OHIO RIVER POLLUTION-ABATEMENT NEEDS

CINCINNATI POOL

Findings on treatment requirements for maintaining oxygen and bacterial-quality objectives, used as the basis for Treatment Standard No. 1.

TELEPHONE
GARFIELD 1151

OHIO RIVER VALLEY WATER SANITATION COMMISSION

410 FIRST NATIONAL BANK BUILDING
CINCINNATI, OHIO

January 26, 1949

Ohio River Valley Water
Sanitation Commission
410 First National Bank Bldg.
Cincinnati 2, Ohio

Gentlemen:

In accordance with formal action of the Commission at its January 5, 1949, meeting at the Hotel Gibson, Cincinnati, Ohio, your Cincinnati Pool Hearing Committee assigned to recommend standards for the treatment of organic wastes before discharge to the stretch of the Ohio River between Dam 36 and Dam 37, referred to as the "Cincinnati Pool," has deliberated and has reached certain conclusions, which are transmitted herewith.

Your Committee has given consideration to a reasonable water quality objective for the Cincinnati Pool; to water quality data of 1939 from the Ohio River Pollution Survey; to summer low stream flow frequency; and to estimated future pollution loads. As a result of this study, the Committee concludes as follows:

(1) For summer periods during dry years, higher degrees of treatment than primary, up to a purification efficiency of substantially complete removal of settleable solids and 65 per cent reduction of biochemical oxygen demand will be required for the treatment of organic wastes discharged to the Cincinnati Pool.

(2) Treatment works capable of delivering 65 per cent biochemical oxygen demand reduction efficiency are recommended, with the proviso that treatment in excess of primary (35 per cent reduction of biochemical oxygen demand) will be required only at such times as may be necessary to attain the reasonable water quality objectives established.

(3) Primary treatment will be adequate during years of average or more than average river flow.

(4) These conclusions may be affected in future years by growth in the area in excess of that estimated, or by a public demand for higher uses of the Ohio River below Cincinnati. It is considered desirable that treatment standards be subject to further consideration in future years, should events prove the reopening of the question advisable.

(5) The Committee recognizes that the established objectives might be attained by installing primary treatment at the Little Miami sewage treatment plant and a higher degree of treatment at the Mill Creek plant, both of the City of Cincinnati. However, Cincinnati and the northern Kentucky communities stand to gain most from the Little Miami plant. It will protect the intakes of Cincinnati and the northern Kentucky communities against possible contamination, and it will serve primarily to restore and protect the utility of Cincinnati's own water front. In justice to the citizens of Cincinnati, the Committee believes that the City should install the higher degree of treatment at

the Little Miami as well as at other treatment plants.

Appended are supporting data and considerations used in reaching the above conclusions.

Yours very truly,

CINCINNATI POOL HEARING COMMITTEE

(s) B. A. Poole
B. A. Poole, Chairman
Technical Secretary
Indiana Stream Pollution Control Board
Indianapolis, Indiana

(s) F. C. Dugan
F. C. Dugan
Director, Div. of Sanitary Engineering
State Department of Health
Louisville, Kentucky

(s) F. H. Waring
F. H. Waring
Chief Engineer, Div. of Sanitary Eng'g.
State Department of Health
Columbus, Ohio

(s) John W. Wiseman
John W. Wiseman
Ohio River Division
U. S. Corps of Engineers
Cincinnati, Ohio

(s) M. LeBosquet, Jr.
M. LeBosquet, Jr., Secretary
Sr. Sanitary Engineer
U. S. Public Health Service
Cincinnati, Ohio

Ohio River Valley

Water Sanitation Commission

Supporting Data

CINCINNATI POOL HEARING COMMITTEE

Investigations Leading to Recommended
Treatment Standards for Organic Wastes
Discharged to the Cincinnati Pool

Directed by Action of the Commission
January 5, 1949, Hotel Gibson,
Cincinnati, Ohio

CONTENTS

TABLES

FIGURES

Introduction

The matter of the treatment of organic wastes discharged to the Cincinnati Pool has been under consideration for some years and has reached the stage that under date of August 2, 1940, the Ohio Department of Health approved plans for the partial treatment of sewage at the proposed Little Miami Sewage Works of the City of Cincinnati. This approval having become void September 1, 1941, the City of Cincinnati, under date of November 15, 1948, asked for current treatment requirements of the Ohio Department of Health and for evidence that these conformed to requirements of the Ohio River Valley Water Commission. Kentucky municipalities report a like interest.

At the meeting of the Commission at the Hotel Gibson, Cincinnati, Ohio, on January 5, 1949, the matter of treatment standards for the Cincinnati Pool was discussed and a committee was appointed to conduct an investigation and recommend treatment standards for the Cincinnati Pool. For reasons which will be readily apparent, the Committee has interpreted its assignment to include all organic wastes. At the present time, practically all organic industrial wastes in the area flow through municipal sewers to the Cincinnati Pool. As a matter of definition, if sewage is defined as liquid passing through municipal sewers, the assignment, for practical purposes, can be said to apply to sewage.

The investigation has been confined largely to the collection, tabulation and review of existing information. Information on sources of pollution and water supply has been obtained from the States of Ohio and Kentucky, the City of Cincinnati, and the Ohio River Pollution Survey.*

Description

The stretch of Ohio River from Dam No. 36 near Coney Island, 460.9 river miles below Point Bridge at Pittsburgh, to Dam No. 37 at Fernbank, 483.2 miles below Pittsburgh, comprises a pool 22.3 miles long which, during times of low flow, has a very low velocity. According to computations made by

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* Ohio River Pollution Control, HD-266, 78th Congress, 1st Session.

the U. S. Engineer Office in 1939, with a discharge of 5000 c.f.s., the time of flow in the pool is 103 hours, or well over 4 days. With such a low velocity of about 0.2 miles per hour, the stream acts in many respects as a pool. Backwater extends up the Licking River and to a lesser degree up the Little Miami River, so that the lower stretches of these rivers are also part of the pool.

Table No. 1 presents a tabulation of public water supplies and sources of pollution entering the pool. A figure for miles below Pittsburgh is given for each item so that the relative locations of sources of pollution and water intakes may be determined. Figure No. 1 is a map showing all but the extreme lower reaches of the pool.

Table No. 2, in three sheets, furnished by the City of Cincinnati, presents measurements and future estimates of pollution loads from the Cincinnati metropolitan area in Ohio. For purposes of this investigation it has been assumed that the total pollution load will increase in direct proportion to the population increase estimates presented on this table. In substance, the estimates of percentage growth, taken from the grand total metropolitan area estimated populations, are as follows:

Year	Estimated Population	Per cent Increase Since 1940
1930	582,720	--
1940	616,700	0
1950 (interpolated)	---	9
1960	728,800	18
1970 (interpolated)	---	26
1980	824,000	34

Laboratory Data

Important use has been made of the laboratory results, particularly the results of dissolved oxygen determinations of samples from the ranges in the Cincinnati Pool made during 1939 as a part of the Ohio River Pollution Survey. The daily results for the summer and early fall months shown on Tables No. 3 and 4 were not published and it was necessary to extract these results from the basic data files of the survey. Each value shown on the two tables represents the average of three results obtained on samples collected at the center and two quarter points of the stream. The re-

