A study of the pollution of the Meramec River

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A STUDY OF THE POLLUTION OF THE
MERAMEC RIVER

BY

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A

THESIS

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Approved by...Joe B. Butler...

Professor of Civil Engineering.

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Figures 1, 3, and 6 are incorporated in this report by permission.

Figures 2, 4, and 5 were prepared by personnel of the Work Projects Administration under the supervision of the State Planning Board and the State Board of Health to be used in connection with this study.

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A STUDY OF THE POLLUTION OF THE MERAMEC RIVER

INTRODUCTION

Early in 1940 a project was undertaken for a complete survey of the Meramec River Basin. This project, of which the pollution study was a part, was one of the most extensive surveys made of an entire river basin and included detailed studies of soil erosion, land use, pollution, rainfall, and recreation in the Meramec Basin.

The pollution study covered that portion of the Meramec River from its confluence with the Mississippi River to Steelville, a distance of about 140 river miles; the Big River from its mouth to a point west of Flat River, a distance of 107 river miles; and the Bourbeuse River from its mouth to Tea, Missouri, a distance of 90 river miles.

The objectives of the pollution study were twofold in purpose: first, to determine the extent of pollution in those sections of the Meramec Basin which are used most extensively for recreational purposes, and to formulate recommendations for the control of such pollution; and second, to establish reasonable tentative standards of cleanliness for the Meramec River and its principal tributaries. It was felt that such standards might be extended to cover similar streams in other sections of the State which are also used for recreational purposes.

It was originally planned to collect daily samples from each sampling point and transport them to the laboratory where bacteriological and chemical analyses could be made. Because of the limited laboratory facilities available and the necessity of limiting travel to a minimum, it was necessary to curtail the number of samples collected from the Meramec River above Pacific and from the Big and Bourbeuse Rivers. Although additional samples from these sections would have been desirable it is felt that they would not have materially altered the results which were obtained.

The survey was carried out with funds and personnel supplied by the Work Projects Administration under the supervision of the Engineering Division of the State Board of Health of which Mr. W. Scott Johnson is the Chief Engineer. The writer was assigned to active charge of the project and spent much time in the field while the survey was in progress.

Grateful acknowledgment is made to the U. S. Public Health Service and to the various members of the Stream Pollutions Investigations Station and the Ohio River Survey for their assistance in planning the Meramec study. Acknowledgment is also made of the assistance given by the engineering staff of the Missouri State Board of Health, the State Planning Board, the State Conservation Commission, and the State Geological Survey in the various phases of the project, and to the city officials of Union and Kirkwood, Missouri for providing laboratory facilities.

