz, C.J. 1970. *Applied stream sanitation.* Wiley-Interscience, New York, p. 234-253.

14 Kehr, R. W., and C. T. Butterfield. 1943. *Notes on the relation between coliforms and enteric pathogens.* Public Health Reports v. 58:589.

15 Hoskins, J. K., and C. T. Butterfield. 1933. *Some observed effects of dilution on the bacterial changes in polluted water.* Sewage Works Journal v. 5:763.

16 Purdy, W. C, and C. T. Butterfield. 1918. *The effect of plankton animals upon bacterial death-rates.* American Journal Public Health v. 8:499.

17 Frost, W. H., and H. W. Streeter. 1924. *A study of the pollution and natural purification of the Ohio River. II. Report of survey and laboratory studies.* U. S. Public Health Service, Washington, D. C. Public Health Bulletin No. 143.

18 Streeter, H. W. 1934. *A formulation of bacterial changes occurring in polluted water.* Sewage Works Journal v. 6:208.

19 Fair, G. M., and J. C. Geyer. 1963. *Water supply and wastewater disposal.* John Wiley & Sons, Inc., New York, p. 831-835.

20 Klock, J. W. 1971. *Survival of coliform bacteria in wastewater treatment lagoons.* Journal Water Pollution Control Federation v. 43:2071.

21 Geldreich, E. E. 1967. *Fecal coliform concepts in stream pollution.* Water & Sewage Works v. 114: R98-R110.

22 Hoskins, J. K., C. C. Ruchoff, and L. G. Williams. 1927. *A study of the pollution and natural purification of the Illinois River. I. Surveys and laboratory studies.* U. S. Public Health Service, Washington. D. C. Public Health Bulletin No. 171, 208 p.

23 Butts, T. A., V. Kothandaraman, and R. L. Evans. 1973. *Practical considerations for assessing the waste assimilative capacity of Illinois streams.* Illinois State Water Survey Circular 110.

Appendix A. Observed Dissolved Oxygen Concentrations, Upper Illinois Waterway

(Dissolved oxygen in milligrams per liter)

MP	71 7/14	7/15	7/19	7/22	7/23	7/28	7/29	8/4	8/5	8/10	8/11	8/17	8/18	8/25
292.1	0.00	0.00			1.50	1.40	1.80	0.00	1.10	2.90	2.50	3.00	2.60	0.00
290.0	5.40	5.10		4.60	5.70	6.90	5.10	5.60	5.90	6.20	5.90	6.30	5.80	3.60
288.4	3.70	2.30		3.60	4.40	4.30	4.80	4.60	4.90	4.80	4.60	5.80	5.30	2.90
287.3	3.30	0.60		3.90	4.00	4.40	4.80	5.00	5.10	5.70	5.90	5.40	5.00	2.50
286.3														
285.8	6.50	5.70		6.50	6.10	7.00	6.90	7.90	8.20	6.60	6.40	7.30	7.00	5.70
284.0	4.20	5.30		6.30	6.00		7.25	8.20	7.10	7.50	7.50	7.80	7.40	5.80
281.0	3.10	3.60		4.00	5.10		5.95	7.15	6.00	7.00	6.10	6.85	6.00	5.80
278.0	2.70	3.00		3.30	4.30		5.30	6.50	5.10	6.20	5.10	5.95	5.45	5.20
276.1	2.10	2.80		3.70	3.20		4.30	6.15	4.75	5.35	5.00	5.50	5.10	5.10
273.5	2.70	3.50		4.20	3.10		4.00	5.25	4.30	4.70	4.90	4.65		5.00
272.4	3.50	3.50		4.10	3.70		4.40	5.30	4.70	4.60	5.30	4.30		4.70
271.6	3.50	4.90		5.00	5.10		5.00	6.60	5.70	5.80	6.30	5.80		5.00
270.6	6.50	5.80		7.80	6.50		7.10	8.10	7.60	7.20	8.00	7.15		7.00
267.2	6.10	5.50		6.90	6.30		6.90	7.60	7.10	6.55	7.50	6.75		6.50
265.0	6.00	5.40		6.60	6.40		6.60	7.50	7.10	6.65	7.15	6.50		6.20
263.7	5.50	5.40		6.30	6.00		6.50	7.25	6.90	6.55	6.95	6.35		6.05
261.6	5.50	5.30		6.10	5.10		6.10	6.90	6.60	6.15	6.60	5.90		5.60
258.0	5.30	5.20		6.30	5.10		5.60	6.35	6.20	5.80	6.10	5.20		5.40
256.0	5.30	4.90		5.90	5.20		5.10	6.20	5.80	5.65	5.90	5.00		5.30
253.0	5.10	5.00		6.00	5.10		5.40	6.10	5.65	5.50	5.85	4.90		5.60
250.0	4.90	5.10		6.50	4.80		5.25	6.20	5.80	5.60	5.40	4.70		4.70
247.0	5.00	4.30		6.20	5.00		5.30	6.00	5.60	5.65	5.35	4.10		4.50
246.9														
246.0	6.01	6.50	7.05	5.60	4.20	4.30		5.30	5.90	4.40	3.70	3.30	5.20	4.30
243.7	5.06	5.70	5.80	5.30	4.20	5.30		5.60	6.10	4.20	4.50	3.20	5.10	4.20
242.9				6.30		4.70		4.90	5.50	4.10	4.25	4.00	4.75	3.80
240.0	5.04	4.90	5.10	5.20	4.40	4.90		4.80	6.00	4.40	4.40	4.00	4.90	3.40
239.0	5.00	5.10	4.90	4.90	4.40	4.60		5.10	5.70	4.30	4.40	3.80	4.90	3.70
236.8	5.15	4.90	4.80	5.00	4.40	5.30		5.00	5.70	4.50	4.10	4.00	5.20	3.90
234.5	5.25		4.90	5.10	4.60	4.90		5.10	5.90	4.70	4.60	3.90	5.35	3.85
231.0	5.00		5.05	5.40	4.60	5.00		5.20	6.10	4.70	4.80	3.60	4.50	3.60
229.6	6.03		7.60	6.90	6.90	7.20		6.30	6.10	5.00	6.30	5.30	5.80	5.50
226.9	7.09		6.30	6.70	6.90	7.20		6.10	6.00	5.80	6.60	5.50	6.15	5.70
224.7	6.45		5.80	6.10	6.50	7.00		5.90	6.00	5.70	6.00	5.30	6.00	5.60
222.6	6.30		5.70	5.80	6.00	6.70		6.30	5.50	5.30	6.00	5.40	5.25	5.30
219.8			5.10	5.70	6.20	6.30		6.00	5.50	5.20	5.50	4.80	5.90	5.30
217.1	6.00		5.50	5.90	6.60	6.00		6.00	5.40	5.50	5.55	5.10	5.40	5.50
213.4	5.90		5.50	5.60	6.30	6.20		6.60	5.30	5.60	5.10	5.10	5.60	5.60
209.4	5.60		5.10	5.20	5.10	5.70		6.50	4.90	5.30	4.90	5.30	4.50	5.70
205.0	5.10		5.00	5.60	5.70	5.50		6.30	4.60	5.20	4.40	5.20	4.60	4.90
200.4	4.80		4.80	5.00	5.30	5.10		6.40	4.40	5.00	4.30	4.60	4.50	4.95
196.9	5.00		5.10	4.80	4.80	4.90		6.40	4.50	4.50	4.10	4.00	4.50	4.55
190.0	4.50		4.00	4.40	4.70	4.90		5.60	3.80	4.60	3.40	4.00	3.90	3.80
188.0	4.60		4.10	4.20	4.60	4.90		5.60	4.80	3.90	3.30	3.20	3.75	3.55
183.0	3.80		3.70	4.00	4.00	4.90		5.60	4.50	3.50	3.30	2.80	3.05	3.20
179.0	3.70		3.90	3.60	4.00	5.00		5.70	3.80	4.10	2.90	2.70	2.75	3.30
*1.0	9.60	12.00		11.00	10.30	8.40	13.60	10.50	11.20	9.70	9.20	10.60	8.40	8.50
2.0	14.10	11.70		7.60	3.70		5.50	8.00	9.70	3.20	2.90	12.90	10.80	4.90
3.0	7.10	5.30		7.60	8.30	8.40	8.60	10.00	9.50	10.20	7.80	8.20	8.00	8.00
4.0	12.70	9.00		9.10	3.60	11.20		6.00	10.00	4.08	5.80	9.18	10.30	4.10
5.0	7.20	12.50		10.30			13.90		12.40	4.80	5.50		6.90	
6.0														
7.0														

NOTE: *

Station	Location
1.0	Des Plaines River
2.0	Du Page River
3.0	Kankakee River
4.0	Fox River
5.0	Vermilion River
6.0	Dresden Island Power Inlet
7.0	Dresden Island Power Outlet

(Continued on next page)

Appendix A (Concluded)

(Dissolved oxygen in milligrams per liter)