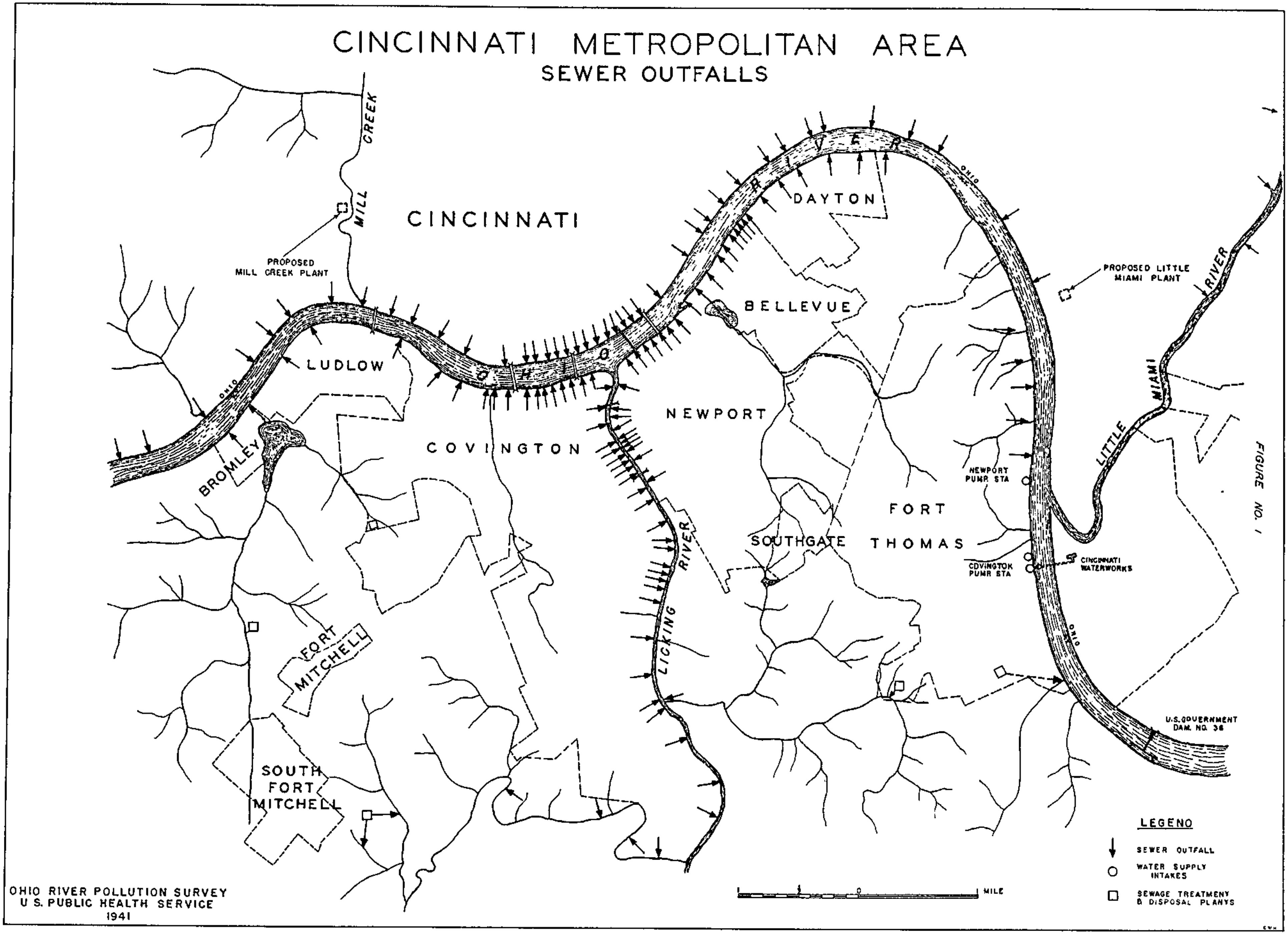
CINCINNATI METROPOLITAN AREA
SEWER OUTFALLS
CINCINNATI
MILL CREEK
PROPOSED MILL CREEK PLANT
LUDLOW
BROMLEY
COVINGTON
NEWPORT
BELLEVUE
DAYTON
SOUTHGATE
FORT THOMAS
FORT MITCHELL
SOUTH FORT MITCHELL
OHIO RIVER
LICKING RIVER
LITTLE MIAMI RIVER
PROPOSED LITTLE MIAMI PLANT
NEWPORT PUMP STA
COVINGTON PUMP STA
CINCINNATI WATERWORKS
U.S. GOVERNMENT DAM NO. 36
LEGEND
SEWER OUTFALL
WATER SUPPLY INTAKES
SEWAGE TREATMENT & DISPOSAL PLANTS
0
MILE
OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1941

FIGURE NO. 1

Table 1 - Cincinnati Pool - Public Water Supplies and Sources of Pollution (Data from Ohio River Pollution Survey)

Location	State	Miles Below Pittsburgh	Water Supply Population	Sewered Population Equivalent**
Dam 36		460.9		
Cincinnati (Coney Is.)	Ohio	461.5		2,700
Cincinnati (Part) *	Ohio	462.8	506,000	
Covington	Ky.	462.9	96,800	
Newport	Ky.	463.6	37,500	
Little Miami R.(Cinti)*	Ohio	464.1		129,000
Dayton	Ky.	467.8		8,000
Bellevue	Ky.	468.8		8,300
Fort Thomas (Part)	Ky.	469.0		10,700
Southgate	Ky.	469.0		1,900
Newport	Ky.	469.8		38,600
Cincinnati (Part)*	Ohio	470.0		214,000
Licking River	Ky.	470.2		
Covington	Ky.	470.5		132,000
Mill Creek	Ohio	472.4		
Cincinnati (Part)*	Ohio	472.4		1,282,000
Ludlow	Ky.	472.5		5,600
Pleasant Run	Ky.	474.0		2,600
Bromley	Ky.	474.0		800
Cincinnati (Part)*	Ohio	478.0		6,600
Dam 37		483.2		
Aurora	Ind.	496.7	4,400	***
Totals:				
Ohio - Sewage			-	525,900
Industrial Wastes			-	1,108,400
Total			506,000	1,634,300
Kentucky - Sewage			-	131,800
Industrial Wastes			-	76,700
Total			134,300	208,500
Indiana - Total			4,400	***
Total - Sewage			-	657,700
Industrial Wastes			-	1,185,100
Total			644,700	1,842,800

* Cincinnati pollution loads based on sewer gaging and sampling studies of City of Cincinnati

** Sewered population equivalent (Biochemical Oxygen Demand) equals sewered population plus equivalent organic pollution load due to industrial wastes

*** Indiana sources of pollution not listed

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CITY OF CINCINNATI

TABLE NO. —— D2
SEWAGE QUANTITIES — METROPOLITAN AREA

APPENDIX ...... D
REPORT ON PLAN OF
SEWAGE DISPOSAL

Sewer Outlet No.	Sewer Outlet —	Day's Gaging	From Sewer Gagings: Estimated Connected Population	Measured Sewage M.G.D.	Average Flow G.C.D.	RATIO Max/Ave %	Adopted Values: Average G.C.D.	Maximum G.C.D.	1940: Estimated Population	Sewage M.G.D. ave.	1955: Estimated Population	Sewage M.G.D. ave.	1960: Estimated Population	Sewage M.G.D. ave.	1980: Estimated Population	Sewage M.G.D. ave.	Interceptor M.G.D. Max.
	LITTLE MIAMI AREA																
1	Duck Creek		59200	9.42	159	141											
	Mariemont																
	Sub-Total						175	525	78,500	13.73	88,000	15.40			104,000	18.20	54.60
2,3,4,4a	Eastern Ave		5,800	2.09	360	198	250	750	4,500	1.13	5,000	1.25			6,000	1.50	4.50
	Newtown						125	375	2,400	0.30	2,700	.34			3,300	.41	1.23
5	Mt Washington	15	2,300	0.24	104	157	125	375	4,300	0.54	5,500	.69			7,400	.93	2.79
	California						175	525	3,300	.58	4,100	.72			5,300	.93	2.79
6	Robb St.	2	450	0.07	156	243	180	540	400	.07	500	.09			600	.11	.33
7&8	Delta Ave	7	18,300	2.55	139	274	180	400	18,600	3.35	20,700	3.73			24,000	4.32	9.60
9	St. Andrews		340	0.05	147		125	375	340	.04	350	.04			380	.05	0.15
	Total — Little Miami Area		86,590	14.42	167				112,340	19.74	126,850	22.26	131,650	23.08	150,980	26.45	75.99
	Note... Possible industrial expansion allowed in plant design for average flow of....											25.00					
	MILL CREEK PLANT AREA																
10	Louisiana St		780	0.04	51	250											
11	Bayou St.	31	2,500	.24	96	320											
12	East Collins St	8	660	.08	121	350											
13	West Collins St.	16	2,940	.18	61	210											
14	Hazen St	2	410	.10	244	240											
15	Waldon St	5	1,910	.20	105	260											
16	Litherbury St	17	2,990	.25	84	390											
17-19	*No Sewage*																
20	Collard St	16	1,990	27	136	150											
21	Parson St.	23	2,460	13	53	340											
	Total Columbia —— Nos. 10-21		16,640	1.49	90		100		16,760	1.68							
							125	375					17,750	2.22	18,720	2.34	7.02
22	Eggleston Ave — *Including Pearl & Front*	16	39,380	11.00	279	195	300	750	39,500	11.85			40,900	12.27	42,200	12.66	31.65
23	Butler St	2		0.07													
24	Pike St	1		.03													
25	Lawrence St	2		.04													
26	Ludlow St.	7		.06													
27	Broadway	7		0.08													
	Total — East City Area —		2,980	0.28	94	270	100		3,000	0.30							
	— Nos. 23-27						175	525					2,900	0.51	2,900	0.51	1.52

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CITY OF CINCINNATI

TABLE NO — D2
SEWAGE QUANTITIES — METROPOLITAN AREA

APPENDIX........D
REPORT ON PLAN OF
SEWAGE DISPOSAL

Sewer Outlet No.	Sewer Outlet —	Day's Gaging	From Sewer Gagings: Estimated Connected Population	Measured Sewage M.G.D.	Average Flow G.C.D.	RATIO Max./Ave. %	Adopted Values: Average G.C.D.	Maximum G.C.D.	1940: Estimated Population	Sewage M.G.D. Ave.	1955: Estimated Population	Sewage M.G.D. Ave.	1960: Estimated Population	Sewage M.G.D. Ave.	1980: Estimated Population	Sewage M.G.D. Ave.	Interception M.G.D. Maximum
28	Sycamore St.	9		.22													
29	Main St	11		.28													
30	Walnut St.	32		1.74													
31	Vine St.	25		1.17													
32	Race St	15		1.80													
33	Elm St.	9		.37													
34	Plum St.	31		.14													
35	Central Ave	23		0.32													
	Total — Central City Area - Nos. 28-35		4,800	6.04		240			4,800	6.04							
	Commercial Area - $\frac{6.04\ MGD}{286\ Ac}$ = 21,100 G.A.D.						24,000 GAD	300%					4,900	6.86	4,900	6.86	20.58
36	Smith St.	7		0.46													
37	Mill St	7		.18													
38	Baymiller St.	7		.62													
39	Carr St.	12		.27													
	Total — West City Area - Nos. 36-39		18,910	1.53	81	200	100		18,900	1.89							
							175	525					18,900	3.31	18,900	3.31	9.93
40	McLean Ave.	28	93,400	10.60	113	225	6310 GAD		93,500	10.60							
	Industrial Area - $\frac{10.60\ MGD}{1679\ Ac}$ = 6310 G.A.D.						7000 GAD	(a) 300%					95,300	11.75	97,100	11.75	58.75
41	Mill Creek Interceptor	61	258,300	45.3	175	(b) 150	175		(c) 264,700	46.35							
							185	(a) 650					340,800	63.05	403,200	74.60	262.08
42	Evans St.	22	4,490	1.23	274	224	300	900	4,510	1.35			4,850	1.46	5,150	1.55	4.65
43	Maryland Ave.	7	3,740	0.12													
44	Mt Hope Rd.	21	5,920	.41													
45	Mt. Echo Rd	28	2,250	.18													
	Total — Mt. Echo - Nos. 43-45		11,910	.71	60	175	100	300	11,990	1.20			12,850	1.29	13,650	1.37	4.11
46	Bold Face	27	19,000	2.20	116	227	100		19,500	1.95							
							150	375					22,200	3.33	25,000	3.75	9.38
	Total - Mill Creek Plant Area - Nos. 10-46		469,810	80.38					477,160	83.21			561,350	106.05	631,720	118.70	409.67
	Used for design												561,350	106.00			410.00
	— LOWER RIVER AREAS																
47	Southside Ave. — *Estimated*		110	0.01													
48	Carpenter St. — *Estimated*		170	0.01													
	Big Four R.R.			0.16													
49	Idaho St.	9	870	.07	81	300											