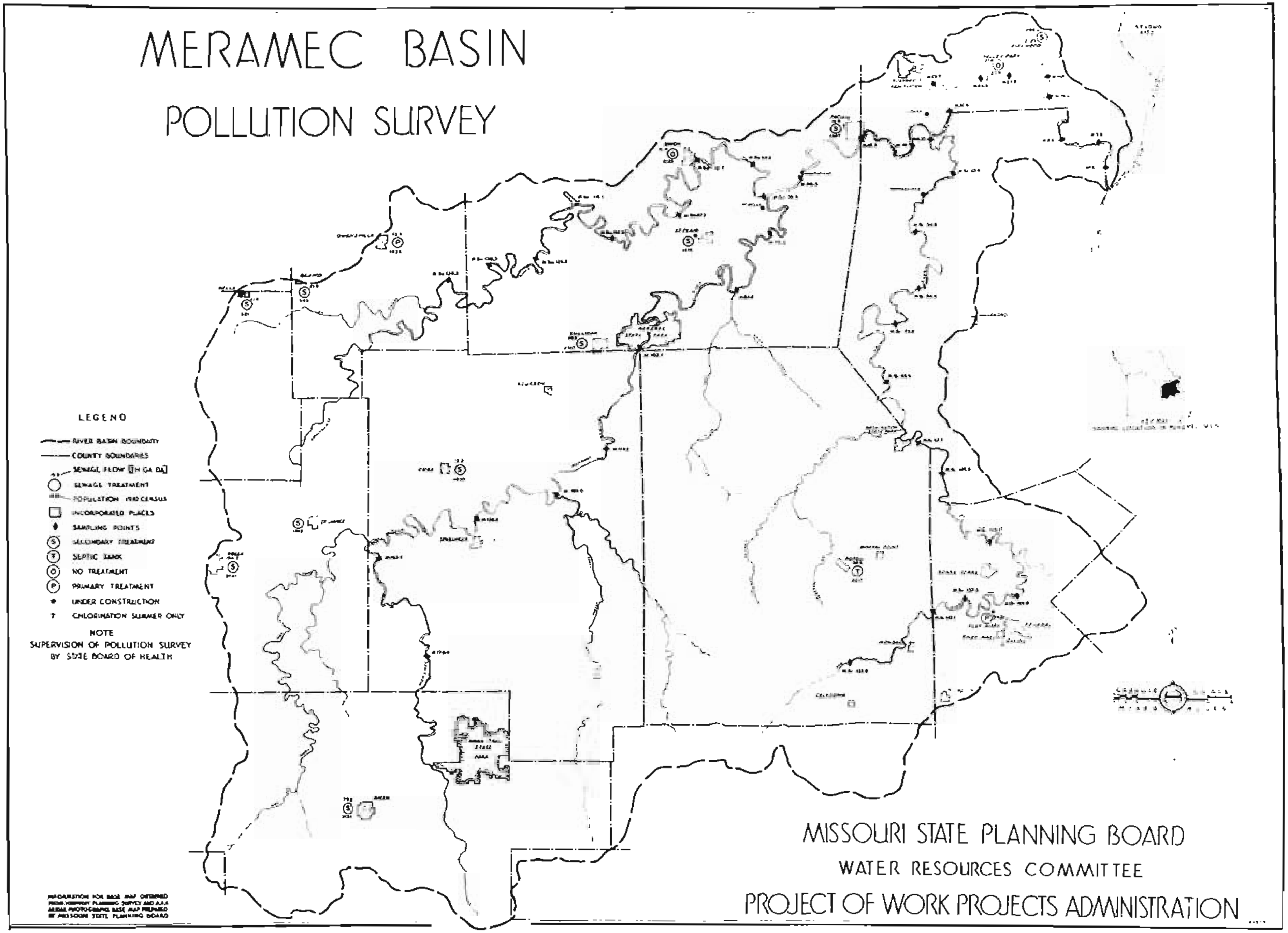

MERAMEC BASIN
POLLUTION SURVEY
LEGEND
RIVER BASIN BOUNDARY
COUNTY BOUNDARIES
SEWAGE FLOW
SEWAGE TREATMENT
POPULATION 1940 CENSUS
INCORPORATED PLACES
SAMPLING POINTS
SECONDARY TREATMENT
SEPTIC TANK
NO TREATMENT
PRIMARY TREATMENT
UNDER CONSTRUCTION
CHLORINATION SUMMER ONLY
NOTE
SUPERVISION OF POLLUTION SURVEY
BY STATE BOARD OF HEALTH
MISSOURI STATE PLANNING BOARD
WATER RESOURCES COMMITTEE
PROJECT OF WORK PROJECTS ADMINISTRATION

Figure 2

DESCRIPTION OF THE MERAMEC BASIN

General

The Meramec River Basin, with a total drainage area of 3980 square miles, lies in the east central section of the State. The basin is somewhat rectangular in shape with the longer axis running generally east and west. The location with respect to other drainage basins in the State is shown in Figure 1. Figure 2 shows the basin in more detail with the location of the principal tributaries and municipalities indicated.

The Meramec River rises east and slightly south of Salem, Missouri, and flows generally north and east to its confluence with the Mississippi River about 20 miles below St. Louis. The main stem is approximately 207 miles in length and varies in width from about one-fourth mile in the upper reaches to one and three-fourths miles in the vicinity of Valley Park. From the upper reaches to the mouth of the Bourbeuse River (mile 59) the Meramec follows a tortuous course and consists principally of a series of shallow pools, riffles, and sharp bends. Below the Bourbeuse the river straightens out and becomes wider with the pools being generally longer and deeper. The average slope of the Meramec River from Steelville (mile 140) to Huzzah Creek (mile 128) is about 4.6 feet per mile; from Huzzah Creek to the Big River (mile 35), 2.3 feet per mile; and from the Big River to the mouth, 0.9 feet per mile (See Figure 3). Near Valley Park

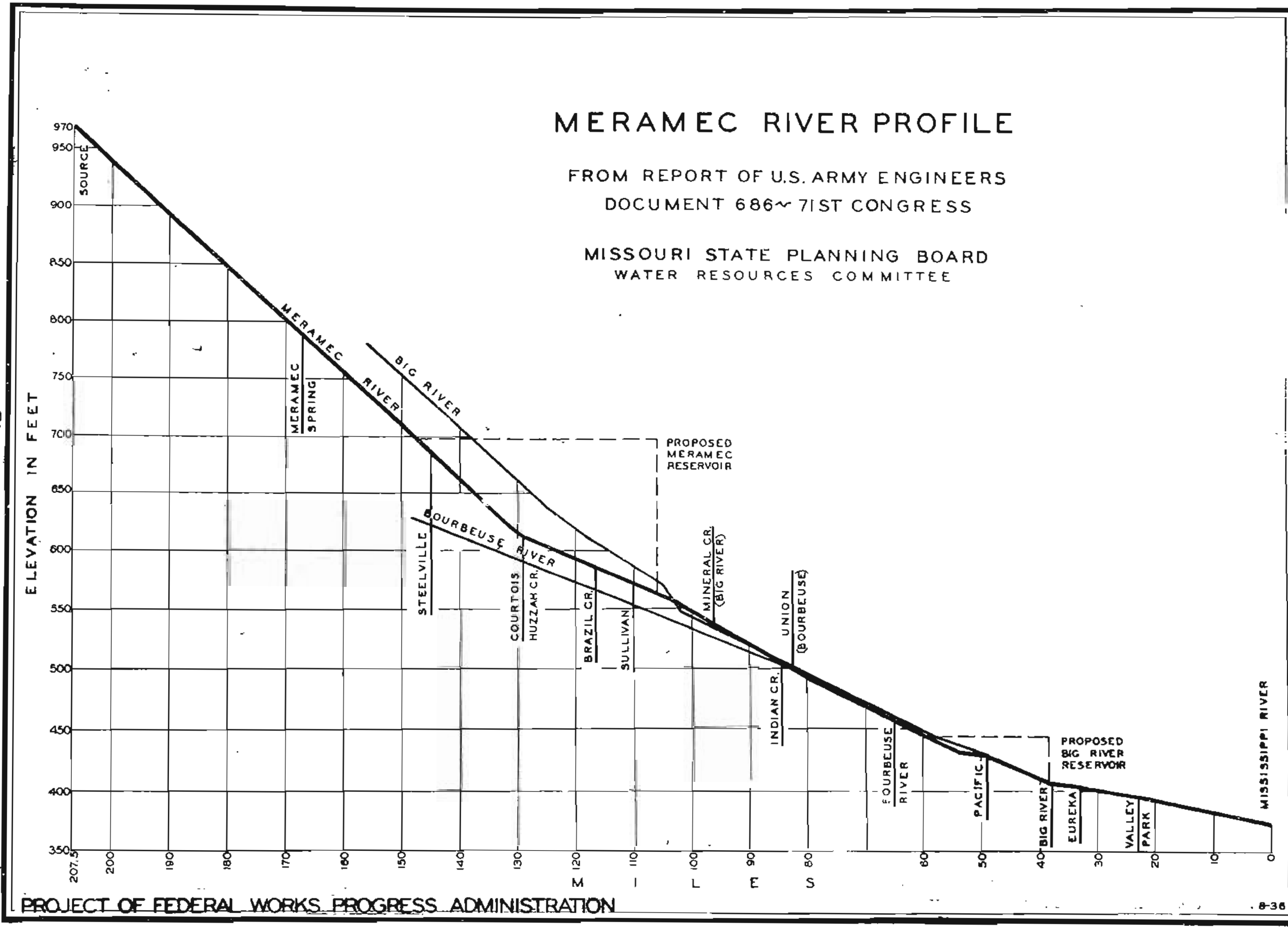


Figure 3
~~PLATE 66~~

(mile 22) there are several abandoned fish dams which tend to check the stream velocity.