	71										72			
MP	8/26	8/31	9/1	9/2	9/3	9/20	9/21	9/22	9/28	9/30	7/11	7/18	7/24	7/26
292.1	0.00	2.70	2.10	1.90	1.10	0.00	0.00	0.35	1.30	0.80	1.00	0.00	1.70	2.40
290.0	4.80	6.30	5.80	5.70	5.40	2.30	3.00	3.10	3.30	3.30	1.50	1.10	2.70	2.50
288.4	3.20	4.80	4.70	4.50	4.40	1.90	2.40	2.30	3.00	2.70	2.50	0.70	2.70	2.90
287.3	2.10	5.00	4.40	4.40	4.60	1.10	1.40	2.30	2.60	2.50	1.30	1.10	1.60	3.00
286.3											0.80	0.60	1.50	1.50
285.8	5.50	6.60	6.90	6.10	6.00	5.90	6.50	5.70	6.00	5.80	6.60	5.60	5.40	6.10
284.0	7.40	6.05	6.10	5.60	5.20	5.35	5.30	5.80	5.40	6.35	5.50	5.60	4.90	5.55
281.0	5.90	5.60	5.00	4.80	5.00	4.05	3.50	4.30	4.30	4.50	4.10	5.10	4.05	4.50
278.0	4.00	4.60	4.30	4.30	4.40	3.45	2.60	3.60	4.20	3.60	3.30	4.75	3.30	4.10
276.1	3.60	4.00	4.10	4.00	3.60	3.35	2.90	2.60		3.60	3.20	4.50	3.10	3.70
273.5	3.30	3.80	3.90	3.30	3.40	3.20	2.70	3.50	4.10	3.25	3.70	4.05	2.85	3.25
272.4	3.60	3.30	4.20	3.15	3.40	3.50	2.80	3.40	4.10	3.80	3.80	4.50	3.15	3.55
271.6	5.55	5.55	4.70	3.50	5.20	4.65	4.50	4.25	5.40	5.20	4.65	7.30	4.20	5.00
270.6	6.45	6.10	6.80	5.60	6.00	5.80	6.50	7.50	7.10	7.20	6.25	6.60	5.75	6.70
267.2	6.20	5.70	6.20	5.20	5.70	5.45	6.30	6.35	6.60	6.50	5.60	5.95	5.30	6.30
265.0	6.10	5.55	6.00	5.00	5.70	5.15	6.20	6.35	6.45	6.30	5.60	5.65	5.20	6.20
263.7	5.85	5.40	5.90	4.90	5.60	5.00	5.90	5.75	6.40	6.25	5.35	5.60	5.10	6.15
261.6	5.80	4.70	5.60	4.60	5.20	4.50	5.40	5.50	5.85	5.50	5.30	5.60	5.00	6.00
258.0	5.25	4.70	5.20	4.20	4.90	4.20	5.00	5.30	5.45	5.30	5.15	5.20	4.70	5.70
256.0	4.95	4.60	5.10	4.15	4.80	4.10	4.90	5.10	5.35	5.35	5.05	5.10	4.75	5.40
253.0	4.75	4.55	5.00	4.30	4.50	4.00	4.50	4.90	4.85	4.60	5.15	4.90	4.60	5.30
250.0	4.60	4.50	4.95	4.30	4.60	3.90	4.20	4.30	4.50	4.30	5.05	4.40	4.35	5.00
247.0	4.30	4.50	5.00	3.85	4.60	4.10	3.70	4.00	4.55	4.50	4.55	4.20	4.20	4.90
246.9											6.70	6.00	6.00	6.10
246.0	4.85	5.10		4.00	4.40	3.50	2.90	3.90	4.10	3.40	5.70	5.10	5.15	6.20
243.7	4.80	3.65		4.20	4.30	4.00	3.60	4.30	4.00	4.10	5.70	4.90	5.05	6.20
242.9	4.70			4.30	4.20	3.90	3.50	4.10	3.80	3.45	5.60	4.95	4.80	6.10
240.0	4.50			4.10	4.35	4.55	3.50	3.70	3.50	3.60	5.50	4.85	4.80	5.80
239.0	4.30			4.30	4.20	5.40	3.60	4.70	4.00	3.55	6.20	5.05	5.00	6.00
236.8	4.20			4.95	4.75	5.30	2.80	4.50	4.60	3.70	6.70	4.95	4.95	5.90
234.5	4.10			4.75	4.40	5.00	4.20	5.30	4.50	4.40	6.10	4.70	4.90	5.50
231.0	4.70			5.50	5.60	5.00	4.50	5.60	4.70	4.80	5.70	4.70	5.50	5.30
229.6	6.60			6.45	6.90	7.40	7.35	7.50	6.70	6.80	6.20	5.45	5.40	5.80
226.9	6.30			6.70	6.85	7.40	7.05	7.20	5.85	6.40	7.20	5.60	5.25	5.70
224.7	6.10			6.60	6.60	7.40	6.85	7.10	5.70	6.30	7.00	5.50	5.10	5.60
222.6	5.60			6.45	5.80	7.30	6.50	7.50	5.55	5.90	6.70	5.25	4.90	5.20
219.8	5.60			6.00	5.80	6.60	6.40	6.90	5.60	5.80	6.40	5.10	4.85	5.30
217.1	5.20			6.20	5.70	6.60	6.45	7.30	5.50	5.40	5.60	4.85	4.80	5.10
213.4	5.00			6.00	5.75	6.50	5.85	7.10	5.40	5.70	5.70	4.55	4.65	4.90
209.4	4.90			5.80	5.15	6.60	5.65	7.00	5.00	5.10	5.00	4.40	4.40	4.60
205.0	4.40			4.75	4.90	6.50	5.40	7.40	4.80	5.15	5.10	3.60	3.95	4.55
200.4	4.30			4.70	4.65	5.40	4.90	6.80	4.30	5.10	5.00	3.15	3.60	4.20
196.9	4.30			4.45	4.30	5.60	4.85	6.50	4.00	4.50	4.00	3.15	3.60	4.25
190.0	3.60			3.80	3.80	5.60	4.60	5.90	3.90	3.90	3.80	2.70	3.60	3.70
188.0	3.60			3.70	3.85	4.70	4.40	5.00	3.60	3.60	3.60	2.40	3.60	3.40
183.0	3.40			3.60	3.50	4.90	4.00	4.80	3.75	4.45	3.80	2.30	3.60	3.40
179.0	2.80			3.50	3.45	4.80	4.00	6.00	3.50	3.80	3.60	2.70	3.50	3.60
1.0	8.90	13.10	10.90	8.40	8.00	8.50	9.30	8.40	10.50	9.70	16.00	3.50	5.90	2.10
2.0	4.40	8.90	6.20	7.80	7.50	8.10	7.70	9.90	9.60	9.50	6.60	6.30	1.30	6.30
3.0	6.90	6.90	6.50	7.10	6.70	8.40	8.80	8.60	8.70	8.30	7.45	6.10	5.75	6.10
4.0	6.30	6.30		10.20	13.90	6.70	18.10	9.40	9.30	10.10	14.40		6.40	6.95
5.0	7.80				6.10		11.20		8.40					
6.0											4.30	6.65	5.40	6.00
7.0											6.30	7.60	6.20	7.00

Appendix B. Observed Water Temperatures, Upper Illinois Waterway

(Temperature in degrees Centigrade)

MP	71 7/14	7/15	7/19	7/22	7/23	7/28	7/29	8/4	8/5	8/10	8/11	8/17	8/18	8/25
292.1		28.00		27.00	26.00	23.00	23.60	22.20	22.10	25.00	24.80	23.90	24.50	25.10
290.0		28.00		26.00	26.00	22.50	22.60	21.00	20.80	25.20	24.40	23.80	24.00	24.60
288.4		28.00		26.50	25.40	23.00	24.20	21.50	21.20	26.50	25.90	23.70	24.00	26.10
287.3		27.50		26.00	26.00	23.70	22.60	21.50	21.50	24.90	23.50	23.40	24.50	25.10
286.3														
285.8	25.00	26.50		26.00	26.90		23.20	23.50	23.20	24.30	23.20	23.80	24.50	26.00
284.0	30.00	31.50		31.00	31.00		27.20	24.40	23.50	29.20	28.00	26.20	26.60	29.00
281.0	29.00	30.00		29.00	29.00		26.30	24.00	23.50	27.50	27.00	26.80	26.20	29.00
278.0	28.50	29.50		29.00	28.20		26.80	24.00	24.00	27.00	27.30	26.80	26.00	28.50
276.1	28.50	29.50		28.50	29.00		26.80	24.00	24.00	27.10	27.00	27.10	26.00	28.00
273.5	28.80	29.00		27.30	29.00		26.20	24.30	23.80	27.00	26.20	26.70		28.00
272.4	27.50	28.50		28.00	28.50		26.40	24.00	24.80	27.00	26.20	27.20		27.50
271.6	29.00	27.50		29.00	28.20		27.20	25.10	25.30	29.90	28.70	28.20		28.00
270.6	27.50	27.80		27.00	28.40		27.00	25.00	25.10	29.00	28.00	27.30		28.00
267.2	27.00	28.00		28.80	28.30		26.90	24.90	24.90	28.00	28.20	27.00		28.00
265.0	27.10	28.00		28.50	28.20		26.90	24.90	24.70	28.20	27.90	27.00		28.00
263.7	27.50	27.50		28.70	28.80		26.90	24.90	24.90	28.10	28.00	26.80		28.50
261.6	27.50	27.00		29.00	28.80		26.70	24.90	24.90	27.90	27.50	26.80		28.00
258.0	28.00	27.00		28.00	28.00		26.10	24.90	24.80	27.60	27.50	26.40		28.50
256.0	27.90	27.00		28.00	28.00		26.10	24.90	24.90	27.70	27.50	26.50		28.00
253.0	27.50	27.00		28.00	27.90		26.00	25.00	24.80	27.70	27.90	26.70		28.00
250.0	27.50	27.00		27.80	27.80		26.00	24.90	24.80	27.70	27.90	27.00		28.50
247.0	27.80	27.00		27.30	27.50		25.90	24.80	24.80	27.70	27.90	27.00		28.50
246.9														
246.0	27.00	27.70	27.20	27.80	26.50	26.80		25.00	25.30	27.90	28.00	27.00	28.00	28.00
243.7	27.10	27.70	27.20	27.30	27.40	27.00		24.80	25.20	27.80	27.50	27.00	28.00	28.00
242.9				29.00		27.00		24.80	25.20	27.80	27.80	26.80	28.00	28.00
240.0	28.00	27.80	27.20	27.00	27.00	26.80		24.80	25.20	27.20	27.80	26.60	28.00	27.00
239.0	28.00	28.00	27.10	26.90	26.90	26.30		24.40	25.00	27.00	27.60	26.30	27.80	27.50
236.8	27.10	28.00	27.20	27.00	27.00	26.20		24.50	25.00	27.00	27.20	26.40	27.80	27.80
234.5	27.10		27.20	27.00	26.00	26.20		24.20	25.20	27.00	27.20	26.90	27.90	27.70
231.0	27.10		26.90	26.30	26.00	26.00		23.90	25.00	26.60	28.00	26.20	28.00	27.70
229.6	27.00		26.50	26.00	26.00	25.70		23.60	24.20	26.30	26.70	26.30	27.20	27.80
226.9	27.00		26.50	26.20	26.00	25.00		23.60	24.00	26.00	26.20	26.30	27.00	27.50
224.7	27.00		27.00	26.20	26.30	25.00		23.80	24.00	26.80	26.30	26.40	27.00	27.20
222.6	26.60		27.00	26.20	26.00	25.00		24.10	24.00	27.00	26.20	27.00	27.00	27.30
219.8			27.00	26.00	26.40	25.20		24.00	24.20	27.00	26.30	26.60	27.60	27.40
217.1	27.00		27.00	25.80	26.30	25.00		24.00	24.00	27.10	26.50	27.00	27.00	27.50
213.4	27.00		26.80	25.70	26.20	25.00		24.00	23.80	27.00	26.20	27.00	26.50	27.70
209.4	27.00		26.80	26.10	26.80	25.00		24.40	24.00	27.80	26.40	27.10	26.50	27.80
205.0	27.00		26.90	25.70	26.80	25.50		24.80	24.00	26.70	26.60	27.00	27.00	27.90
200.4	27.70		27.00	26.00	26.20	25.60		25.00	24.30	28.00	26.80	27.00	27.00	28.10
196.9	28.00		25.50	25.70	25.70	24.80		25.00	24.20	27.50	26.00	27.00	26.90	28.50
190.0	27.70		26.00	26.10	26.20	24.80		25.00	24.20	27.30	26.10	27.00	26.60	28.10
188.0	27.60		26.00	26.00	26.10	25.60		24.80	24.00	26.50	26.20	27.00	26.20	27.80
183.0	27.00		26.00	25.80	25.60	25.00		24.20	24.00	26.30	26.00	26.10	26.10	27.40
179.0	26.80		25.50	26.00	25.90	24.40		24.20	23.20	27.80	26.00	25.50	26.30	27.10
1.0		28.00		24.50	24.60	18.50	21.10	21.50	21.00	27.00	25.90	25.90	25.00	28.10
2.0		25.50		24.00	24.00		19.30	22.50	21.90	25.20	22.10	23.60	22.00	24.00
3.0		25.00		23.00	24.30	20.50	20.50	22.50	21.00	26.90	23.50	24.50	25.00	25.20
4.0		25.80		25.00	25.00	23.30		22.80	23.80	27.50	25.00	24.00	26.00	27.00
5.0		26.00		24.50			21.30		22.60	26.50	24.50		26.50	
6.0														
7.0														