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CITY OF CINCINNATI

TABLE NO. ~ D 2
SEWAGE QUANTITIES ~ METROPOLITAN AREA

APPENDIX........D
REPORT ON PLAN OF
SEWAGE DISPOSAL

Sewer Outlet No.	Sewer Outlet ~	Day's Gaging	From Sewer Gagings: Estimated Connected Population	From Sewer Gagings: Measured Sewage M.G.D.	From Sewer Gagings: Average Flow G.C.D.	From Sewer Gagings: RATIO Max./Ave. %	Adopted Values: Average G.C.D.	Adopted Values: Maximum G.C.D.	1940 Estimated Population	1940 Sewage M.G.D. Ave.	1955 Estimated Population	1955 Sewage M.G.D. Ave.	1960 Estimated Population	1960 Sewage M.G.D. Ave.	1980 Estimated Population	1980 Sewage M.G.D. Ave.	Interception M.G.D. Maximum
50	Hampton Pl ~ *Storm drain*																
50A	Fithian Pl	2	680	.01	15												
50B	McGinnis Ave. ~ *Estimated*		200	01													
51	Colfax Ave.	24	620	.07	113	300											
52	Anderson's Ferry Rd.	2	570	.04	70	237											
	Total ~ Nos. 47-52		3,220	.38	118		125	375	3,500	0.44			4100	0 51	4,800	0 60	1 80
53	Fenimore St. ~ *Estimated*			01													
54	Mt St. Joseph Ave	1		.01													
	Total ~ Nos 53-54		580	02			100	300	600	.06			700	0 07	900	.09	27
54A	Rapid Run ~ *Proposed Outlet, Estimated*		2,480	0 25			125	300	2,500	0.31			2,900	0.36	3,300	0.41	.99
55	Belmore St.	2		0.03													
56	Revere St.	2		.04													
57	Ivanhoe St.	2		.06													
58	Elco St.	1		.01													
59	Topinabee Rd.	1		.01													
	Total ~ Nos 55-59		2,730	015	55		60		2,800	0.17							
							100	300					3,800	0.38	4700	0.47	1.41
60	Muddy Creek	14	17,510	1 14	65	200	70		(c)17,800	1 25							
							100	300					24,300	2.43	27,600	2.76	8.28
	Total ~ Lower River ~ Nos. 47-60		26,520	1.94					27,200	2 23			35,800	3 75	41 300	4 33	12 75
	Grand total Metropolitan Area		582,720	96 74					616,700	105.18			728,800	132.88	824,000	149.48	498.41
	Total ~ Metropolitan Area																
	Less Little Miami Area		496,330	82.32					504,360	85.44			597,150	109.80	673,020	123.03	422.42

Notes (a). Ratio of interception increased because of sewage concentration and to reduce frequency of overflows.
(b). Ratio given is for dry weather flow only.
(c) Including only area of present sewerage service Populations taken from table number B4.

Sewer gagings taken from City Records 1938-1940 and reflect adjustments. The values used in this table depart slightly from those of Table No F-1. For Populations, present and future, see Appendix - B. Gagings represent dry weather flows.

Table 3 - Cincinnati Pool - Summary of Daily Laboratory Results, Ohio River Pollution Survey

Riverside - Mileage Below Pittsburgh 475

Date 1939	Average Discharge c.f.s.	Temp. °C.	Dissolved Oxygen p.p.m.	5 Day B.O.D. p.p.m.	Coliforms M.P.N. per ml.
Aug. 8	18,400	26.5	6.9	2.1	1,590
Aug.10	19,000	26.0	7.0	1.2	930
Aug.14	18,400	27.5	7.6	2.4	750
Aug.16	22,800	27.5	6.1	1.8	2,400
Aug.18	10,800	27.0	5.4	2.9	11,000
Aug.22	13,000	26.0	5.5	2.8	19,700
Aug.24	8,200	25.7	6.2	2.2	4,300
Aug.28	7,400	25.5	7.0	2.1	1,500
Aug.30	5,400	25.7	5.5	3.2	11,000
Sept.1	7.700	26.2	3.9	3.0	24,000
Sept.7	7,400	26.2	3.1	2.9	24,000
Sept.13	6,900	25.7	2.0	3.0	110,000
Sept.15	6,400	26.5	2.4	2.8	43,000
Sept.19	8,300	25.0	5.5	2.4	9,630
Sept.21	15,200	23.7	7.7	2.3	2,300
Sept.25	6,400	23.2	5.7	2.5	24,000
Sept.29	5,200	22.5	0.6	4.0	24,000
Oct. 3	5,200	19.5	2.4	4.7	60,000
Oct. 5	11,500	20.2	7.8	1.8	15,000
Oct. 9	7,300	24.0	6.8	2.1	9,300
Oct.11	7,700	22.0	4.1	3.1	110,000

Table 4 - Cincinnati Pool - Summary of Daily Laboratory Results, Ohio River Pollution Survey

Lock and Dam 37 - Mileage Below Pittsburgh 483

Date 1939	Average Discharge c.f.s.	Temp. °C.	Dissolved Oxygen p.p.m.	5 Day B.O.D. p.p.m.	Coliforms M.P.N. per ml.
Aug. 8	18,400	27.0	5.6	2.6	24,000
Aug. 10	19,000	27.0	6.0	1.3	9,300
Aug. 14	18,400	27.0	6.6	2.6	910
Aug. 16	22,800	27.0	5.0	1.6	1,200
Aug. 18	10,800	27.0	4.2	1.7	4,600
Aug. 22	13,000		5.2	2.5	11,000
Aug. 24	8,200	25.0	4.8	2.2	11,000
Aug. 28	7,400	26.0	6.3	1.8	313
Aug. 30	5,400	26.0	4.2	2.2	930
Sept. 1	7,700	26.0	4.3	2.0	430
Sept. 5	8,200	25.0	5.2	3.1	91
Sept. 7	7,400	26.0	4.6	1.6	930
Sept.11	11,600	26.0	3.0	1.1	373
Sept.13	6,900	26.0	4.0	1.1	93
Sept.15	6,400	26.0	1.6	1.5	460
Sept.19	8,300	25.0	5.7	1.6	240
Sept.21	15,200	23.0	3.1	2.3	2,400
Sept.25	6,400	24.0	2.2	2.6	2,400
Sept.27	6,400	22.0	5.2	1.7	230
Sept.29	5,200	23.0	3.2	2.0	2,400
Oct. 3	5,200	19.0	6.7	2.1	230
Oct. 5	11,500	21.0	3.1	2.3	24,000
Oct. 9	7,300	22.0	4.6	1.9	13,100
Oct.11	7,700	21.0	5.1	1.4	430

sults on one or two of the individual samples may be expected to be smaller than the values shown.

One of the important justifications for sewage treatment, and for sewage treatment in excess of primary treatment, is the importance of eliminating or at least substantially reducing the public health hazard caused by the discharge of raw sewage. This hazard is measured by results of the coliform determination. The hazard is to public water supplies and to recreational use. Coliform results obtained during the Ohio River Pollution Survey are shown also on Tables No. 3 and 4. In addition, Table No. 5 shows results of coliform determinations by the Indiana State Board of Health of samples from the public water supply intake of Aurora, Indiana, collected during the years 1934 to 1947.

A brief study has been made of the coliform results presented plus coliform results of the Ohio River Pollution Survey. The medians of the results examined are shown on Table No. 6. These are considered excessive for a raw water for a normal water treatment plant. This is true even though the figures given in Table No. 6 are medians and not maxima. Tables No. 3, 4 and 5 show some of the higher individual results greatly in excess of conservatively safe limits. It has been necessary for Ohio River water treatment plants to take extraordinary steps to deliver a safe water. While this has generally been accomplished, a marked reduction in raw water pollution loads is urgent.