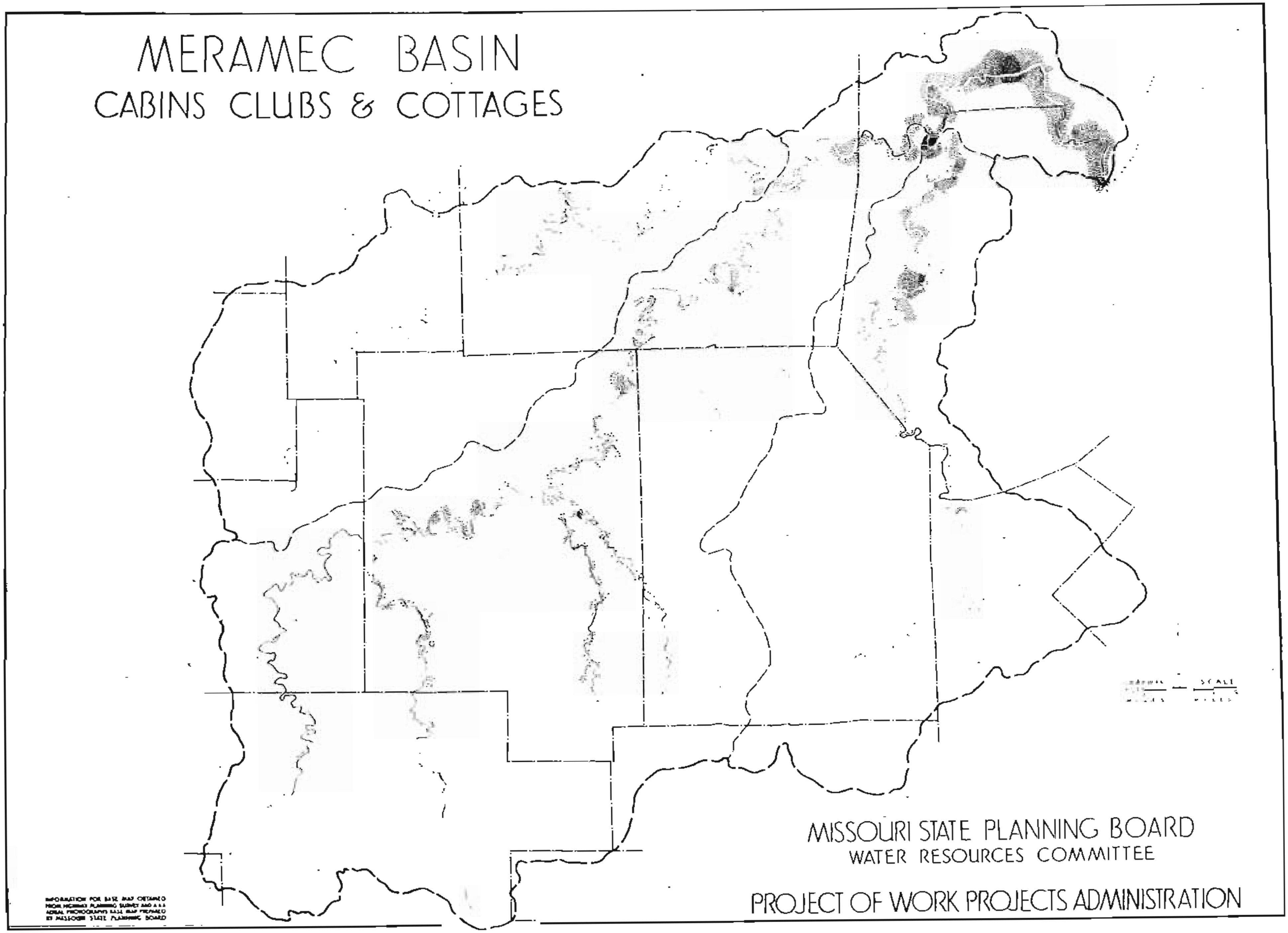
Land elevations vary from about 1250 feet above sea level in the upper portions of the basin to about 450 feet at the mouth of the Meramec. The entire basin is quite rugged in character and is generally not well suited for agricultural purposes. Some sections, however, have been extensively cultivated with the result that much top soil has been lost through erosion. This is particularly true of the Bourbeuse watershed.

In the extreme southeast corner of the basin, near Flat River, are located some of the largest lead mines in the southwest. Contrary to expectations, the pollution introduced by mine drainage did not appear to materially affect the condition of the Big River below this point. Although the alkalinity of the receiving stream was at times below normal, it was not materially depleted and the general physical condition of the stream below this point appeared to be satisfactory during the survey period.

North of Flat River and along the eastern edge of the basin there are many tiff mines, most of which are individually operated by hand methods. There was no evidence of any pollution of consequence from this source. With the exception of lead and tiff mining, there are no major industries of a type which might be expected to contribute pollution of any consequence.

The development of the Meramec Basin for recreational

Figure 4


MERAMEC BASIN
CABINS CLUBS & COTTAGES
MISSOURI STATE PLANNING BOARD
WATER RESOURCES COMMITTEE
PROJECT OF WORK PROJECTS ADMINISTRATION

purposes is indicated in Figures 4 and 5. Figure 4 shows the location of cabins throughout the basin and Figure 5 shows the various bathing beaches, picnic grounds, and camping areas. From these two maps it is evident that the lower portions of the Meramec River and its principal tributaries have been developed extensively for recreational use.

It has been estimated that the total investment in cabins and the land occupied by the cabins is $5,203,036. (1) This does not include the value of beaches, picnic and camping grounds, docks or boats. The annual estimated expenditure for recreation in the basin is $3,085,633 (2) which includes depreciation and carrying charges on the capital investment. If the investment for recreational facilities is to be properly safeguarded, it is essential that ways and means be developed to provide adequate control of pollution over the entire basin.