(Continued on next page)

Appendix B (Concluded)

(Temperature in degrees Centigrade)

	71										72			
MP	8/26	8/31	9/1	9/2	9/3	9/20	9/21	9/22	9/28	9/30	7/11	7/18	7/24	7/26
292.1	25.00	25.00	25.30	27.30	27.80	22.90	22.80	25.60	25.50	25.10	27.40	26.00	26.50	24.50
290.0	24.10	24.50	25.00	26.10	26.30	22.10	22.00	25.00	24.90	25.10	27.10	26.00	26.00	25.00
288.4	25.10	25.10	25.80	26.40	26.50	22.40	21.90	23.60	23.10	23.20	26.80	25.50	27.00	25.00
287.3	24.80	24.40	26.10	25.90	26.10	21.90	21.70	22.50	23.10	23.00	26.70	24.50	27.00	25.00
286.3											26.10	24.00	27.00	25.00
285.8	25.60	24.90	25.40	26.50	26.80	22.10	21.70	21.70	23.30	23.40	26.00	26.00	26.90	25.10
284.0	27.40	29.50	29.00	32.00	31.80	27.00	25.90	26.80	27.40	31.30	31.40	26.00	28.40	27.00
281.0	26.50	28.50	27.80	29.00	29.20	25.20	25.90	25.20	26.80	27.50	29.50	25.80	28.90	27.10
278.0	27.00	28.00	27.80	29.00	29.00	24.80	26.00	24.40	25.50	28.00	29.00	25.80	29.00	27.00
276.1	26.70	27.70	27.30	28.80	29.00	24.20	25.70	24.00		28.00	28.80	25.20	29.00	27.00
273.5	26.50	28.00	27.50	29.00	29.00	24.00	24.00	24.40	25.00	27.20	29.50	25.00	28.90	27.20
272.4	26.50	27.80	27.30	29.00	29.00	24.00	23.50	24.00	26.00	26.70	29.80	25.30	28.80	27.00
271.6	27.50	31.00	28.30	30.00	31.20	24.90	24.50	25.00	25.40	26.00	30.00	27.30	29.20	27.00
270.6	27.30	27.90	28.20	29.50	30.00	24.20	24.00	24.50	25.50	25.00	30.00	26.00	29.50	27.00
267.2	27.60	27.80	28.00	29.20	30.00	24.60	24.00	24.20	25.50	25.00	29.30	26.00	29.70	27.10
265.0	27.30	27.60	28.00	29.00	29.80	24.80	23.80	24.00	25.50	25.00	29.00	25.90	29.40	27.00
263.7	27.10	27.30	28.00	29.00	29.60	24.60	23.20	23.80	25.00	25.10	28.80	26.00	29.30	27.40
261.6	27.00	27.20	27.80	28.60	29.20	24.80	23.00	23.50	25.00	25.30	28.80	25.90	29.40	27.30
258.0	26.70	27.00	27.80	28.40	29.20	24.30	23.10	23.30	24.90	25.60	28.20	26.00	29.20	27.00
256.0	26.30	27.00	27.80	28.20	29.00	24.00	23.20	23.20	24.90	25.20	28.10	26.30	29.10	27.00
253.0	26.80	27.00	27.80	28.20	29.20	23.80	23.80	23.10	25.00	25.00	28.40	26.70	29.10	27.30
250.0	26.80	27.00	27.80	28.00	29.20	23.70	23.80	23.00	25.00	25.00	28.50	26.90	29.00	27.30
247.0	26.90	27.00	27.50	28.00	29.00	23.30	23.50	22.90	25.00	25.00	28.30	27.30	28.80	27.50
246.9											28.10	26.00	27.50	26.50
246.0	27.10	27.00		28.00	29.20	23.00	24.00	23.10	25.00	25.10	29.10	28.00	29.10	27.00
243.7	26.70	27.00		28.10	29.10	23.00	24.00	23.00	25.00	25.00	29.10	28.00	29.10	27.00
242.9	27.00			28.10	29.00	23.60	24.00	23.00	25.00	24.90	29.10	28.00	28.80	26.80
240.0	27.00			28.00	28.60	23.00	23.40	22.90	24.30	24.80	29.00	28.00	29.00	26.80
239.0	26.40			28.00	28.20	23.00	22.90	22.80	24.10	24.70	29.00	27.00	28.10	25.90
236.8	26.00			28.00	28.30	23.90	22.80	22.90	24.10	25.00	28.50	26.90	28.20	26.00
234.5	26.00			28.00	28.20	22.80	23.00	22.60	24.00	25.00	29.00	26.50	29.00	26.20
231.0	26.70			27.60	27.80	22.30	22.20	22.10	23.20	24.70	29.10	26.20	29.00	26.40
229.6	26.00			28.00	27.30	22.00	21.40	21.50	23.20	24.30	27.00	26.00	29.00	26.20
226.9	26.50			27.50	25.30	21.70	21.00	22.00	23.10	24.30	27.10	26.00	29.00	26.30
224.7	26.90			27.50	27.20	21.60	20.90	21.80	23.00	24.60	27.00	25.80	29.00	26.10
222.6	27.00			27.50	27.20	22.00	20.90	22.00	23.00	24.80	27.00	26.00	29.00	26.70
219.8	27.00			27.50	27.20	21.60	21.00	21.80	23.00	24.80	27.00	26.00	29.00	26.20
217.1	27.00			27.80	27.20	22.00	21.00	21.70	22.90	24.40	27.00	26.30	29.00	26.40
213.4	26.50			27.60	27.00	21.40	20.10	21.10	22.10	24.10	26.70	26.80	29.00	27.00
209.4	26.90			27.70	27.20	21.50	20.80	22.80	23.00	24.20	26.50	26.80	29.00	27.00
205.0	26.50			27.20	27.20	21.50	20.50	22.10	22.00	24.90	26.50	27.00	29.00	27.30
200.4	26.90			27.70	27.00	21.50	20.10	21.20	21.80	24.90	26.00	27.00	28.80	27.00
196.9	26.00			27.40	26.50	21.40	19.80	20.80	21.30	24.00	26.00	27.00	29.00	26.50
190.0	26.20			27.00	26.90	21.50	19.80	21.00	21.50	24.00	26.00	27.20	29.00	26.90
188.0	26.50			27.20	26.80	21.40	19.70	21.00	21.30	23.90	26.00	27.20	29.00	26.90
183.0	26.50			27.10	26.50	20.80	20.00	20.20	21.50	24.50	28.00	27.10	29.00	27.00
179.0	26.50			27.00	26.80	20.40	19.80	21.10	21.30	24.00	26.00	26.60	29.00	27.00
1.0	27.30	27.50	27.70	28.10	28.30	17.60	16.70	23.60	23.50	24.30	28.30	24.00	25.00	25.10
2.0	22.40	24.00	24.30	24.90	25.30	15.60	14.90	17.50	22.80	23.20	26.10	22.50	26.00	22.00
3.0	23.20	24.20	24.50	23.90	27.40	17.60	16.10	17.50	20.30	21.00	25.50	24.80	26.20	24.00
4.0	23.30	25.00		26.50	27.30	16.00	18.00	17.10	22.30	23.10	28.00		25.80	24.00
5.0	23.80				26.20		18.10		26.50					
6.0											29.30	25.70	27.00	24.20
7.0											34.00	30.50	31.40	30.00