Hydrometric Data

The hydrometric data considered in this report reflect critical flow conditions from June 1 to October 31 in the Ohio River with regard to pollution control in the Cincinnati area. The data from 1929 to 1939 are from records of the Corps of Engineers, Department of the Army. These data are based on flow measurements at Louisville and, except for the year 1939, are converted to flow at Cincinnati on a drainage area basis. The tabulated low mean day flows obtained by this method may vary considerably from the actual occurrence, but are sufficiently accurate for the purpose of this report since the critical periods are considered on the basis of the 14-day mean flows. No adjustment in dates is made for flow time between Cincinnati and Louisville. The data from 1939 to 1944 are taken from records of flow at Dam No. 37 below Cincinnati published by the U.S.G.S. The data from 1944 to 1946 are from unpublished records.

Table 5 - Aurora, Indiana, Public Water Supply - Coliform and Odor Determinations by Indiana State Board of Health

Date	Odor**	Coliforms per 100 ml.	
		Phelps Index	Most Probable Number
1934			
December 27	0	40,000	
1933			
January 9	0	60,000	
February 5	0	20,000	
March 15	0	6,000	
April 10	E-2	10,000	
May 17	0	4,000	
October 25	0	100,000 +	
November 20	0	40,000	
December 27	0	20,000	
1936			
January 22	0	8,000	
March 11	0	20,000	
April 17	0	2,000	
May 15	M-1	20,000	
December 2		10,000	
1937			
January 6	0	4,000	6,000
April 2	0	4,000	6,000
May 12	0	100	250
December 11	0	20,000	35,000
1938			
March 2	0	10,000	24,000
May 13	0	20,000	22,000
November 23	M-0-3	4,000	5,400
1939			
January 25	Ch-3	800	1,100
April 12	M-3	80	130
*November 22	0-2	0	0
1940			
*March 21	M-2	800	1,600
November 22	M-1	10,000	24,000

Table 5 Cont'd - Aurora, Indiana, Public Water Supply - Coliform and Odor Determinations by Indiana State Board of Health

Date	Odor**	Coliforms per 100 ml. Phelps Index	Coliforms per 100 ml. Most Probable Number
1941			
February 13	M-1	1,000	1,700
May 1	M-2	10,000	24,000
December 12	M-2	20,000	35,000
1942			
March 19	M-1	600	680
October 14	M-2	20,000	35,000
1943			
March 3	G-1	8,000	16,000
1944			
October 27	A, E	100,000 +	240,000 +
*October 27	A, C-2	0	0
October 31	E, A-2	1,000,000 +	2,400,000 +
1945			
March 16	0	-	-
June 7	0		35,000
*June 7			23
December 12	0	10,000	24,000
*December 12	0	200	280
1947			
January 29	E-1		54,000

* Prechlorinated-Raw. All other samples - Raw.

** C - Chemical
Ch - Hydrocarbon
E - Earthy
G - Grassy
M - Musty
O - Oily

Table 5 Cont'd - Aurora, Indiana, Public Water Supply - Coliform and Odor Determinations by Indiana State Board of Health

Median	Coliforms per 100 ml. Phelps Index	Coliforms per 100 ml. Most Probable Number
1934	40,000*	-
1935	20,000	-
1936	10,000	-
1937	4.000	6,000
1938	10,000	22,000
1939	80	130
1940	5,400	12,800
1941	10,000	24,000
1942	10,300	17,840
1943	8,000*	16,000*
1944	100,000+	240,000+
1945	5,100	12,140
1947	-	54,000*

* Single result

Table 6 Cincinnati Pool - Median Coliform Results

Location	Miles Below Pittsburgh	Coliform Results-Medians Most Probable Number Per ml.	Per 100 ml.
Riverside	475	2,400	240,000
Dam 37	483	387	38,700
Aurora, Ind.*	497	240	24,000
Dam 38	503	247	24,700

*Results from 1937 to 1947. Others 1939 only.

The records of flow data shown in Table No. 8 contain corrections for low-flow regulation from multiple-purpose reservoirs in the drainage area above Cincinnati in order to reflect future flow conditions to be expected under run-off conditions similar to those which have occurred in the past. The values of this regulation are limited to reservoirs which have been completed, are under construction, or are contemplated in the immediate future. No increase in low flows has been added for reservoirs which may be proposed for construction if the benefit from such reservoirs cannot be assured within a reasonable time.

Table No. 7 - Cincinnati Pool - Flow Increases by Corps of Engineers Reservoirs

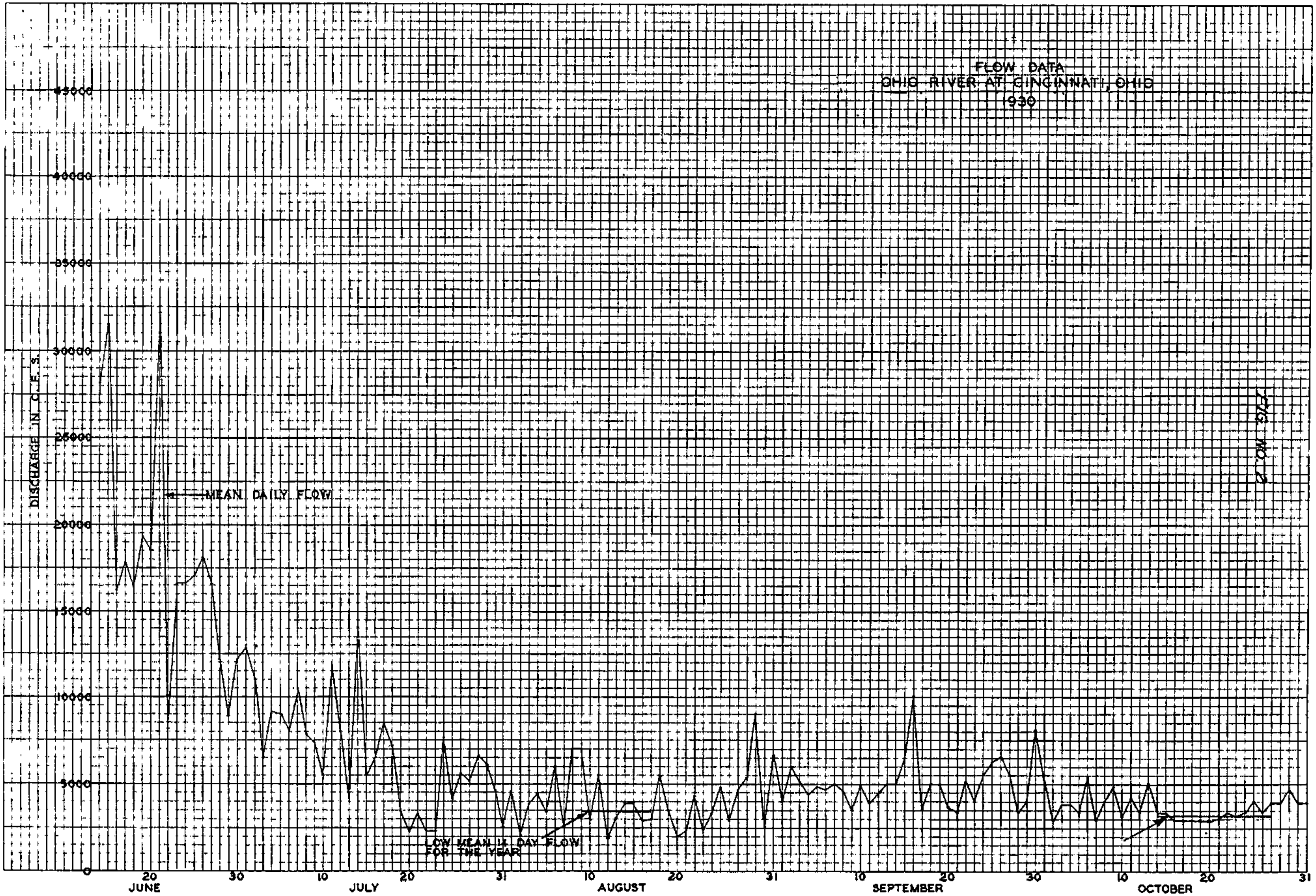
Date	Minimum Flow Increase in c.f.s.	Flow Increase to be Added to Flows of Record
Prior to 1938	None	1,790
1938 to July,1943	340	1,450
July,1943,to April,1944	510	1,280
1944 to 1948	710	1,080
1948 to Present	1,210	580
Immediate Future	1,790	-

Table No. 8 contains flow data at Cincinnati for the period 1929 through 1946, along with corrected flows for reservoir operation as stated above. The reservoir flow increments are shown as a uniform addition to the mean daily and mean 14-day flow in accordance with the above Table No. 7 in order to avoid an extensive discussion of reservoir regulation. It is to be expected that more advantage from reservoir operation will be obtained from relatively higher releases during low natural flows and lower releases as the natural flows increase. However, the table demonstrates the effect of reservoir regulation on those critical low flows which would be considered in design of pollution abatement structures.

The attached charts show estimated daily flow for the critical years 1930, 1932, 1939, 1943, and 1946, selected from the period of record contained in Table No. 8. The charts also show the low 14-day mean flow for each year.