Tributaries

The Big River is about 130 miles in length and joins the Meramec at mile 35. It has a drainage area of about 955 square miles and lies along the east side of the Meramec Basin. The Big River rises near Brule, Missouri and flows in a northerly direction to its junction with the Meramec. The average slope of the Big River from mile 105 to mile 67 is about 3.9 feet per mile; from mile 67 to mile 64, 7.7 feet per mile; from mile 64 to mile 21, 2.3 feet per mile; and from mile 21 to its junction with the

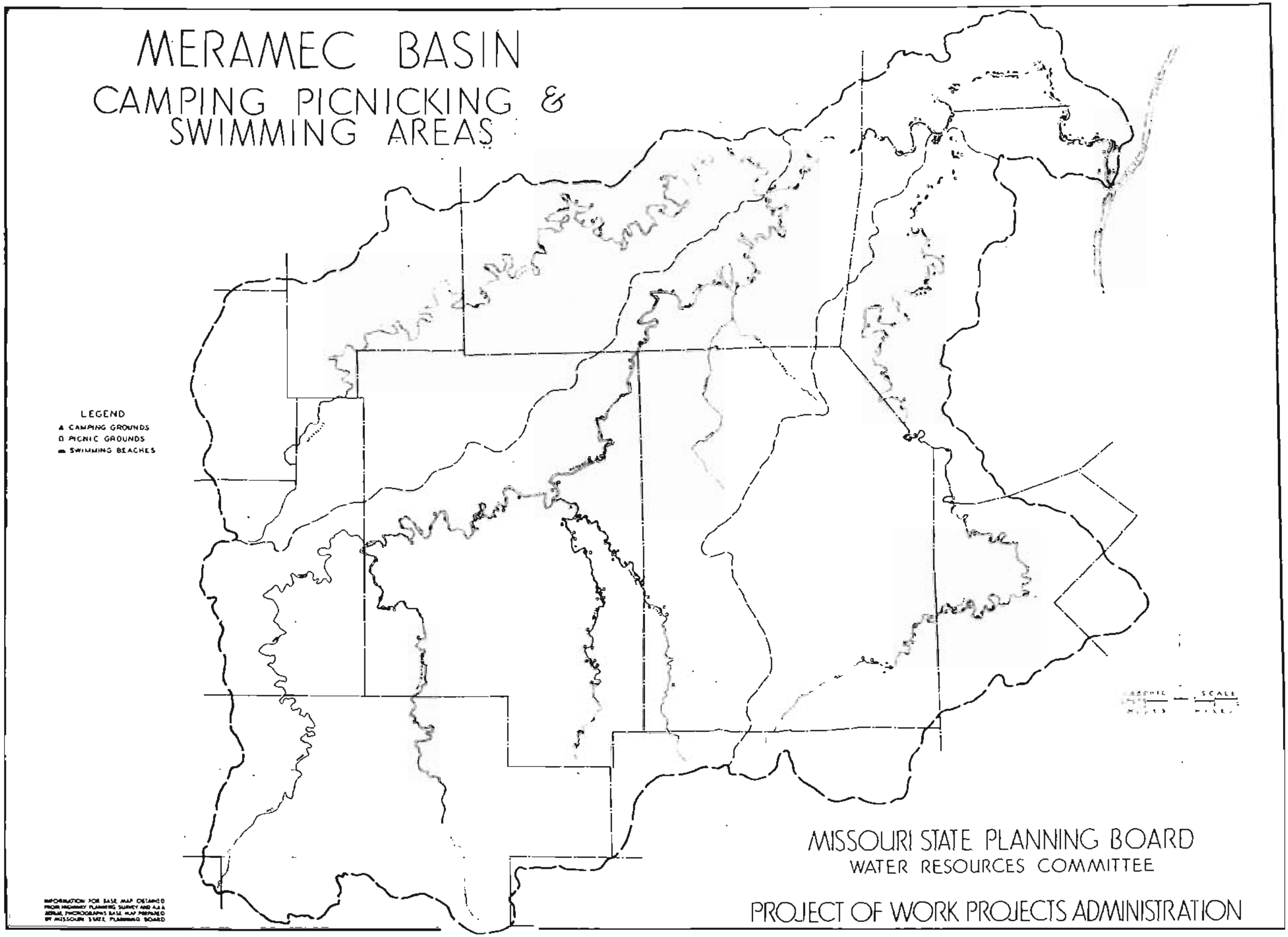

MERAMEC BASIN
CAMPING PICNICKING &
SWIMMING AREAS
LEGEND
▲ CAMPING GROUNDS
□ PICNIC GROUNDS
▬ SWIMMING BEACHES
MISSOURI STATE PLANNING BOARD
WATER RESOURCES COMMITTEE
PROJECT OF WORK PROJECTS ADMINISTRATION

Figure 5

Meramec, 2.0 feet per mile. The Big River is, in general, shallower and swifter than the Bourbeuse except in the extreme lower portion where deep pools exist. There are many fish dams and several abandoned mill dams along the river which tend to increase the time of flow by creating small pools which act as holding basins.

The Bourbeuse River is about 140 miles in length and has physical characteristics more nearly like those of the main stem. It has a drainage area of about 808 square miles and joins the Meramec River at mile 59. The Bourbeuse River rises near Rolla, Missouri, flows generally north and east to a point near Union, and then south and east to its confluence with the Meramec. The slope of the Bourbeuse from mile 84 to mile 14 is 1.9 feet per mile; from mile 14 to mile 7, 2.9 feet per mile; and from mile 7 to the mouth, 2.0 feet per mile. Although the average slope does not change greatly, from a point below Union to its mouth the Bourbeuse River consists of a series of pools which tend to reduce the time of flow.

Other tributaries which are of lesser importance include the Huzzah-Courtois Creeks, about 35 miles long, Indian Creek, about 25 miles long, and Brazil Creek, about 12 miles long.

Geology and Soils (3)

The rocks which outcrop in the greater part of the basin are principally dolomite and flinty dolomite with some beds of brown or grey-brown sandstone. At places in the southeastern part of the basin, granites and associated lavas of Pre-Cambrian age are exposed at the surface. Much of the upland area of the northern part of the basin is capped with shales and clays of the Des Moines formation which lie upon the cherty dolomite and sandstone beds of the Cotter-Jefferson City and Roubidoux formations.

In the western part of St. Louis County and adjacent parts of Jefferson County, outcrops of the St. Peter sandstone and the overlying dolomite and limestone beds of the Ordovician age are exposed. These strata are seen in the bluffs which make the valley walls of the Meramec and Big Rivers in the vicinity of Pacific, House Springs, and Eureka. Below Valley Park the Meramec, as it approaches its mouth, flows across geologically younger beds of limestone of the Mississippian age. In the eastern part of St. Louis County, these Mississippian beds are covered in places at the surface by shales and thin limestones of the Des Moines group of sedimentary rocks of the Pennsylvanian age.