Appendix C. Ammonia, Nitrate, and Nitrite Data, Upper Illinois Waterway

MP	7/28/71	7/29/71	8/4/71	8/10/71	8/17/71	8/25/71	8/31/71	9/20/71	7/11/72	7/18/72	7/24/72	7/26/72
Ammonia concentrations, NH_3-N, *in milligrams per liter*												
292.1	3.68		3.12	3.32	3.84	2.45	2.60	6.12	6.02	5.17	2.90	5.14
290.0	3.60		3.34	3.23	3.88	3.10	2.32	6.05	6.70	5.26	2.95	5.49
287.3	3.60		2.79	3.58	4.08	3.00	2.60	5.73	6.25	4.05	2.32	4.69
286.3									6.27	3.78	2.84	4.63
285.8	3.48		2.76	2.94	3.36	3.10	2.75	5.63				
285.4									5.83	4.33	2.88	4.30
278.0		3.76	2.46	2.92	3.17	3.80	2.25	5.81	6.01	3.72	3.10	4.19
273.5		2.54	.11	3.19	3.04	3.52	2.55	5.82	6.12	3.49	3.17	4.16
271.6		2.68	1.65	2.31	2.84	3.18	1.75	3.93	4.79	.64	1.52	3.27
270.6		2.80	1.84	2.26	3.13	2.50	2.28	4.17	4.65	2.37	1.83	2.88
265.0		2.82	1.83	2.43	2.94	2.30	2.20	4.62	4.76	2.63	1.78	1.93
261.6		2.46	1.74	2.40	3.31	2.45	2.30	4.55	4.53	2.50	1.25	1.66
253.0		2.66	1.59	2.08	2.77	2.45	1.70	4.48	3.84	2.62	1.47	1.62
247.0	2.64		1.59	2.14	2.87	2.55	1.35	3.65	3.31	2.77	2.05	1.44
243.7	2.68		1.18	2.11	2.55	1.50		3.33	2.91	2.57	1.44	1.56
236.8	2.24		1.13	1.54	1.80	1.16		2.94		2.03	1.06	1.12
231.0	2.24		1.34	1.31	1.71	1.76		3.20	2.22	1.88	.64	1.21
226.9	2.26		1.82	1.16	1.78	1.46		2.59	1.66	1.66	.70	1.18
222.6	1.80		1.29	1.20	1.32	2.00		2.30	1.75	1.68	.52	1.66
213.4	1.54		1.48	1.22	1.63	1.67		2.24	1.36	1.76	.35	.93
196.9	1.11		.80	1.21	1.12	1.29		1.16	1.46	1.33	.12	.88
179.0	.62		.86	.81	.58	.74		.45	.67	.66	.18	.60
Ammonia loads in pounds per day												
292.1	117,983		100,333	120,834	132,465	101,847	82,937	91,413	109,636	243,298	87,634	155,296
290.0	115,807		107,642	126,587	134,662	129,370	74,180	90,956	122,743	246,719	88,843	166,729
287.3	119,093		92,116	109,220	147,817	132,957	87,064	90,786	121,811	257,413	133,995	163,066
286.3									123,147	239,457	163,526	162,003
285.8	116,025		91,647	110,527	123,328	138,628	92,667	90,509				
285.4									115,071	288,376	166,187	151,407
278.0		124,406	83,545	115,393	123,630	176,723	77,653	99,521	125,530	211,713	175,372	154,628
273.5		119,555		126,597	123,452	171,096	88,007	104,030	136,335	242,423	181,776	169,838
271.6		110,540	57,320	101,204	129,107	170,128	71,283	97,433	152,830	37,747	126,783	219,913
270.6		115,731	75,277	98,977	143,164	133,554	93,094	103,901	143,015	250,427	152,393	194,089
265.0		118,051	75,916	106,252	189,522	126,613	91,182	118,756	156,672	274,695	146,713	132,637
261.6		103,871	72,821	104,901	160,585	137,000	96,245	119,315	153,034	337,371	105,832	118,110
253.0		113,177	67,101	90,813	127,303	141,896	72,689	122,754	134,713	300,050	122,596	118,320
247.0	115,021		68,844	93,144	151,792	151,281	58,599	103,027	119,154	313,675	169,133	107,106
243.7	123,168		51,512	92,122	134,894	88,174		96,661	105,350	285,347	120,747	118,244
236.8	107,169		52,814	70,574	98,123	72,860		94,550		226,637	96,769	93,153
231.0	106,657		63,590	60,485	92,802	109,132		104,516	89,539	202,816	59,924	103,548
226.9	109,188		87,340	58,866	96,274	89,656		84,470	67,382	177,499	66,765	103,093
222.6	85,410		62,817	56,138	71,202	121,684		77,018	73,913	201,203	53,566	154,015
213.4	73,458		73,848	57,784	87,256	99,355		76,823	58,181	199,701	36,751	90,021
196.9	51,508		41,661	58,608	59,164	73,674		41,577	64,616	141,754	13,605	92,207
179.0	28,383		46,862	40,196	30,185	40,339		16,871	30,368	62,270	21,781	67,572

(Continued on next page)

Appendix C (Continued)

MP	8/17/71	8/25/71	8/31/71	9/20/71	7/11/72	7/18/72	7/24/72	7/26/72
Nitrate concentrations, NO_3-N, *in milligrams per liter*								
292.1	.18	.08	.46	.39	.45	.57	.86	1.03
290.0	.12	.10	.44	.36	.15	.59	.98	1.24
287.3	.21	.09	.44	.38	.30	.86	1.03	1.29
286.3					.05	.74	.91	1.15
285.8	.15	.34	.52	.39				
285.4					.10	.81	1.17	1.26
278.0	.32	.42	.62	.52	.35	1.08	1.22	1.31
273.5	.35	.52	.69	.58	.60	1.34	1.37	1.59
271.6	.45	.66	.84	.90	1.80	1.47	2.94	2.91
270.6	.48	.63	.74	.93	1.80	1.18	2.35	2.81
265.0	.58	.64	.92	1.04	1.80	1.40	2.80	3.15
261.6	.52	.61	.84	1.08	1.95	1.33	2.96	3.22
253.0	.56	.86	.94	1.27	2.30	1.33	3.19	3.55
247.0	.54	.92	.90	1.46	2.60	1.42	3.16	3.58
243.7	.62	1.14		1.76	3.15	1.74	3.32	3.65
236.8	.75	1.18		1.86		2.56	3.26	3.65
231.0	.66	1.16		1.85	3.10	2.60	3.47	3.63
226.9	.76	1.21		2.09	3.25	2.58	3.78	3.75
222.6	.89	1.34		1.98	3.50	3.30	4.22	4.07
213.4	1.01	1.26		2.22	4.45	2.07	4.26	5.60
196.9	1.05	1.70		2.36	4.20	3.28	4.63	4.30
179.0	1.42	1.90		2.66	4.35	3.41	4.83	4.10
Nitrate loads in pounds per day								
292.1	6,209	3,326	14,650	5,816	8,195	26,827	31,125	31,120
290.0	4,165	4,173	14,046	5,403	2,748	26,674	37,344	37,658
287.3	7,608	3,989	14,710	6,011	5,847	54,661	74,473	44,852
286.3					982	46,878	66,217	40,238
285.8	5,506	15,204	17,494	6,260				
285.4					1,974	53,946	72,707	44,366
278.0	12,480	19,533	21,363	8,893	7,314	70,175	74,109	48,344
273.5	14,213	25,276	24,300	10,350	13,366	93,079	91,175	61,986
271.6	20,459	35,310	34,161	22,277	57,431	155,605	242,720	195,700
270.6	21,955	33,837	30,166	23,135	57,684	124,605	234,003	189,370
265.0	27,525	35,231	38,069	26,690	59,246	146,226	259,633	216,480
261.6	25,228	34,110	35,094	28,275	65,895	154,725	272,624	229,085
253.0	28,605	49,808	40,128	34,742	80,688	152,316	296,066	259,280
247.0	28,560	54,580	39,003	41,144	93,595	160,801	295,864	266,278
243.7	32,713	67,012		51,088	114,039	193,192	306,059	276,660
236.8	40,884	74,116		59,817		285,809	333,215	308,580
231.0	35,182	71,928		60,423	125,032	280,491	339,883	310,645
226.9	41,106	74,304		69,051	131,923	275,871	357,670	327,626
222.6	48,008	81,528		62,107	147,826	395,220	411,428	377,614
213.4	54,067	74,963		76,206	190,372	325,649	447,309	542,060
196.9	55,466	97,089		84,587	185,882	349,588	487,512	450,554
179.0	73,902	103,574		99,728	197,164	321,729	496,115	461,782

(Continued on next page)

Appendix C (Concluded)

MP	7/11/72	7/18/72	7/24/72	7/26/72	Average
Nitrite concentrations in milligrams per liter					
292.1	0.36	0.41	0.22	0.20	
290.0	0.28	0.42	0.22	0.20	
287.3	0.24	0.32	0.17	0.15	
286.3	0.20	0.26	0.16	0.18	
285.4	0.22	0.39	0.21	0.16	
278.0	0.27	0.26	0.26	0.22	
273.5	0.30	0.24	0.24	0.21	
271.6	0.28	0.16	0.14	0.06	
270.6	0.38	0.21	0.16	0.06	
265.0	0.40	0.24	0.17	0.05	
261.6	0.38	0.24	0.16	0.04	
253.0	0.45	0.24	0.21	0.04	
247.0	0.61	0.29	0.21	0.05	
243.7	0.60	0.32	0.22	0.06	
236.8		0.35	0.14	0.02	
231.0	0.65	0.47	0.20	0.08	
226.9	0.61	0.45	0.30	0.12	
222.6	0.65	0.45	0.37	0.28	
213.4	0.75	0.59	0.42	1.25	
196.9	0.89	1.24	0.65	1.60	
179.0	0.93	1.49	0.52	1.88	
Nitrite loads in pounds per day					
292.1	6,556	19,293	6,648	6,043	8,124
290.0	5,130	19,700	6,626	6,074	9,383
287.3	4,678	20,339	9,814	5,215	10,015
286.3	3,928	16,471	9,213	6,298	8,978
285.4	4,342	25,974	12,118	5,634	12,017
278.0	5,642	15,894	14,709	8,119	11,341
273.5	6,683	16,671	13,762	8,187	11,326
271.6	8,934	16,937	11,677	4,035	11,146
270.6	12,178	22,190	13,324	4,044	12,934
265.0	13,166	25,067	14,012	3,436	13,920
261.6	12,837	27,920	13,547	2,846	14,288
253.0	15,787	27,486	17,514	2,921	15,927
247.0	21,959	32,840	17,326	3,719	18,961
243.7	21,722	35,529	18,447	4,548	20,062
236.8		39,075	12,781	1,663	19,372
231.0	26,216	50,704	18,726	6,846	25,623
226.9	24,761	48,117	28,614	10,484	27,994
222.6	27,453	53,894	37,403	25,978	36,182
213.4	32,085	66,945	44,101	121,000	66,032
196.9	39,389	132,161	73,694	167,650	103,223
179.0	42,152	140,580	68,922	211,726	114,345

Appendix D. Algal Densities, Upper Illinois Waterway, 1971

(Counts per milliliter)