Table 8 Cincinnati Pool - Low Discharges in Ohio River at Cincinnati, for Minimum Summer Daily and 14-Day Periods

Year	Flow in cubic feet per second				Month
	Low 2-week mean		Low mean day		
	Actual	Corrected for reservoir operation	Actual	Corrected for reservoir operation	
1929	15,200	16,990	5,700	7,490	September-October
1930	3,190	4,980	2,850	4,640	October
1931	15,500	17,290	8,560	10,350	October
1932	5,600	7,390	3,780	5,570	September
1933	7,650	9,440	3,780	5,570	October
1934	9,250	11,040	4,120	5,910	September
1935	11,100	12,890	8,900	10,690	September-October
1936	6,970	8,760	5,170	6,960	September
1937	9,000	10,790	3,440	5,230	September-October
1938	10,800	12,250	3,860	5,310	August-September
1939	7,200	8,650	5,180	6,630	September
1940	10,760	12,210	10,000	11,450	October
1941	9,800	11,250	3,540	4,990	September-October
1942	24,800	26,250	14,300	15,750	September
1943	7,073	8,353	3,530	4,810	October
1944	8,905	9,985	5,840	6,920	August
1945	16,485	17,565	9,140	10,220	August-September
1946	7,621	8,701	3,500	4,580	September-October


FLOW DATA
OHIO RIVER AT CINCINNATI, OHIO
930
FIG. NO. 2
DISCHARGE IN C. F. S.
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
MEAN DAILY FLOW
LOW MEAN 14 DAY FLOW
FOR THE YEAR
20
JUNE
30
10
JULY
20
31
10
AUGUST
20
31
10
SEPTEMBER
20
30
10
OCTOBER
20
31

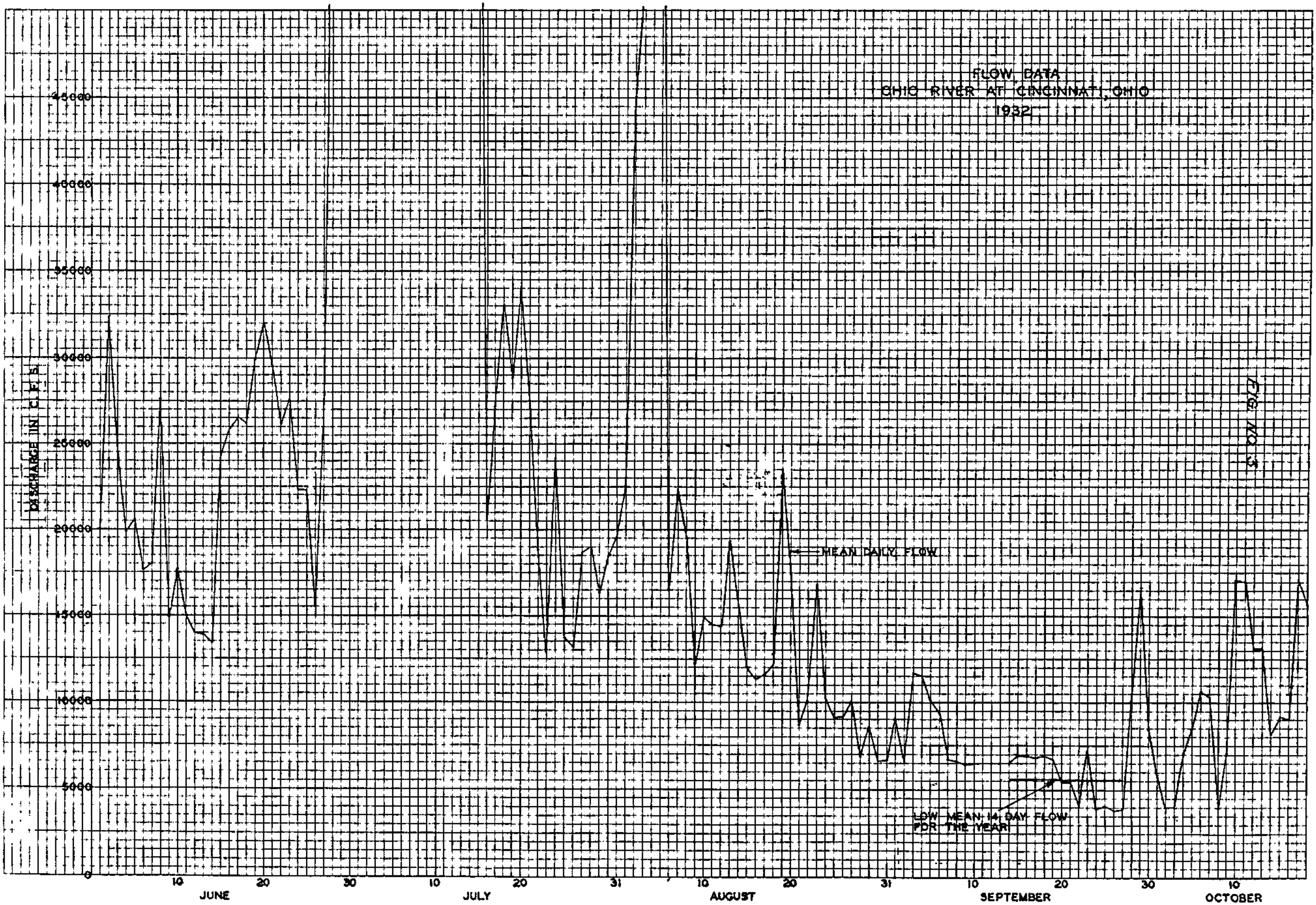

FLOW DATA
OHIO RIVER AT CINCINNATI, OHIO
1932
DISCHARGE IN C.F.S.
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
10
JUNE
20
30
10
JULY
20
31
10
AUGUST
20
31
10
SEPTEMBER
20
30
10
OCTOBER
MEAN DAILY FLOW
LOW MEAN 14 DAY FLOW
FOR THE YEAR