The soils in the southern half of the basin are characteristic of the main Ozark region. They are light in color, stony and of low fertility. In the northern half of the basin, the soils are more productive and only the steep slopes are stony. In general, the better soils occur in the northeastern part of the basin where the surface is covered with a mantle of loess.

PRECIPITATION AND HYDROLOGICAL DATA

According to the records of the U. S. Weather Bureau, the average annual precipitation in the Meramec Basin as of January 1, 1941 varied from 40.97 inches per year at Pacific to 44.61 inches per year at Arcadia, which is located near the extreme southeast corner of the basin. The average of the three stations located at Pacific, Rolla, and Arcadia was 42.46 inches. The year of least rainfall in the basin as indicated by the average of these three stations occurred during 1901 when the precipitation was 26.2 inches. The next driest year occurred during 1936 with the average precipitation being only a few tenths of an inch greater than in 1901. The year of heaviest rainfall occurred in 1927 with an average of 55.7 inches. The heaviest average monthly precipitation occurs during May with the months from March to September inclusive exceeding one-twelfth of the average annual rainfall at each of the three above stations.

Flow data were available from five gaging stations which are maintained by the Missouri Geological Survey, cooperating with the U. S. Geological Survey, the U. S. Weather Bureau, and the U. S. Army Engineers. Three of these stations were located on the Meramec River and one each on the Big and Bourbeuse Rivers. Those on the Meramec were located at Steelville, Robertsville, and Eureka. The gaging station on the Bourbeuse was located at Union and the one on the Big River at Byrnesville.

Table I gives the average, maximum, and minimum daily flows at each of the gaging stations for the survey period. The average daily flow for each of these months for the period during which the gaging station has been in operation is also shown. The number of years which each of the gaging stations has been in operation is indicated under the station location.

TABLE I

FLOW DATA FOR 5 GAGING STATIONS IN THE
MERAMEC BASIN

All flows expressed in cfs.

Location Yrs. in Operation		Steelville 14 yrs.	Robertsville** ----	Eureka 13 yrs.	Union 13 yrs.	Byrnesville 15 yrs.
July Average		269	----	1514	206	416
July 1940	Mean. Max. Min.	162 325 116	750 3240 330	1078 5420 441	109 711 28	240 1050 95
August Average		239	----	1031	155	263
August 1940	Mean. Max. Min.	250 636 116	779 1820 318	1056 2590 419	752 616 26	296 932 101
September Average		278	----	991	233	221
September 1940	Mean. Max. Min.	120 162 109	371 697 288	496 1060 360	51.1 223 24	105 243 49
October Average		254	----	1252	213	337
October * 1940	Mean. Max. Min.	123 132 116	322 352 280	435 533 375	27 35 22	120 215 74

*October figures for October 1 to 15 only.
**No previous records were available on this station.

DISTRIBUTION OF POPULATION

From data taken from the 1940 decennial census published by the Bureau of the Census, the 1940 population of the Meramec Basin was computed to be 131,719. This population was found by adding the populations of the various townships in the basin. For those townships lying partly outside the basin, the population of any municipalities was subtracted from the township population and the remaining rural population assumed to be uniformly distributed over the area involved. The population living in the watershed was then determined by calculating the percentage of township area within the basin from large scale maps and applying this factor to the township population with municipal populations excluded. Municipalities having greater than fifty per cent of their area in the Meramec watershed were included as though the whole of the municipality was located therein because of the difficulty of segregating areas of concentrated population. From the Report of the Water Resources Committee of the State Planning Board (4) the population in the Meramec Basin has been as follows:

1890 - 89,989	1920 - 109,745
1900 - 101,040	1930 - 117,310
1910 - 115,250	1940 - 131,719*

*Added to the Report of the State Planning Board.

These populations were computed as described previously. The average density of population in the basin has increased from