MP	7/28	8/4	8/10	8/17	8/25	8/31	9/2	9/20	9/22
292.1	310	1,700	470	5700	2500	2000		1300	1100
287.3	1600	6,000	630	3100	1300	3000		3300	1700
285.8	2500	2,500	4900	3300	2400	1700		1400	1100
278.0	3800	2,400	5000	4600	3100	2200		3000	790
271.6	4100	2,400	1100	3900	2700	2800		5000	3600
270.6	2200	4,600	1100	3300	2700	3100		1400	2800
265.0	1400	5,200	2800	4100	2500	2200		3600	1900
261.6	2400	5,700	2800	2400	1400	4400		4400	2500
247.0	1900	1,600	4400	2800	1400	3000		1300	1900
243.7	3800	7,900	4200	4200	2300		3100	2200	2700
236.9	2200	2,200	5000	2400	1100		2800	2000	1300
231.0	3900	2,200	3500	3600	3300		3100	3900	1700
226.9	2200	10,000	5500	2000	3600		2700	2800	5200
222.6	2800	13,000	2800	3100	1900		4200	4400	2800
213.4	1700	3,600	4100	3500	2000		1600	3600	2700
196.9	3000	8,500	3900	3500	1900		3500	6700	2800
188.0	5600	4,600	3900	3600	2500		4400	3600	2700
179.0	1700	4,100	4700	3900	2200		2700	2700	2400

Appendix E. Total and Fecal Coliform Densities, Upper Illinois Waterway, 1971

MP	7/28	8/4	8/10	8/17	8/25	8/31	9/20	9/22	9/28
Total coliform densities per 100 ml									
292.1	240,000	220,000	65,000	110,000	9,900,000	10,000	1,600,000	100,000	
290.0	250,000	380,000	200,000	210,000	9,500,000	180,000	550,000		10,000
287.3	280,000	360,000	210,000	230,000	330,000	220,000	440,000	140,000	45,000
285.8	240,000	230,000	5,800,000	520,000	150,000	1,000,000	530,000	900,000	95,000
278.0		1,300,000	540,000	280,000	180,000	590,000	210,000	150,000	43,000
271.6		540,000	40,000	56,000	310,000	80,000	66,000	48,000	15,000
270.6		260,000	43,000	33,000	120,000	62,000	67,000	32,000	
265.0		1,000,000	20,000	25,000	8,000	34,000	33,000	15,000	21,000
261.6		1,300,000	20,000	19,000	230,000	64,000	57,000	15,000	18,000
247.0		120,000	17,000	7,400	21,000	35,000	2,000	5,100	3,600
243.7	14,000	20,000	71,000	30,000	27,000		10,000	6,000	10,000
236.9	7,100	280,000	40,000	24,000	500		14,000	4,700	4,000
231.0	38,000	43,000	15,000	3,300	10,000		9,500	4,000	2,400
226.9	19,000	21,000	6,600	2,000	1,100		2,300	4,300	4,600
222.6	5,500	44,090	16,000	1,500			7,100	5,400	3,200
213.4	3,800	6,400	2,500	1,900	1,300		18,000	4,700	5,300
196.9	940	600	86,000	880	3,800		1,300	6,900	5,000
188.0	1,200	200	380	480	7,700		330	4,400	2,000
179.0	1,100	200	29,000*	240	600		360	2,400	880
Fecal coliform densities per 100 ml									
292.1	13,000	1,800	200	3,800	400,000	1,000	270,000	10,000	
290.0	12,000	15,000	4,900	7,500	350,000	12,000	78,000		1,800
287.3	14,000	16,000	16,000	10,000	25,000	43,000	80,000	25,000	
285.8	18,000	10,000	42,000	48,000	6,500	220,000	85,000	46,000	6,000
278.0		400,000	9,500	10,000	4,800	34,000	34,000	6,500	14,000
271.6		9,300	1,700	1,000	5,100	5,000	13,000	1,400	2,000
270.6		14,000	800	1,400	3,400	3.900	9,800	1,000	
265.0		68,000	600	1,300	100	2,000	6,400	450	2,400
261.6		240,000	600	1,500	5,600	3,000	3,000	950	2,600
247.0		1,400	300	230	1,200	460	370	630	350
243.7	740	1,800	440	210	490		560	340	620
236.9	240	10,000	900	700	60		670	350	480
231.0	220	9,000	200	160	220		410	180	210
226.9	400	340	150	80	100		95	320	290
222.6	130	5,500	1,600	100			1,900	400	330
213.4	160	550	230	200	100		3,800	670	630
196.9	65	130	7,000	46	50		290	400	1,900
188.0	60	72	57	40	94		95	390	650
179.0	100	34		21	4		87	34	260

* *Collected on 8/11, very turbid*

Appendix F. BOD Curve Fitting Summary

Station 290.0 – 10/19/1971

Power factor	K_1 (l/day)	L_a (mg/l)	t_0 (days)	Standard error
Total BOD				
1.0	.08677	45.38	2.786	2.79
1.9	.13913	33.14	2.549	1.01
2.0	.13324	33.04	2.225	0.98
2.1	.12764	33.01	1.908	0.93
Carbonaceous BOD				
1.0	.07464	3.24	−2.358	0.06
1.9	.07128	2.58	−6.982	0.06
2.0	.06857	2.57	−7.552	0.06
2.1	.06692	2.55	−8.041	0.06
Nitrogenous BOD				
1.0	.08038	43.87	2.855	3.01
1.9	.15186	30.63	3.290	0.51
2.0	.14906	30.57	3.150	0.45
2.1	.14769	30.21	3.006	0.44

Station 290.0 – 10/21/1971

Power factor	K_1 (l/day)	L_a (mg/l)	t_0 (days)	Standard error
Total BOD				
1.0	.11589	38.01	2.670	2.62
1.9	.17894	29.58	2.678	0.96
2.0	.17097	29.49	2.414	0.96
2.1	.16115	29.53	2.087	0.94
Carbonaceous BOD				
1.0	.10487	2.92	−1.448	0.15
1.9	.09188	2.46	−5.063	0.14
2.0	.08792	2.45	−5.578	0.14
2.1	.08642	2.43	−5.859	0.14
Nitrogenous BOD				
1.0	.09772	37.84	2.756	2.68
1.9	.19221	26.45	3.089	0.62
2.0	.19187	26.26	3.019	0.56
2.1	.18861	26.16	2.899	0.51

Station 290.0 – 10/28/1971

Power factor	K_1 (l/day)	L_a (mg/l)	t_0 (days)	Standard error
Total BOD				
1.0	.11293	46.77	2.622	3.21
1.9	.16811	36.49	2.547	1.50
2.0	.15954	36.44	2.237	1.46
2.1	.15228	36.43	1.952	1.41
Carbonaceous BOD				
1.0	.06769	4.87	−2.186	0.07
1.9	.06212	3.95	−7.619	0.08
2.0	.06171	3.88	−8.008	0.08
2.1	.05962	3.86	−8.625	0.08
Nitrogenous BOD				
1.0	.11952	41.53	2.902	3.25
1.9	.18289	32.90	3.093	1.25
2.0	.17960	32.83	2.985	1.18
2.1	.17495	32.76	2.830	1.13

Station 290.0 – 11/9/1971

Power factor	K_1 (l/day)	L_a (mg/l)	t_0 (days)	Standard error
Total BOD				
1.0	.07388	57.99	2.406	5.04
1.9	.10049	48.31	2.122	2.37
2.0	.09687	48.14	1.729	2.31
2.1	.09416	47.88	1.386	2.24
Carbonaceous BOD				
1.0	.06200	17.32	0.420	0.58
1.9	.07213	13.12	−3.014	0.44
2.0	.07158	12.89	−3.357	0.44
2.1	.07031	12.73	−3.760	0.44
Nitrogenous BOD				
1.0	.07137	42.08	2.939	4.85
1.9	.10883	36.20	3.396	1.90
2.0	.10357	37.80	3.247	1.64
2.1	.10174	38.01	3.090	1.53

Station 287.3 – 10/19/1971

Power factor	K_1 (l/day)	L_a (mg/l)	t_0 (days)	Standard error
Total BOD				
1.0	.09561	42.17	2.506	2.64
1.9	.12828	32.69	1.648	1.28
2.0	.12396	32.57	1.358	1.26
2.1	.11989	32.48	1.074	1.16
Carbonaceous BOD				
1.0	.16044	3.32	−0.460	0.11
1.9	.10422	3.08	−4.371	0.12
2.0	.10041	3.07	−4.770	0.12
2.1	.09521	3.07	−5.302	0.12
Nitrogenous BOD				
1.0	.09364	38.51	2.693	2.68
1.9	.14128	29.45	2.537	1.01
2.0	.13456	29.49	2.206	0.98
2.1	.13021	29.29	1.920	0.94

Station 287.3 – 10/21/1971

Power factor	K_1 (l/day)	L_a (mg/l)	t_0 (days)	Standard error
Total BOD				
1.0	.09059	42.84	2.621	2.86
1.9	.12152	33.44	1.693	1.44
2.0	.11821	33.22	1.413	1.38
2.1	.11540	33.01	1.159	1.33
Carbonaceous BOD				
1.0	.20702	3.37	−0.964	0.07
1.9	.11658	3.22	−4.924	0.06
2.0	.11286	3.21	−5.223	0.06
2.1	.10673	3.20	−5.761	0.06
Nitrogenous BOD				
1.0	.07686	42.72	3.033	3.14
1.9	.16576	27.66	3.507	1.02
2.0	.16264	27.75	3.402	0.95
2.1	.15937	27.65	3.253	0.92

(Continued on next page)

Appendix F (Concluded)