FIG. NO. 3

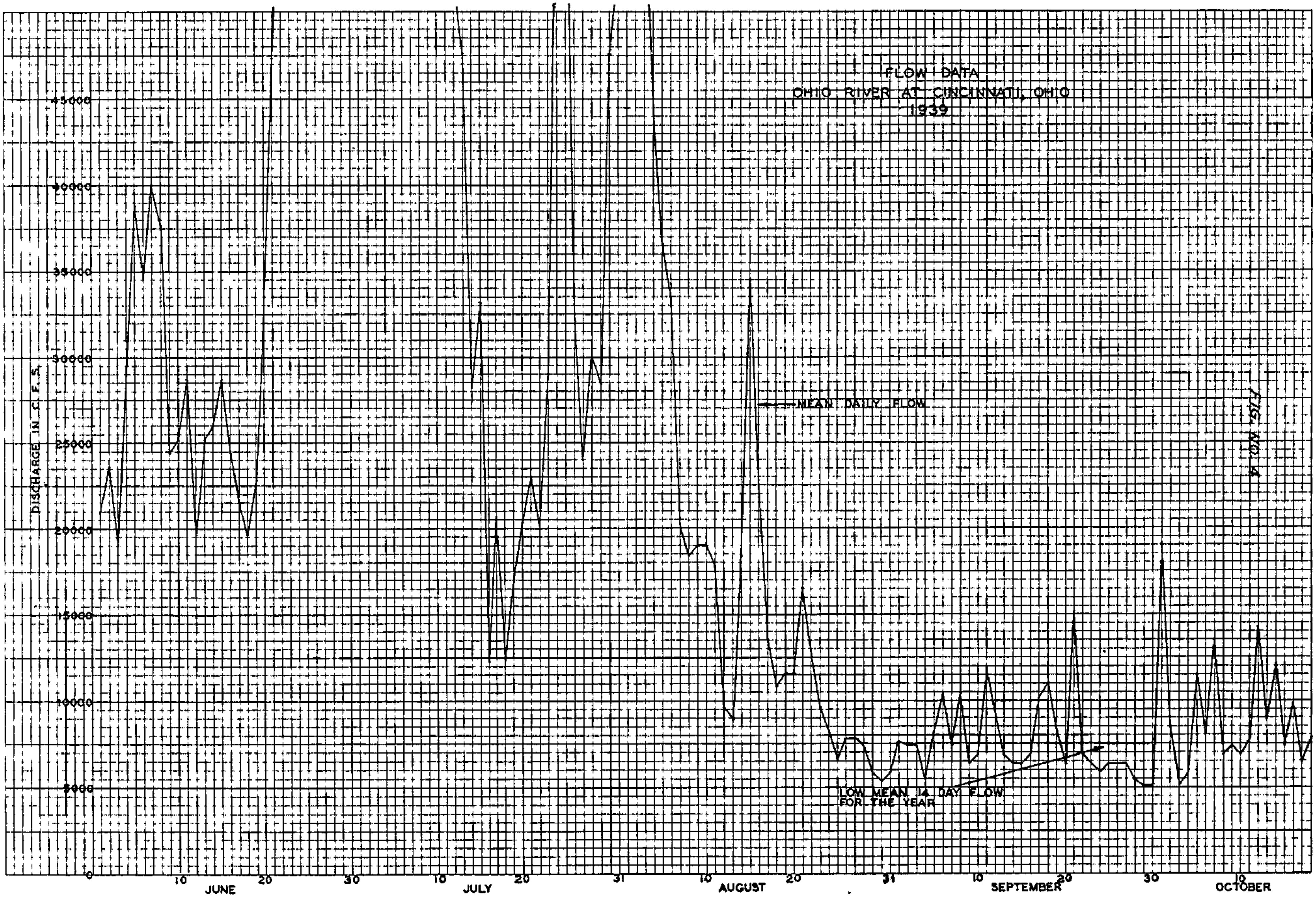
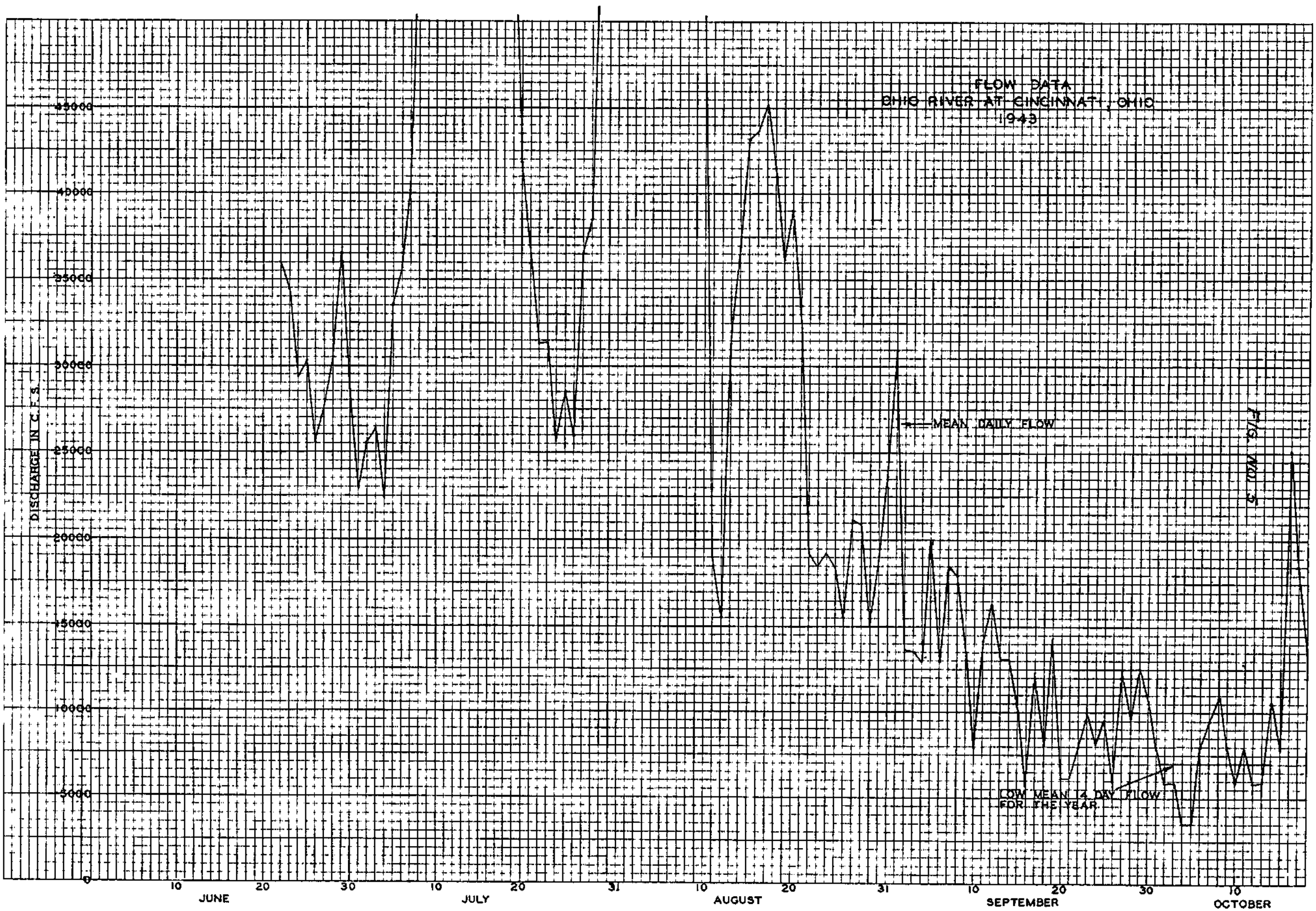
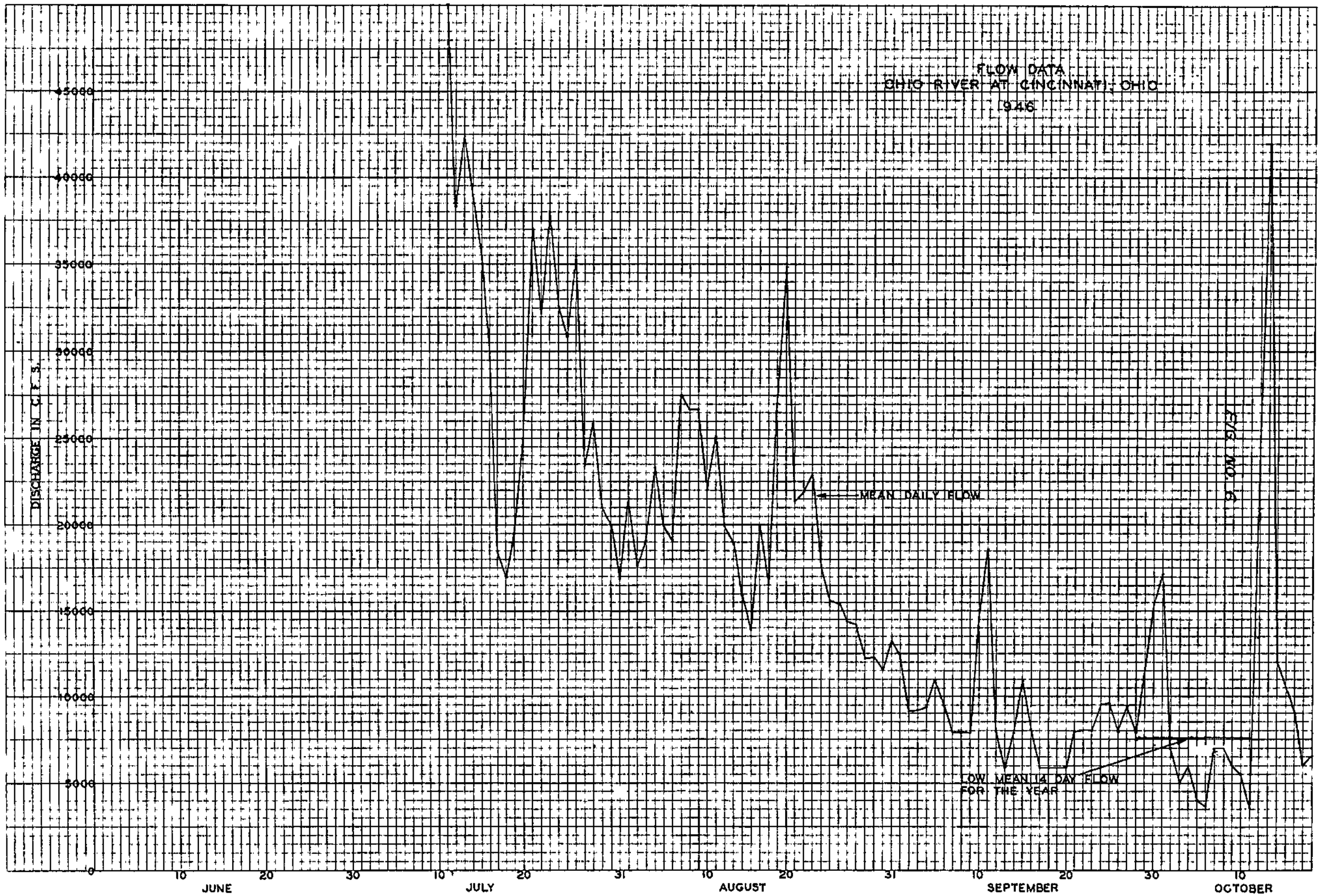

FLOW DATA
OHIO RIVER AT CINCINNATI, OHIO
1939
MEAN DAILY FLOW
LOW MEAN 14 DAY FLOW
FOR THE YEAR
DISCHARGE IN C. F. S.
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
10
JUNE
20
30
10
JULY
20
31
10
AUGUST
20
31
10
SEPTEMBER
20
30
10
OCTOBER

FIG. NO. 4



FLOW DATA
OHIO RIVER AT CINCINNATI, OHIO
1943
MEAN DAILY FLOW
LOW MEAN 14 DAY FLOW FOR THE YEAR
DISCHARGE IN C. F. S.
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
10
JUNE
20
30
10
JULY
20
31
10
AUGUST
20
31
10
SEPTEMBER
20
30
10
OCTOBER

FIG. NO. 5


FLOW DATA
OHIO RIVER AT CINCINNATI, OHIO
1946
FIG. NO. 6
MEAN DAILY FLOW
LOW MEAN 14 DAY FLOW FOR THE YEAR
DISCHARGE IN C. F. S.
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
10
20
30
31
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

Treatment Requirements

In order to reach conclusions as to degree of treatment of organic wastes applicable to that stretch of Ohio River from Dam No. 36 above Coney Island to Dam No.37 at Fernbank and commonly referred to as the Cincinnati Pool, it has been necessary to decide on fundamental factors involved, as follows:

(1) A reasonable quality objective was determined, having in mind present and reasonable future stream use.

(2) The future pollution load from the metropolitan district was estimated, having in mind the past rate of growth of the district and a reasonable future period on which to base design of degree of treatment as differentiated from design of size of treatment units.

(3) A critical low-flow duration was determined having in mind the pool action of the slack-water Ohio River such that the large volume of the Pool furnishes dilution as a lake during the initial days of a low-flow period.

(4) Future low-flow periods were estimated from past experience plus low-flow increases normally to be expected from U. S. Engineer reservoirs through multiple-purpose use of reservoirs designed primarily for flood control.