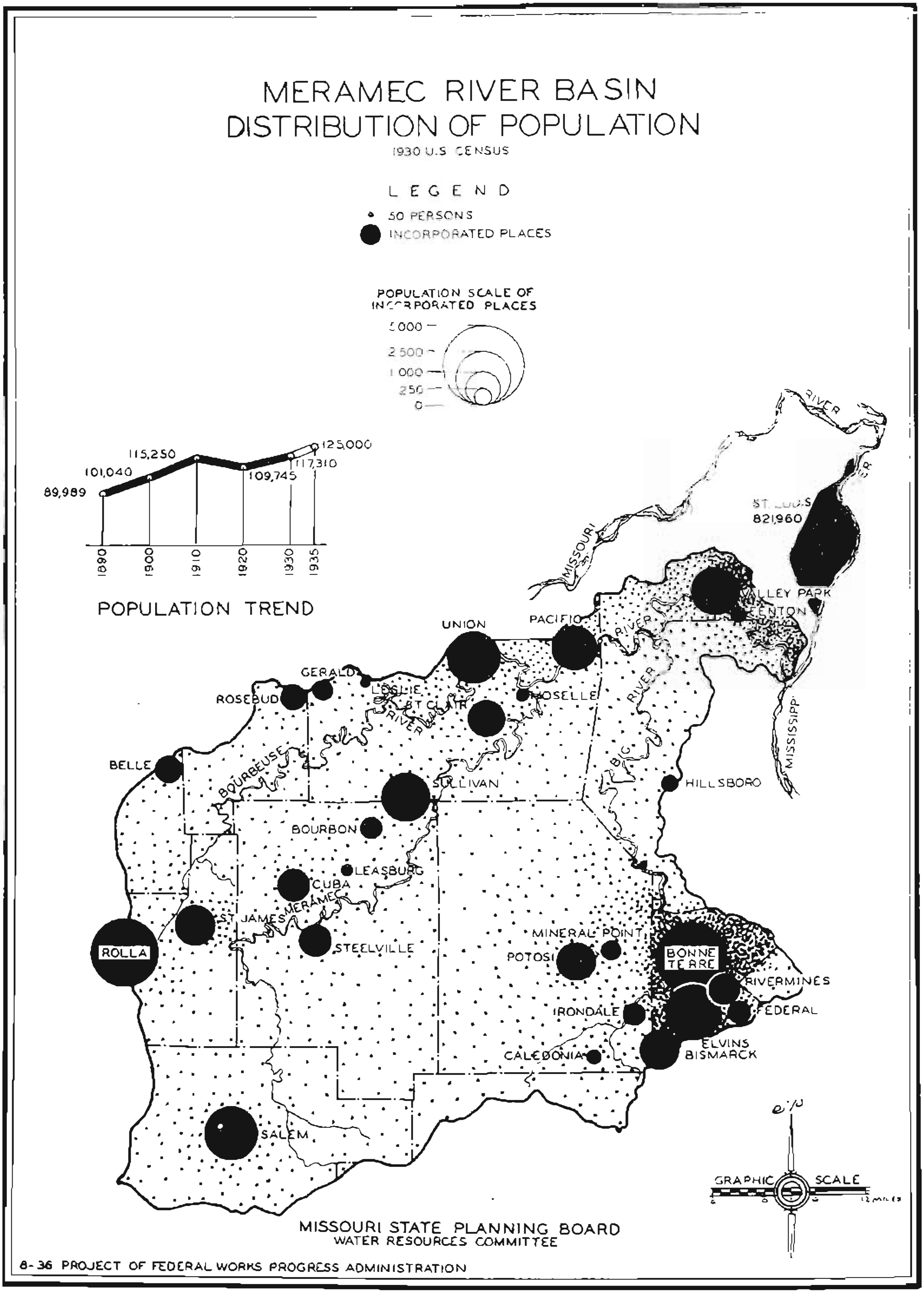

MERAMEC RIVER BASIN
DISTRIBUTION OF POPULATION
1930 U.S. CENSUS
LEGEND
50 PERSONS
INCORPORATED PLACES
POPULATION SCALE OF INCORPORATED PLACES
2500
1000
250
0
POPULATION TREND
89,989
101,040
115,250
109,745
117,310
125,000
1890
1900
1910
1920
1930
1935
821,960
VALLEY PARK
UNION
PACIFIC
GERALD
ROSEBUD
ST CLAIR
BELLE
BOURBEUSE
SULLIVAN
HILLSBORO
BOURBON
LEASBURG
CUBA
ROLLA
ST JAMES
STEELVILLE
MINERAL POINT
POTOSI
BONNE TERRE
RIVERMINES
FEDERAL
IRONDALE
ELVINS
BISMARCK
CALEDONIA
SALEM
MISSOURI
MISSISSIPPI
BIG
RIVER
GRAPHIC SCALE
MISSOURI STATE PLANNING BOARD
WATER RESOURCES COMMITTEE
8-36 PROJECT OF FEDERAL WORKS PROGRESS ADMINISTRATION

Figure 6

22.6 persons per square mile in 1890 to 33.1 persons per square mile in 1940.

Figure 6 shows the distribution of population throughout the Meramec Basin as given by the 1930 census. It has been included to give the reader a visual picture of the location and concentration of the population throughout the basin. Although the 1940 census indicates many minor changes, the relative location of population concentrations remains the same. A reasonably clear conception of the source and relative magnitude of the human pollution involved in this study can be obtained from Figures 4 and 6.

SOURCE OF POLLUTION

As previously indicated, there were no industrial wastes which were considered to be of significance. The pollution in those portions of the basin studied, therefore, was principally of a sanitary nature, and consisted of the domestic wastes from the various municipalities together with such other wastes as might be contributed by the various cabins and camps located throughout the basin. The location of all municipal sewerage systems in the basin with the type of treatment indicated is shown in Figure 2. However, several cities without a municipal sewerage system were found to contribute pollution, probably from individual septic tanks discharging into a tributary water course.

Another source of pollution, but one which is of questionable public health significance, is the surface wash which finds its way into streams during periods of wet weather. Since organisms of the coli group are found in the fecal discharges of warm blooded animals, it is quite obvious that when the accumulated fecal matter from all animals on a watershed is washed into a stream following a period of rainfall of sufficient intensity to produce surface runoff, the concentration of coliform organisms will greatly increase. It was originally planned to show this effect by dividing the data into several flow ranges. Lack of flow data for many of the sampling stations, particularly on the Big and Bourbeuse Rivers, made it unwise to present the data in this form, although much of the work was completed before it became evident that serious errors would be introduced by attempting to compute flows too far upstream from a gaging station. Table II has been prepared to show the effect of high flows on the concentration of coliforms and total bacteria plate counts for the five sampling points where accurate flow data were available.

The data in Table II represent the arithmetic average of all determinations for the station and flow range indicated. The flow ranges were selected in such a manner that the number of determinations in each of the four groups for a given station would be approximately equal. It will be noted that in several instances the data are not consistent. In most cases this is due to the inclusion of a single high count with an insufficient number of determinations to reduce the effect of the one unusually high determination. The general effect of surface wash on the coliform and total plate count determinations is, however, quite clearly shown. Approximately three times the number of samples were collected at station M 32.0 as at each of the other stations, and those results are therefore more reliable.

TABLE II

AVERAGES OF COLIFORM AND TOTAL PLATE COUNT DETERMINATIONS
FOUR FLOW RANGES AT FIVE SAMPLING STATIONS

Station	Flow Range c.f.s. per sq. mi.	Coliforms M.P.N. per 100 ml.	Total Plate Count per ml. - 37°
M 138.8	0 - 0.140	151	711
	0.141 - 0.210	824	2050
	0.211 - 0.280	440	6225
	0.281 and over	2510	4535
M 58.5	0 - 0.140	1199	866
	0.141 - 0.210	171	793
	0.211 - 0.280	625	1526
	0.281 and over	8610	11,349
M 32.0	0 - 0.140	302	887
	0.141 - 0.210	839	1723
	0.211 - 0.280	1234	1500
	0.281 and over	4733	2345
M Bo 72.7	0 - 0.040	1655	354
	0.041 - 0.060	191	2725
	0.061 - 0.080	2317	3450
	0.081 and over	968	18,140
M Bi 54.0	0 - 0.120	979	661
	0.121 - 0.180	938	758
	0.181 - 0.240	1577	5168
	0.241 and over	4142	6855

LOCATION OF SAMPLING STATIONS

In order to prevent confusion as to the location of any sampling point, it was decided to use the procedure followed by the U. S. Public Health Service for designating the location of all points. Each of the principal rivers was assigned one or more letters from its common name to designate the general location of a point, and the distance in miles from a fixed point (in this case the mouth of the Meramec River) to the sampling point was used to indicate the exact location. Thus M was used to denote the Meramec River, Bi the Big, and Bo the Bourbeuse. For sampling points not on the main stem, the designation for the tributary on which the point was located was also included. Thus station M 40 is located 40 river miles upstream from the mouth of the Meramec River, and M Bi 103 is located 103 river miles upstream starting at the mouth of the Meramec and proceeding to the mouth of the Big River thence up the Big River to mile 103. It should be understood that in the latter example 103 represents the total river mileage from the mouth of the Meramec to the sampling point on the Big, and not the mileage from the mouth of the Big River to the point in question.