Power factor	K_1 (l/day)	L_a (mg/l)	t_o (days)	Standard error
Station 287.3 – 10/28/1971				
Total BOD				
1.0	.07388	54.09	2.881	3.03
1.9	.11799	37.98	2.208	1.48
2.0	.11284	37.97	1.839	1.41
2.1	.10870	37.88	1.499	1.34
Carbonaceous BOD				
1.0	.13319	3.89	−1.621	0.07
1.9	.08312	3.64	−6.786	0.09
2.0	.07896	3.63	−7.428	0.09
2.1	.07535	3.62	−8.043	0.09
Nitrogenous BOD				
1.0	.08686	43.74	3.358	3.38
1.9	.13325	33.79	3.322	1.13
2.0	.13139	33.55	3.158	1.06
2.1	.12946	33.30	2.988	1.00
Station 287.3 – 11/9/1971				
Total BOD				
1.0	.08663	44.83	1.817	2.98
1.9	.10140	37.31	0.492	1.37
2.0	.09874	37.12	0.183	1.30
2.1	.09740	36.74	−0.057	1.25
Carbonaceous BOD				
1.0	.06220	17.54	0.227	0.48
1.9	.07204	13.20	−3.283	0.37
2.0	.07138	12.94	−3.653	0.37
2.1	.06968	12.82	−4.095	0.37
Nitrogenous BOD				
1.0	.07920	32.45	2.217	2.44
1.9	.11606	25.40	2.062	0.86
2.0	.11518	25.01	1.862	0.84
2.1	.11431	24.62	1.664	0.81
Station 285.8 – 10/19/1971				
Total BOD				
1.0	.09916	41.54	2.324	2.36
1.9	.12193	32.92	1.062	1.17
2.0	.11845	32.76	0.790	1.11
2.1	.11516	32.58	0.512	1.06
Carbonaceous BOD				
1.0	.12708	4.34	−0.767	0.11
1.9	.09303	3.87	−4.834	0.11
2.0	.08965	3.86	−5.275	0.11
2.1	.08644	3.84	−5.724	0.11
Nitrogenous BOD				
1.0	.10022	36.61	2.489	2.04
1.9	.13440	28.46	1.790	0.89
2.0	.12959	28.41	1.517	0.85
2.1	.12595	28.59	1.273	0.82

Power factor	K_1 (l/day)	L_a (mg/l)	t_o (days)	Standard error
Station 285.8 – 10/21/1971				
Total BOD				
1.0	.11674	41.87	2.415	2.83
1.9	.14946	33.63	1.649	1.53
2.0	.14404	33.62	1.404	1.48
2.1	.14082	33.40	1.202	1.44
Carbonaceous BOD				
1.0	.21764	3.70	−0.363	0.12
1.9	.12893	3.53	−3.745	0.11
2.0	.12298	3.52	−4.125	0.11
2.1	.11776	3.51	−4.495	0.11
Nitrogenous BOD				
1.0	.09729	40.51	2.771	2.94
1.9	.18854	28.43	3.010	1.04
2.0	.18494	28.34	2.883	1.01
2.1	.17942	28.20	2.692	1.00
Station 285.8 – 10/28/1971				
Total BOD				
1.0	.11554	47.39	2.328	2.89
1.9	.13491	38.88	1.234	1.48
2.0	.13021	38.81	0.969	1.41
2.1	.12564	38.76	0.695	1.34
Carbonaceous BOD				
1.0	.23710	6.64	−0.106	0.10
1.9	.12983	6.46	−3.629	0.14
2.0	.12338	6.45	−4.030	0.14
2.1	.11774	6.45	−4.419	0.14
Nitrogenous BOD				
1.0	.10512	41.42	2.997	3.07
1.9	.16713	31.83	3.068	0.88
2.0	.16404	31.71	2.930	0.26
2.1	.15994	31.59	2.756	0.25
Station 285.8 – 11/9/1971				
Total BOD				
1.0	.08156	89.38	1.269	5.13
1.9	.09681	70.75	−0.578	2.92
2.0	.09299	71.02	−0.944	2.76
2.1	.08971	70.99	−0.133	2.63
Carbonaceous BOD				
1.0	.11698	24.58	−1.271	0.71
1.9	.08119	22.49	−5.951	0.81
2.0	.07603	22.49	−6.749	0.82
2.1	.07456	22.36	−7.069	0.82
Nitrogenous BOD				
1.0	.08998	57.64	2.462	5.34
1.9	.13776	45.76	2.839	1.44
2.0	.13585	45.85	2.276	1.24
2.1	.13458	45.67	2.267	1.10

Appendix G. DO_U Modeling Parameters

Pool Code

1 — Brandon Road Pool
2 — Dresden Island Pool
3 — Marseilles Pool
4 — Starved Rock Pool
5 — Peoria Pool
6 — Marseilles-Starved Rock Pools
x/y* — Special Pool Reaches

Note

***Where long reaches existed such as the Peoria Pool (here designated as 5) or where considering the Marseilles and Starved Rock Pools as a single reach (here designated as 6) the DO_u curve sometimes displayed abrupt changes in slope. When this occurred the pool was considered as two reaches and computations were made for K'_d and L_a for the two distinct curves generated for each reach. These are tabulated here as 'special pool reaches'. The x values are the pool number and the y values are simply an arbitrary identification code useful for data retrieval.**

Conventional Pool Reaches

		Power 2				*Power 1*			
Date	**Pool code**	**K'_d (1/day)**	**L_a (10^5 lbs/day)**	**t_o (days)**	**SE**	**K'_d (1/day)**	**L_a (10^5 lbs/day)**	**t_o (days)**	**SE**
1971									
7/14	**1**	**0.32514**	**6.189**	**−0.7024**	**.0144**	**0.28720**	**4.481**	**−0.2303**	**.0412**
	2	**0.33200**	**4.315**	**−1.158**	**.0870**	**0.29602**	**4.954**	**−0.3880**	**.0717**
	3	**0.32779**	**4.199**	**−0.7553**	**.0849**	**0.32220**	**3.582**	**−0.1472**	**.0716**
	4	**0.29496**	**2.581**	**−1.750**	**.0389**	**0.20818**	**3.997**	**−0.7710**	**.0458**
	5	**0.41215**	**3.726**	**−0.5354**	**.0873**	**0.16179**	**8.816**	**0.02327**	**.0646**
7/15	**1**	**0.40675**	**23.91**	**−0.3233**	**.0744**	**0.36437**	**13.42**	**−0.03838**	**.0497**
	2	**0.32140**	**5.279**	**−0.5777**	**.169**	**3.64975**	**0.9335**	**0.08851**	**.0077**
	3	**0.32312**	**6.519**	**−0.2116**	**.0472**	**0.09400**	**10.08**	**0.09298**	**.0864**
7/19	**4**	**0.25291**	**1.730**	**−0.2309**	**.0791**	**0.14750**	**3.310**	**−1.078**	**.0757**
	5	**0.11068**	**7.559**	**−2.446**	**.0866**	**0.07709**	**9.171**	**−0.6192**	**.1120**
7/22	**1**	**0.18901**	**1.102**	**−2.368**	**.0841**	**0.10656**	**1.328**	**−1.595**	**.0240**
	2	**0.33881**	**10.52**	**−0.2661**	**.2200**	**4.34977**	**0.9586**	**0.1176**	**.0015**
	6	**0.55372**	**1.278**	**−0.7342**	**.0375**	**0.75007**	**1.429**	**−0.0738**	**.0388**
	5	**0.18630**	**3.759**	**−1.154**	**.0740**	**0.07671**	**8.064**	**−0.02949**	**.0861**
7/23	**1**	**0.35399**	**10.23**	**−0.4772**	**.0106**	**0.33052**	**5.609**	**−0.1348**	**.0050**
	2	**1.70062**	**1.188**	**−0.03144**	**.0379**	**0.82900**	**2.167**	**0.0734**	**.0695**
	6	**0.50394**	**1.654**	**−0.5725**	**.1030**	**0.48050**	**2.152**	**0.02934**	**.0929**
	5	**0.27074**	**2.835**	**−0.8584**	**.1030**	**0.11962**	**6.174**	**0.00712**	**.0966**
7/28	**1**	**0.25772**	**1.997**	**−0.2765**	**.0160**	**0.27101**	**2.461**	**−1.441**	**.0153**
	4	**0.31275**	**2.125**	**−1.096**	**.0365**	**0.20605**	**3.131**	**−0.3238**	**.0437**
	5	**0.48432**	**2.107**	**−0.4282**	**.0770**	**0.45243**	**2.687**	**0.1230**	**.0425**
7/29	**1**	**0.18131**	**0.6847**	**−1.769**	**.0035**	**0.12085**	**0.738**	**−0.7768**	**.0033**
	2	**0.30933**	**5.847**	**−0.6663**	**.1010**	**0.29118**	**5.062**	**−0.03806**	**.0762**
	3	**2.03634**	**0.9445**	**0.04354**	**.0236**	**1.84633**	**1.130**	**0.1501**	**.0619**
8/4	**1**	**0.22360**	**1.476**	**−2.086**	**.0110**	**0.28206**	**1.294**	**−0.8812**	**.0108**
	2	**0.30683**	**5.774**	**−0.5452**	**.0356**	**0.27956**	**4.485**	**−0.00268**	**.0471**
	6	**0.66400**	**1.990**	**−0.3051**	**.0790**	**0.54429**	**2.739**	**0.0907**	**.0952**
	5	**0.18124**	**3.232**	**−1.063**	**.0938**	**0.06312**	**7.174**	**−0.09175**	**.1130**
8/5	**1**	**0.24005**	**1.380**	**−2.006**	**.00997**	**0.17045**	**1.878**	**−0.9638**	**.0095**
	2	**0.36060**	**4.538**	**−0.8734**	**.1360**	**1.89971**	**1.693**	**−0.04071**	**.0255**
	3	**1.30252**	**0.9489**	**−0.1485**	**.0490**	**0.76751**	**1.567**	**0.02310**	**.0615**
	6	**0.74255**	**1.308**	**−0.3888**	**.0635**	**0.66565**	**1.741**	**0.01454**	**.0599**
	4	**0.07943**	**1.7580**	**−5.026**	**.0035**	**0.11811**	**1.175**	**−2.095**	**.0033**
	5	**0.22712**	**4.502**	**−0.6634**	**.0865**	**0.07059**	**11.99**	**0.1925**	**.1140**
8/10	**1**	**0.25846**	**2.035**	**−2.005**	**.0126**	**0.25654**	**2.094**	**−1.020**	**.0115**
	2	**0.32235**	**13.27**	**−0.2387**	**.0991**	**0.31368**	**6.898**	**0.1155**	**.0411**
	6	**0.67484**	**2.240**	**−0.3474**	**.0721**	**0.56460**	**2.993**	**0.03925**	**.1130**
	5	**0.14919**	**7.716**	**−0.6220**	**.0979**	**0.06313**	**11.02**	**0.2117**	**.1650**

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Appendix G (Continued)
Conventional Pool Reaches