Water Quality Objective

For purposes of treatment design, a water quality objective has been taken as 4.0 parts per million of dissolved oxygen at the bottom of the oxygen sag in the Ohio River below Cincinnati. This figure is taken as a daily minimum as measured by the average of three samples taken on a range across the stream, one sample of which is at midstream and the other two of which are at the quarter points. It is expected that the dissolved oxygen at one or two of the points on the range may be below the specified figure. However it is expected that oxygen results on ranges above and below the bottom of the sag will be above the specified figure.

The figure of 4.0 p.p.m. of dissolved oxygen has been established by agreement as representing a reasonably clean condition in which nuisances will definitely be absent and limited recreation such as boating but not swimming will be inviting. The figure is 1.0 p.p.m. lower than recommended* for healthy fish life, but this fact is offset by the higher oxygen content to be available above and below the minimum oxygen point. The substantial reduction in organic matter contemplated will be accompanied by a like substantial reduction in bacterial content, thus greatly improving the stream for public water supply use.

Future Growth

Estimates of future growth of Cincinnati as shown for the Sewage Quantities, Grand Total, Metropolitan Area, on Sheet 3 of Table D-2, City of Cincinnati, have been accepted. These figures show a growth in estimated population from 1940 (water Quality data used are 1939) to 1970, of 26 per cent.

Critical Flow Duration

Two periods, one the minimum day and one the minimum 14 days, have been analyzed in determining treatment requirements. Figure No. 7 shows minimum dissolved oxygen results below Cincinnati plotted in parallel with an Ohio River hydrograph. It is apparent by inspection of this figure that minimum oxygen results do not follow immediately with the onset of low flows but are reached only after a continuous low-flow period of an apparent 14 days.

Critical Flows

Estimates of summer low 2-week mean flows and low mean day flows from 1929, as actually occurred and as would have occurred had U. S. Engineer reservoirs now built or definitely assured been in operation, are shown in Table No. 8. It is to be noted that low flows would have been substantially increased a maximum of 1790 cubic feet per second. This increased flow has a marked effect in decreasing the maximum degree of treatment needed at the Cincinnati Pool and decreasing the periods requiring the higher degrees of treatment. The resulting saving can be considered a benefit realized from the reservoir system. An extension of the reservoir system will not only result in further re-

* Detection and Measurement of Stream Pollution. M. M. Ellis, Bull. 22, U.S. Bureau of Fisheries, 1937.

OHIO RIVER – CINCINNATI POOL
SUMMER, 1939
DAILY DISSOLVED OXYGEN*
DAILY HYDROGRAPH

NOTE:
* LOW DAILY AVERAGE FOR RANGES BELOW CINCINNATI.

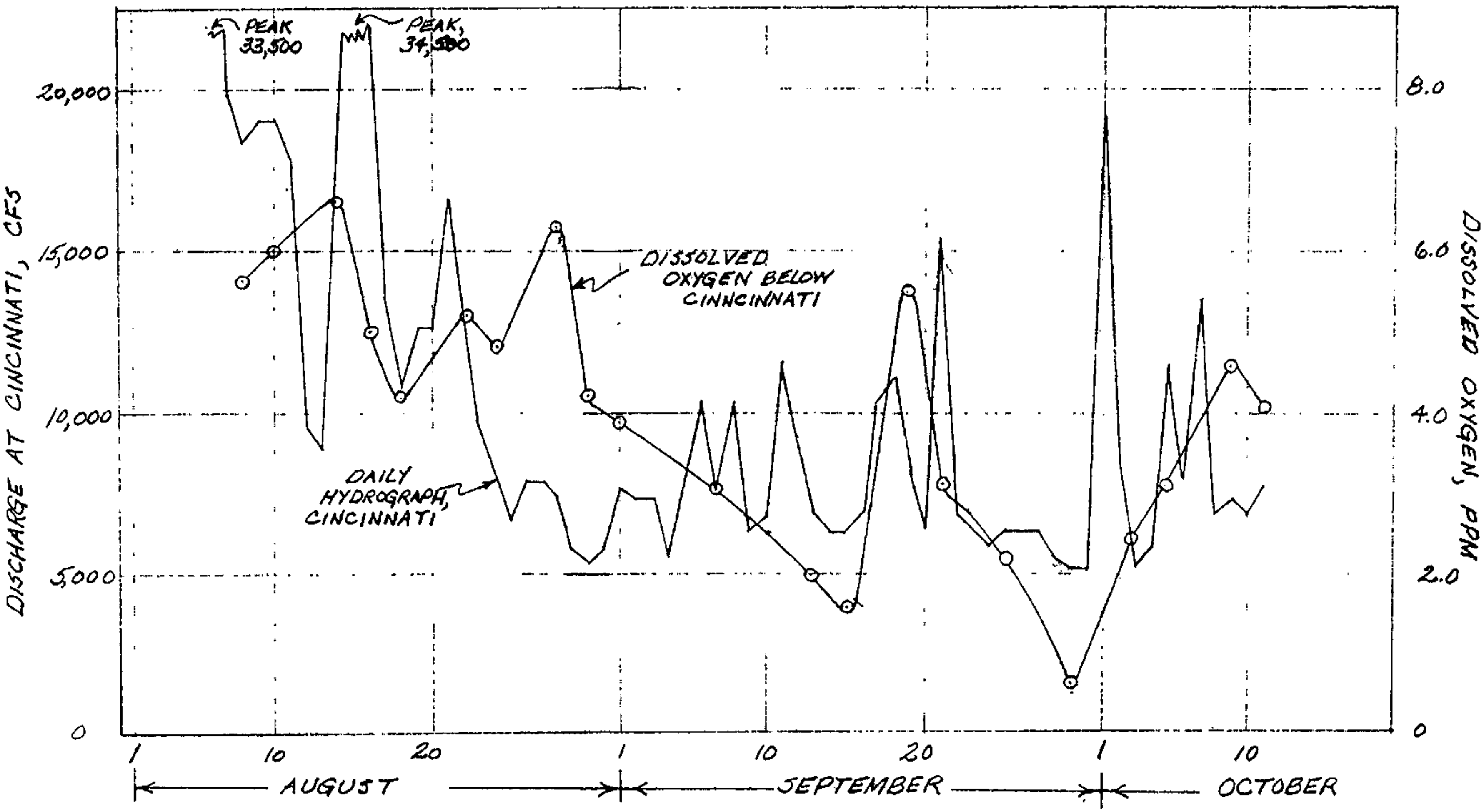


FIG. NO. 7

ducing the periods when the higher degrees of treatment are required but also will permit further growth in the metropolitan area without the necessity of reconsidering the matter of the design of degree of treatment.

Treatment Estimates

In estimating treatment requirements, the low oxygen results obtained during the summer and fall of 1939 during the Ohio River Pollution Survey have been used as base data. In general it will be noted in Figure No. 7 and Tables No. 3 and 4 that the low oxygen results were obtained at the end of periods of low flow. In general these low results followed a pattern when plotted against the average flow the day of the sampling and the day following as shown on Figure No. 8. Higher oxygen results for low flows are shown by a scattering of points above the curve. These represent oxygen results obtained after only a short period of flow, as will be observed from Figure No. 7 and Tables No. 3 and 4. This phenomenon will be understood when it is realized that during high flows the Cincinnati Pool is filled with water of high quality and it is only after a stable low-flow condition is reached that concentrations of pollution become high, and low oxygen results are obtained.

A fundamental brought out by the work on the oxygen sag by H.W. Streeter* is that if all other factors such as time of flow and deoxygenation and reaeration coefficients are constant, the dissolved oxygen deficit below saturation will vary directly as the unit pollution load. Furthermore, if the total pollution load is constant and the amount of dilution water is varied, the unit pollution load, in terms such as pounds per 1000 cubic feet per second, will vary inversely as the flow.

This discussion merely states that the stream flow multiplied by the dissolved oxygen deficit below saturation is a constant (as in pounds) with a constant pollution load. The curve shown on Figure 8 is merely the graphical representation of this fact. It will be noted that the curve follows the low dissolved oxygen results rather closely.

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* H. W. Streeter. "The Rate of Atmospheric Reaeration of Sewage-Polluted Streams." Public Health Reports, U. S. Public Health Service, Feb. 12, 1926, 247-63 (Reprint 1063); also Transactions American Society of Civil Engineers, Vol. 89, 1351 (1926).

OHIO RIVER – CINCINNATI POOL

DISSOLVED OXYGEN† VS. DISCHARGE*

AUG. 8 – OCT. 11, 1939

NOTE:

† LOW DAILY AVERAGE FOR RANGES BELOW CINCINNATI.

* AVERAGE DISCHARGE, DATE OF SAMPLE AND DAY PREVIOUS.