Where possible, sampling points were selected at bridges for accessibility. However, consideration was given to the desirability of the point in question for use as a sampling station. Points were generally selected at least one-fourth mile below a riffle, with at least two riffles between the point and any known source of pollution to insure thorough mixing. At three points, M 9.6, M 24.5, and M 29.5, it was necessary to collect the samples from a boat. Two boats were secured from the State Conservation Commission and the services of a third boat were obtained from a local bathing beach. At several points on the Bourbeuse it was necessary to collect samples from a ford. At such points the sampling schedule was interrupted during periods of high water.

The location of all sampling stations is shown on Figure 2. For various reasons it was necessary to omit several of the stations originally proposed from the sampling schedule, although all of the original points are indicated on the map.

SAMPLING PROCEDURE

Except for the first few days samples were collected by the use of a sampling can constructed for that purpose. The type of can used is described in detail in Public Health Bulletin No. 171 (5). Since no samples were to be collected for biochemical oxygen demand (B.O.D.) determinations, only one 250 ml. sample was collected instead of the usual two. This was used for the determination of dissolved oxygen. In addition a 125 ml. sample was collected in a sterile wide mouth bottle for bacteriological determinations.

Because of the distance from the Union laboratory to the end points on the Big, Bourbeuse, and upper Meramec sampling runs, sampling was started at the upstream end and proceeded downstream. In this way the time elapsing between the collection and analysis of samples was reduced to a minimum. The average time between collection and arrival at the laboratory was between 2 and 3 hours, with the maximum time about 4 hours. Because of the fact that no seriously polluted samples were collected it was not deemed necessary to ice the samples. Of the 18 points originally selected on the Meramec, 13 on the Big, and 9 on the Bourbeuse, routine samples were collected from 17 points on the Meramec, and 9 each on the Big and Bourbeuse Rivers. All samples were collected from mid-stream and the time, location, temperature, and bottle numbers were recorded at the time of collection.

Through the cooperation of the city officials at Union and Kirkwood, Missouri, space was provided in the water plant laboratory at each of these cities for setting up the laboratory equipment. Although it was originally planned to collect daily samples from all sampling points, it was evident that the laboratory equipment and other facilities available would be inadequate to handle the number of samples involved. It was then decided that the lower portion of the Meramec was the most important to the survey because of the greater use of this section for recreational purposes. Consequently arrangements were made to collect daily samples from all points on the Meramec between the mouth and Pacific, and to transport them to the Kirkwood laboratory for analysis. Samples were taken alternately from the Meramec above Pacific and the Big and Bourbeuse Rivers, with samples taken from the first sampling point on the Big and Bourbeuse Rivers daily.

Because of the W.P.A. regulations it was necessary to use three sampling crews with one crew collecting samples alternately for the Kirkwood and Union laboratories. Samples were collected five days out of six, but the sampling schedule was shifted occasionally so that the day off always occurred on a week day. In this manner samples were collected during every weekend when the recreational load was heaviest.

LABORATORY METHODS

Except as outlined below the laboratory procedures, both for chemical and bacteriological determinations, followed those given in "Standard Methods of Water Analysis" (6). The following determinations were made on the samples collected: turbidity, dissolved oxygen, alkalinity, most probable number of coliforms, and total number of bacteria using agar plates incubated at 37° Centigrade.

Turbidity. The methods used to determine the turbidity are described in "Standard Methods of Water Analysis", pages 7-10.

Dissolved Oxygen. Because of the uncertainty as to the occurrence of nitrites in certain sections of the streams sampled, the procedure used was a variation of the Alsterberg modification of the Winkler procedure. This method is described in "Industrial and Engineering Chemistry" (7). Sodium azide is used to destroy any nitrites present. The dissolved oxygen content was determined on all samples collected.

Alkalinity. The procedure followed was that outlined in "Standard Methods of Water Analysis", pages 64-65. Only the total alkalinity as indicated by using methyl orange as an indicator was determined. An average of about one sample each week from each sampling station was used for alkalinity determinations.

Determination of the Most Probable Number of Coliforms. In determining the most probable number of coliforms, the presumptive test was performed as outlined in "Standard Methods of Water Analysis" on page 211. Three tubes each of three dilutions having a ratio of 100:10:1 were used. Attempts were made to select such dilutions that all of the tubes of the lowest dilution would be positive and all of the highest dilution negative. The positive presumptive tubes were then confirmed by the use of brilliant green bile broth, the transfers being made by means of a standard 3 mm. platinum loop. No attempt was made to complete any of the confirmed tests, the formation of gas in brilliant green bile broth being taken as indicative of the presence of the coli-aerogenes group.

In order to insure uniform media throughout the survey, sufficient media of all types were ordered to complete the entire survey with the specification that all media of a given type be taken from the same batch.

The most probable number of coliform organisms was determined by the use of tables compiled by Hoskins (8).

Determination of the Total Plate Count. The procedure used followed that outlined in "Standard Methods of Water Analysis" on pages 207-208. Two plates were planted with a dilution estimated to produce from 25 to 400 colonies. Two additional plates were also used having one-tenth and ten times the dilution of the first plates in order to minimize unsatisfactory results should the sample contain more or less bacteria than estimated.

The pipettes used were of one ml. capacity calibrated to 0.1 ml. Dilutions were made by adding one ml. of sample to 99 ml. of sterile tap water. Plates were incubated for 24 hours at 37° C.

A Spencer colony counter was used for all plate counts. In computing the total plate count, the following rules, suggested by Principal Bacteriologist C. T. Butterfield of the U. S. Public Health Service, were adopted:

1. When the duplicate plates in a series of three give more than 25, and less than 400 colonies per plate, and the third plate less than 25 or more than 400 colonies, the third plate should be omitted from the average unless it falls between the other two.