		Power 2				*Power 1*			
Date	Pool code	K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE	K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE
1971									
8/11	1	0.23726	1.128	−2.654	.0135	0.27308	1.707	−1.410	.0131
	2	0.33944	2.499	−1.265	.1270	0.29163	3.327	−0.3882	.1200
	6	0.75323	2.611	−0.1508	.1810	0.43672	4.303	0.1201	.2230
	5	0.30313	3.939	−0.7326	.0755	0.11126	10.04	0.04690	.0788
8/17	1	0.40706	18.23	−0.1518	.0190	0.33471	6.181	0.003384	.0079
	2	0.32322	8.633	−0.3993	.0577	0.30475	5.685	0.04745	.0410
	6	0.61922	2.988	−0.2864	.1530	0.31677	5.689	0.1085	.1520
	5	0.21519	6.799	−0.5544	.1390	0.07992	1.473	0.3095	.0212
8/18	1	0.34878	13.51	−0.2272	.0177	0.27700	5.312	−0.01961	.0004
	4	0.30042	3.032	−0.6677	.0952	0.33072	2.369	−0.1191	.0853
	5	0.21141	4.873	−0.9918	.1590	0.08916	10.58	0.06168	.1540
8/25	1	0.40094	19.21	−0.2507	.0493	0.33308	8.033	−0.04669	.0270
	2	0.22457	1.447	−1.603	.0154	0.18289	1.610	−0.5871	.0163
	6	0.67467	3.480	−0.3051	.1100	0.31087	7.195	0.03722	.1240
	5	0.32763	4.796	−0.2325	.1320	0.11896	12.43	0.5181	.1710
8/26	1	0.39894	21.37	−0.3518	.1450	0.31686	12.40	−0.07803	.1120
	2	0.34611	6.603	−0.7704	.2590	5.64037	1.644	0.1862	.0449
	6	0.67567	1.920	−0.2784	.0576	0.30302	4.146	0.07930	.0477
	5	0.28267	4.363	−0.9570	.1160	0.14860	8.341	−0.07469	.0931
8/31	1	0.33176	2.751	−1.178	.0263	0.30221	2.717	−0.5044	.0240
	2	0.31142	6.580	−0.5626	.1180	0.29037	4.971	−0.04293	.0799
	3	1.80072	0.8281	−0.1036	.0582	0.35650	2.427	−0.1454	.0974
9/1	1	0.34434	10.87	−0.4469	.0105	0.31284	5.595	−0.1234	.0032
	2	2.16937	1.184	−0.1604	.0360	3.17046	1.284	0.01167	.0159
	3	1.45310	0.9110	−0.2041	.0178	1.67383	1.066	0.02407	.0330
9/2	1	0.29402	2.295	−1.354	.0034	0.31896	2.030	−0.5549	.0048
	2	0.32842	5.582	−0.5850	.0767	0.33127	4.169	−0.06062	.0421
	3	0.32415	2.383	−0.8858	.0959	0.25491	3.067	−0.1191	.0801
	4	0.33012	3.579	−0.2666	.0501	0.29503	1.955	0.03022	.0270
	5	0.38806	3.003	−0.2275	.0785	0.13242	7.796	0.3060	.0989
9/3	1	0.30189	2.493	−1.135	.0201	0.27552	2.206	−0.4776	.0181
	2	0.3289	5.199	−0.6286	.0800	0.28026	4.568	−0.09788	.0743
	6	0.70009	1.303	−0.3028	.0464	0.47708	2.073	0.08010	.0372
	5	0.29283	3.424	−0.7519	.0972	0.10461	8.846	0.02774	.0875
9/20	1	0.31200	4.735	−0.3215	.0478	0.39383	1.924	0.03699	.0257
	2	0.25357	1.548	−1.328	.0890	1.66367	0.6644	0.07653	.0176
	6	0.28171	1.761	−0.9646	.0658	0.19455	2.799	0.006174	.0514
	5	0.24888	2.172	−0.5496	.1140	0.07458	6.371	0.2667	.1170
9/21	1	0.30529	9.480	−0.2835	.0589	0.28071	4.363	0.02600	.0284
	2	1.52667	0.9486	−0.1880	.0072	2.40717	0.9862	0.05122	.0189
	6	0.54639	1.723	−0.1301	.0952	0.41865	2.376	0.2858	.1170
	5	0.21376	2.811	−0.9724	.0392	0.06178	8.610	0.0399	.0422
9/22	1	0.16989	1.174	−1.979	.0025	0.11228	1.377	−0.8309	.0015
	2	0.31920	3.733	−0.3365	.0831	0.34488	2.447	0.1332	.0392
	6	0.35563	1.867	−1.064	.0470	0.30959	2.570	−0.2152	.0637
	5	0.11660	5.805	−0.7879	.0941	0.06590	6.905	0.4608	.1460
9/28	1	0.30889	6.680	−0.1712	.0104	0.33479	2.184	0.07061	.0136
	2	0.11395	3.441	−2.083	.0818	0.22322	1.509	−0.4385	.0676
	6	0.52254	2.027	−0.3393	.0515	0.33337	3.245	0.1158	.0708
	5	0.26317	2.675	−0.6434	.0412	0.15677	4.723	0.3622	.0883
9/30	1	0.28092	2.096	−0.6727	.0066	0.24905	1.458	−0.1554	.0002
	2	0.19457	1.711	−2.122	.0511	0.19856	2.033	−0.5326	.0451
	6	0.53731	1.998	−0.4609	.0774	0.56311	2.403	0.07033	.1060
	5	0.17305	3.549	−1.146	.0832	0.04526	11.36	−0.0020	.1010

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Appendix G (Continued)

Conventional Pool Reaches

Date	Pool code	Power 2				Power 1			
		K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE	K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE
1972									
7/11	1	0.31696	6.903	−0.2374	.1220	0.29241	3.155	0.04938	.0993
	2	0.34241	2.754	−0.8563	.0921	0.29450	3.135	−0.1603	.0644
	3	0.17568	2.389	−1.557	.0482	0.19102	1.932	−0.3799	.0517
	4	0.34806	2.529	−0.3495	.0232	0.27799	2.560	0.1440	.0284
	5	0.35951	2.701	−0.6245	.1390	0.25675	4.114	0.07496	.1290
7/18	1	0.49303	2.880	−0.09347	.0282	0.33078	9.005	0.00464	.00879
	2	0.41600	2.197	−0.1866	.1220	0.34132	10.970	0.03327	.0219
	3	0.39719	22.24	−0.4031	.0764	0.32682	16.400	−0.04761	.1070
	4	0.34296	14.00	−0.5022	.1220	0.31158	9.132	−0.1038	.0740
	5	0.97035	6.069	−0.1901	.1270	0.70072	8.894	0.05866	.1520
7/24	1	0.40028	21.70	−0.5424	.3690	0.32128	14.96	−0.2060	.3570
	2	0.33452	16.48	−0.5311	.2440	3.78209	2.083	0.005213	.0477
	3	0.33129	10.57	−0.5562	.0495	0.30117	7.712	−0.0965	.0384
	4	0.30593	1.946	−1.015	.1060	0.24124	2.141	−0.3236	.1010
	5	0.86041	2.380	−0.1686	.1030	0.35152	5.081	0.05452	.1400
7/26	1	0.78270	50.47	0.9704	.0305	0.33057	11.070	0.0936	.1700
	2	0.31713	6.880	−0.6245	.1130	0.36390	4.508	−0.08379	.0680
	3	0.31985	7.940	−0.4420	.0674	0.31057	4.997	−0.01026	.0661
	4	0.35075	10.35	−0.2314	.0892	0.31212	5.151	0.02031	.0530
	5	0.51900	3.683	−0.3042	.1270	0.18171	9.546	0.1120	.1390

Special Pool Reaches

Date	Pool code	Power 2				Power 1			
		K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE	K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE
1971									
7/14	5/7	0.63444	2.617	−0.3094	.0385	0.28107	5.486	0.03818	.0677
	5/8	0.32836	6.681	−0.4035	.3230	6.12886	0.8896	0.1563	.0000
7/19	5/9	0.35176	1.916	−1.571	.0870	0.20199	3.707	−0.6895	.0845
	5/10	0.64809	1.554	−0.01245	.0522	0.29691	3.160	0.2894	.0669
7/22	5/11	0.29344	2.513	−0.7864	.0627	0.29597	1.587	0.03023	.0483
	5/12	0.49635	1.736	−0.06085	.0493	0.23149	3.425	0.3485	.0489
7/23	5/13	0.32696	1.109	−0.6736	.0124	0.23485	3.488	0.02605	.0128
	5/14	0.2983	2.587	−0.4277	.0596	0.30265	2.437	0.3087	.0617
8/4	6/3	0.158797	0.9075	−0.09704	.0353	1.59022	1.106	0.08308	.0545
	6/4	0.29068	1.871	−1.938	.1200	0.24814	2.695	−0.8088	.1150
	5/15	0.26940	1.280	−1.315	.0651	0.27411	1.400	−0.3150	.0574
	5/16	2.33130	0.6188	0.1404	.0221	3.14272	0.650	0.2049	.0087
8/5	5/17	1.07627	1.052	−0.2199	.0559	0.81647	1.490	0.02146	.0610
	5/18	0.30989	4.357	−0.4349	.1470	0.21790	4.563	0.04415	.1470
8/10	5/19	0.23470	2.591	−0.8687	.0712	0.25357	1.168	−0.01020	.0610
	5/20	0.30246	2.000	−0.5562	.1300	0.10546	8.994	−0.01112	.1610
8/11	5/21	0.35732	3.403	−0.6037	.0599	0.27297	4.466	0.06962	.0558
	5/22	0.74063	1.680	−0.3240	.1050	0.29396	3.988	0.007568	.0931
8/17	6/23	0.31034	6.662	−0.4685	.1290	0.28398	5.244	0.05516	.0938
	6/24	0.32468	6.840	−0.08208	.0445	0.13851	7.105	0.1771	.1030
	5/25	2.59801	0.6674	0.02274	.0658	3.53244	0.7131	0.1533	.0469
	5/26	0.35861	4.157	−0.7494	.1290	0.27081	5.859	−0.02496	.1320
8/18	5/27	1.20711	1.349	−0.01983	.0722	1.23293	1.624	0.2101	.0665
	5/28	0.58754	2.312	−0.1397	.0297	0.26991	4.941	0.2859	.0340
9/2	3,4/29	0.46665	1.615	−0.7085	.0790	0.29481	2.798	−0.0951	.0694