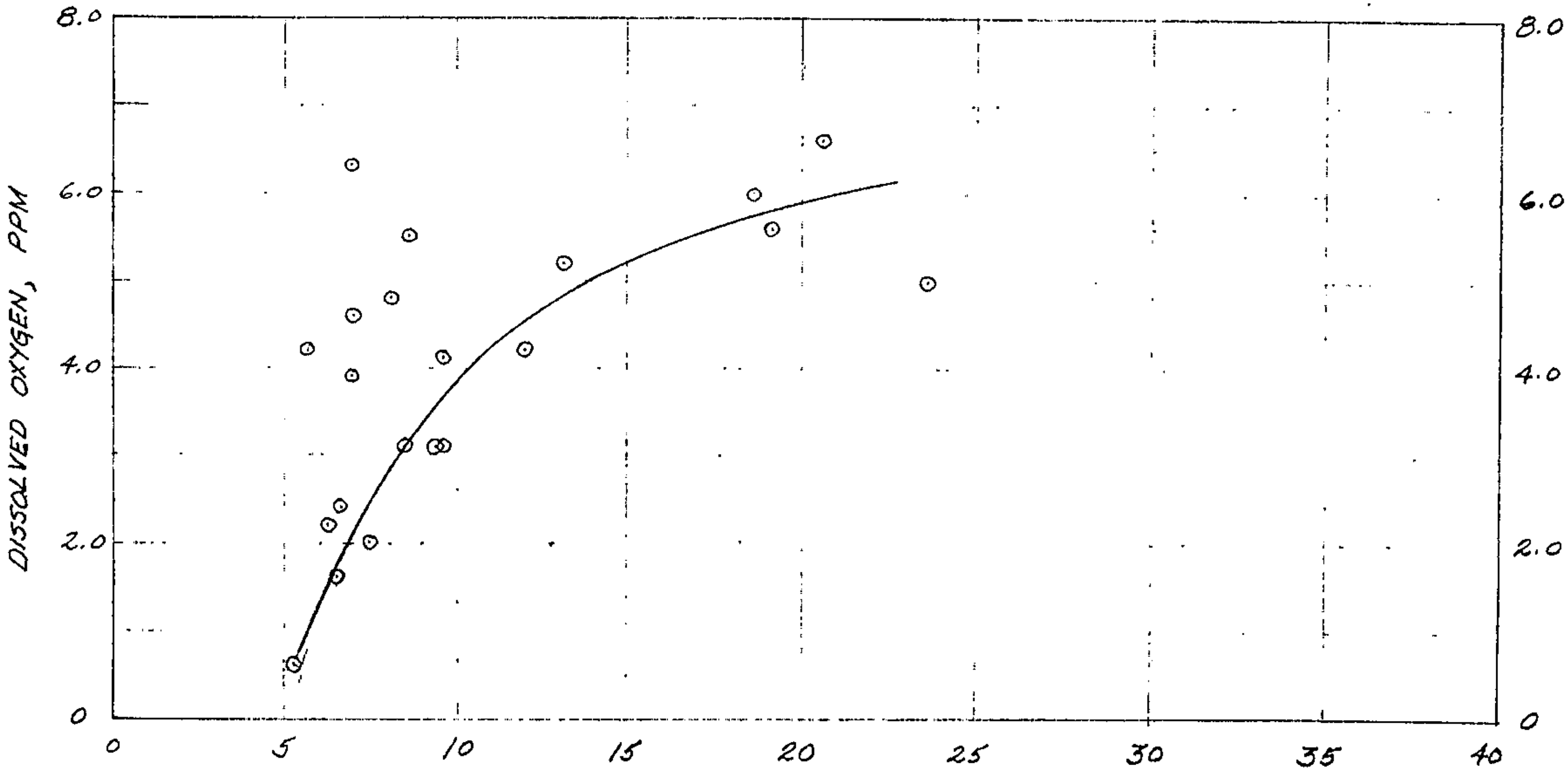


FIG. NO. 8

With the help of this curve, and reasoning that a given percentage purification or reduction in biochemical oxygen demand will result in an equivalent reduction in the oxygen deficit or improvement in dissolved oxygen, computations can be made of the degrees of treatment required under present conditions, under conditions as of 1970 (26 per cent increase in pollution load), under conditions for other years and with various flows. The results of such computations are given in Table No. 9, using 14-day flows.

The flow figures given in Table No. 8 have been compared with the treatment requirements shown in Table No.9 for 1939-40 and 1970 and with similar tables for other years by even decades from 1940 to 1970. The result of this study, shown on Table No. 10 and Figure No. 9, indicates the number of years treatment requirements are in excess of the reduction in biochemical oxygen demand indicated.

Referring to Figure No. 9, it can be concluded that a B.O.D. (biochemical oxygen demand) reduction of over 40 per cent will be required every 2 years; a B.O.D. reduction over 50 per cent will be required every 3 years; and a B.O.D. reduction over 55 per cent will be required every 10 years. During one summer in 20 years, a B.O.D. reduction of 65 per cent will not be adequate to attain the objective specified. However, 65 per cent treatment is the limit of treatment that can be reasonably justified.

Table 9 Cincinnati Pool - Biochemical Oxygen Demand Reduction Required in Midsummer for 1939 and Estimated 1970 Pollution Loads
(Based on average flow for 14 days previous to day of sample)

Degree of Treatment*	Flow in c.f.s. required to maintain 5.0 p.p.m. D.O.		Flow in c.f.s. required to maintain 4.0 p.p.m. D.O.	
	1939	1970	1939	1970
35	12,600	15,900	9,110	11,500
40	11,640	14,700	8,410	10,620
45	10,680	13,480	7,710	9,730
50	9,700	12,250	7,010	8,850
55	8,720	11,030	6,310	7,960
60	7,750	9,800	5,610	7,070
65	6,790	8,580	4,910	6,190

*Percent reduction in Biochemical Oxygen Demand

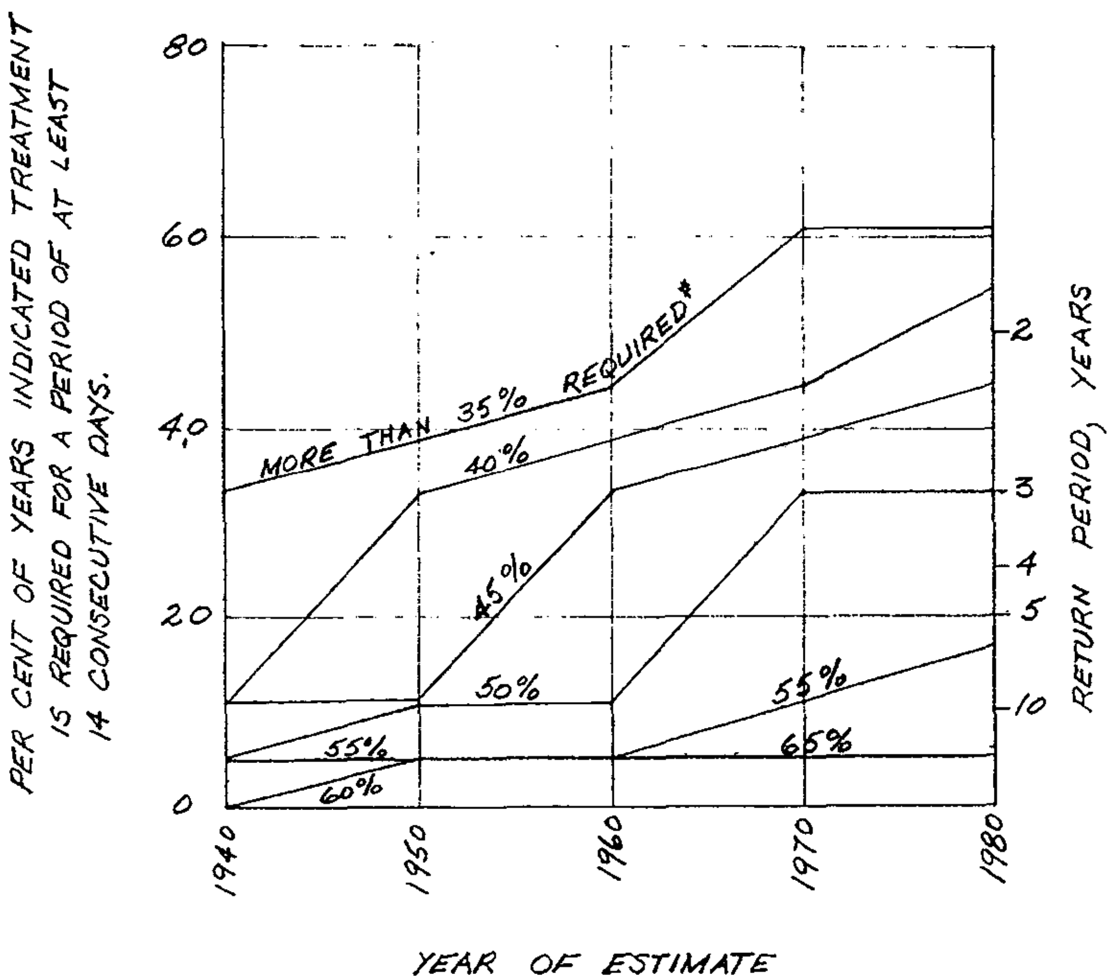
Table 10 Cincinnati Pool - Percent Reduction in Biochemical Oxygen Demand and Percent of Years in Which More Than Indicated Reduction is Needed for at Least 14 Consecutive Days for Estimated Condition to 1980

Year	Percent Reduction in Biochemical Oxygen Demand						
	35	40	45	50	55	60	65
	Percent of Years in Which Indicated Reduction is Insufficient						
1940	33.3	11.1	11.1	5.6	5.6	5.6	0
1950	38.9	33.3	11.1	11.1	5.6	5.6	5.6
1960	44.5	38.9	33.3	11.1	5.6	5.6	5.6
1970	61.1	44.5	38.9	33.3	11.1	5.6	5.6
1980	61.1	55.5	44.5	33.3	16.7	11.1	5.6

FIG. NO. 9

CINCINNATI POOL

ESTIMATED DEGREE OF TREATMENT REQUIRED*
AND
FREQUENCY OF NEED
1940 - 1980



*NOTE:
Per cent reduction in biochemical oxygen demand