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Appendix G (Concluded)

Special Pool Reaches

		Power 2				Power 1			
Date	Pool code	K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE	K'_d *(1/day)*	L_a *(10^5 lbs/day)*	t_o *(days)*	SE
1971									
9/21	6/3	0.58918	1.301	−0.2168	.0433	0.27547	2.697	0.1855	.0325
	6/4	0.17071	1.739	−1.093	.0187	0.15712	1.378	−0.1794	.0053
9/30	6/3	0.88559	1.219	−0.3127	.0449	0.28171	3.129	−0.1011	.0716
	6/4	0.10884	1.851	−2.968	.0174	0.12577	1.463	−0.9919	.0250
	5/30	0.72971	0.9062	−0.3302	.0280	0.25043	2.247	−0.05132	.0449
	5/31	0.63836	1.403	−0.09024	.0355	0.52365	1.912	0.3004	.0224
8/4	5/32	0.30287	2.890	−0.5798	.0421	0.30240	1.849	−0.0920	.0317
	5/33	0.75015	0.8980	0.07482	.0946	0.30137	1.937	0.3098	.1100

Appendix H. Average Flow in Pools and Minimum Pool DO at Varying Reductions in Waste Loads

(Average flow, Q in cfs and minimum DO concentrations in mg/l)

	Percent	Brandon Road		Dresden Island		Marseilles		Starved Rock		Peoria	
Date	reduction	Q	Min DO	Q	Min DO	Q	Min DO	Q	Min DO	Q	Min DO
1971											
7/14	0	4,969	2.84	5,392	2.40	11,446	4.63	13,318	5.07	10,973	4.02
	35		3.65		3.80		5.16		5.44		5.45
	50		4.11		4.40		5.39		5.59		6.05
	75		4.75		5.35		5.78		5.83		7.06
	90		5.13		5.36		6.00		5.99		7.66
7/15	0	4,478	0	4,873	2.94	9,709	3.80				
	35		0		3.41		4.49				
	50		0.80		4.40		4.77				
	75		2.84		5.13		5.23				
	90		4.04		5.49		5.52				
7/19	0							7,512	4.65	10,174	3.25
	35								5.26		4.40
	50								5.51		4.89
	75								5.90		5.63
	90								6.20		6.19
7/22	0	4,395	3.80	4,666	3.27	6,406	4.83	6,602	4.82	8,662	3.79
	35		4.16		4.39		5.68		5.85		4.84
	50		4.31		4.87		5.80		5.94		5.30
	75		4.56		5.68		6.66		6.58		6.07
	90		4.72		6.16		7.02		6.93		6.54
7/23	0	5,452	3.25	5,419	3.05	6,343	4.28	6,441	4.17	7,927	3.65
	35		4.16		4.23		5.24		5.10		4.68
	50		4.49		4.71		5.79		5.60		5.30
	75		5.24		5.65		6.31		6.15		6.18
	90		5.64		6.12		6.53		6.55		6.71
7/28	0	6,109	4.31					8,479	4.78	8,225	4.81
	35		5.20						4.99		5.97
	50		5.58						5.07		6.34
	75		6.17						5.35		
	90		6.58						5.35		
7/29	0	5,957	4.98	6,261	4.35	7,984	5.01				
	35		5.08		4.74		5.68				
	50		5.12		5.23		6.40				
	75		5.17		6.04						
	90		5.20								
8/4	0	6,126	4.33	6,422	5.11	7,989	4.97	8,168	5.08	9,765	5.53
	35		4.64		6.01		5.94		5.30		5.96
	50		5.16		6.40				5.39		
	75		5.43						5.54		
	90		5.58						5.63		
8/5	0	6,154	4.92	6,488	4.60	8,063	5.44		6.10	10,155	3.32
	35		5.30		5.79		6.07				4.43
	50		5.45		6.30						4.85
	75		5.72								5.67
	90		5.88								6.05
8/10	0	7,327	4.89	7,356	4.92	8,064	4.30	8,122	4.02	8,999	3.42
	35		5.39		5.78		5.37		5.14		4.49
	50		5.61		6.22		6.00		5.77		4.99
	75		5.96		6.88		6.63		6.43		5.77
	90		6.14		6.34		7.10				5.80

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Appendix H (Continued)

(Average flow, Q, in cfs and minimum DO concentrations in mg/l)

Date	Percent reduction	Brandon Road Q	Brandon Road Min DO	Dresden Island Q	Dresden Island Min DO	Marseilles Q	Marseilles Min DO	Starved Rock Q	Starved Rock Min DO	Peoria Q	Peoria Min DO
1971											
8/11	0	6,403	4.70	6.970	4.88	8,922	4.14	9,221	3.53	8,956	3.18
	35		5.13		5.65		5.19		4.92		4.60
	50		5.31		5.98		5.86		5.57		5.21
	75		5.61		6.50		6.40		6.34		6.30
	90		5.80								
8/17	0	6,738	4.60	8,390	4.54	9,710	4.15	10,003	4.04	9,404	2.84
	35		5.13		5.49		4.95		5.12		4.26
	50		5.33		5.89		5.29		5.54		4.88
	75		5.69		6.15		5.85		6.14		5.56
	90		5.91		6.97		6.19		6.51		5.56
8/18	0	6,050	4.49					8,066	4.54	8,871	2.70
	35		4.97						4.97		3.99
	50		5.18						5.10		4.55
	75		5.52						5.18		5.62
	90		5.72						5.23		6.16
8/25	0	8,231	2.30	9,885	5.68	10,929	4.19	11,621	3.50	10,116	3.07
	35		2.84		5.71		4.77		4.37		4.52
	50		2.99		6.29		5.17		4.90		5.15
	75		3.46				5.85		5.76		5.73
	90		3.72				6.25		6.23		5.74
8/26	0	6,683	1.47	7,080	3.44	8,776	4.24	8,764	4.13	9,490	3.11
	35		2.74		4.76		5.00		5.50		4.63
	50		3.29		5.38		5.32		5.32		5.28
	75		4.19		6.27		5.87		5.97		6.33
	90		4.65				6.19		6.19		
8/31	0	6,213	4.83	7,521	3.67	7,873	4.45				
	35		5.42		4.65		5.03				
	50		5.67		5.12		5.28				
	75		6.10		6.00		5.70				
	90						6.01				
9/1	0	6,378	4.02	6,586	4.00	7,748	4.93				
	35		4.69		5.02		5.57				
	50		4.98		5.46		5.85				
	75		5.47		6.20		6.31				
	90		6.20								
9/2	0	6,161	4.48	7,328	2.93	7,901	3.85	7,939	3.84	8,886	3.42
	35		4.98		4.33		4.51		4.51		4.73
	50		5.15		4.79		4.79		4.79		5.30
	75		5.40		5.53		5.24		5.24		6.25
	90		5.55		5.97		5.47		5.51		
9/3	0	6,202	4.49	7,273	3.23	7,776	4.18	7,809	4.17	8,819	3.40
	35		4.81		4.40		4.83		4.83		4.76
	50		4.95		4.72		5.11		5.11		5.35
	75		5.18		5.41		5.58		5.58		6.31
	90		5.32		5.82		5.85		5.86		
9/20	0	2,950	0.31	3,342	3.45	5,288	3.44	5,329	3.43	6,879	4.76
	35		1.17		4.39		4.32		4.32		5.86
	50		1.54		4.79		4.69		4.68		6.42
	75		2.16		5.46		5.32		5.32		
	90		2.48		5.75		5.66		5.70		

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Appendix H (Concluded)

(Average flow, Q, in cfs and minimum DO concentrations in mg/l)

Date	Percent reduction	Brandon Road		Dresden Island		Marseilles		Starved Rock		Peoria	
		Q	Min DO	Q	Min DO	Q	Min DO	Q	Min DO	Q	Min DO
1971											
9/21	0	3,380	0.16	3,704	2.64	5,652	3.80	5,791	3.73	7,091	3.90
	35		1.28		4.03		4.73		4.72		5.21
	50		1.77		4.63		5.19		5.19		5.82
	75		2.58		5.60		5.79		5.79		6.66
	90		3.06		6.20		6.19		6.19		
9/22	0	3,295	2.45	3,437	2.76	5,139	3.87	5,261	3.15	6,874	4.03
	35		2.80		3.98		5.16		5.06		5.21
	50		2.90		4.89		5.72		5.62		5.73
	75		3.07		5.38		6.64		6.55		
	90		3.18		5.90						
9/28	0	3,261	1.83	3,563	4.02	6,618	3.89	6,642	3.71	6,945	3.75
	35		2.50		4.83		5.00		4.93		5.20
	50		2.78		5.18		5.40		5.39		5.77
	75		3.26		5.76		6.17		6.15		6.65
	90		3.55		6.01						
9/30	0	3,079	2.38	3,083	3.24	5,583	4.40	5,560	4.40	6,529	3.39
	35		2.89		4.42		5.12		5.16		4.68
	50		3.11		4.93		5.97		6.00		5.26
	75		3.42		5.69		6.75		6.80		6.42
	90		3.48		5.96		7.18		6.39		
1972											
7/11	0	3,629	0.21	4,048	2.93	6,635	4.67	6,739	6.39	8,389	3.54
	35		3.15		4.17		5.16		6.51		4.79
	50		3.48		4.70		5.36				5.32
	75		4.02		5.68		5.71				6.21
	90		4.35		6.15		5.92				
7/18	0	11,770	1.19	12,933	4.03	21,004	3.61	20,017	4.75	18,324	2.58
	35		1.43		4.75		4.55		5.03		4.29
	50		1.54		5.05		5.13		5.07		4.97
	75		1.71		5.56		5.63		5.15		5.70
	90		1.75		5.66		6.04		5.20		5.73
7/24	0	10,694	1.41	10,671	2.85	15,334	4.18	17,363	4.99	21,930	3.39
	35		2.44		3.76		4.83		5.27		4.07
	50		2.89		4.05		4.98		5.45		4.31
	75		3.62		4.41		5.51		5.66		4.70
	90		4.07		4.86		5.62		5.78		4.90
7/26	0	6,470	1.43	7,179	3.19	13,734	4.92	15,731	6.00	20,755	3.23
	35		1.84		4.21		5.40				3.96
	50		2.01		4.64		5.60				4.28
	75		2.29		5.37		5.93				4.80
	90		2.46		5.81						5.11