2. Where the duplicate plates both show too many or too few colonies, only the third plate should be considered in the average result.

3. Where one of the duplicate plates gives an obviously erroneous count, it should be disregarded in recording the average result.

4. When one of the duplicate plates comes within the prescribed limits and the other shows too many or too few colonies, both plates must be either included in or excluded from the average as follows, except as indicated under 3: (a) where the average of the two duplicate plates falls within the limits, both shall be included in the average; and (b) when the average of the

two falls outside the limits, both shall be excluded.

5. When more than one set of duplicate plates is made, equal authority should be given to each set, providing the number of colonies on the plates fall within the prescribed limits.

RESULTS OF BACTERIOLOGICAL DETERMINATIONS

In first attempting to analyze the mass of data which had been accumulated during the survey, the laboratory results were divided into four flow ranges in order to segregate the effects of high flows previously referred to in this report, and to obtain one or two groups of data which might be expected to apply to the condition of the streams during periods when optimum conditions for recreational use existed; that is, when the river was not at flood flow or too turbid for swimming and fishing. Unfortunately, the accurate flow data were limited to the five stations located in the vicinity of gaging stations, and attempts to estimate the flow by assuming a constant runoff per square mile for the drainage areas above each of the sampling stations resulted in the inclusion of some flood flows with data in the lower flow ranges. This was clearly shown by the turbidities and high bacterial and coliform concentrations and was particularly true of data on the Big and Bourbeuse Rivers.

The next attempt to analyze the data was to correlate such factors as turbidity, flow, and temperature against the actual use of the stream for swimming and fishing. Accurate figures on the actual number of people swimming and fishing were collected as part of the survey and were available. The purpose in making such correlations was essentially the same as before - to limit the data used as nearly as possible to times when stream

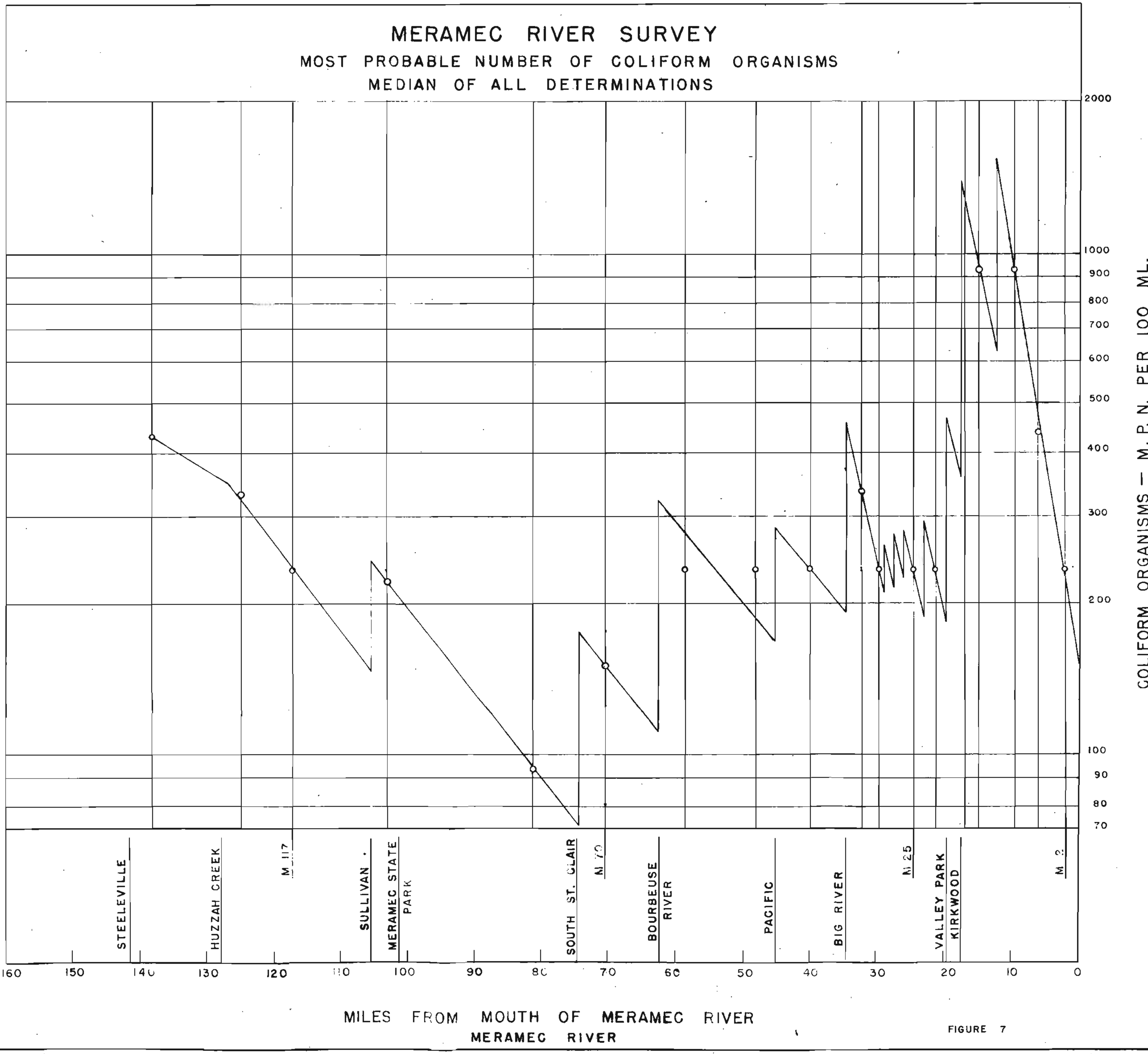

MERAMEC RIVER SURVEY
MOST PROBABLE NUMBER OF COLIFORM ORGANISMS
MEDIAN OF ALL DETERMINATIONS
COLIFORM ORGANISMS — M. P. N. PER 100 ML.
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
STEELEVILLE
HUZZAH CREEK
M 117
SULLIVAN
MERAMEC STATE PARK
SOUTH ST. CLAIR
M 70
BOURBEUSE RIVER
PACIFIC
BIG RIVER
M 25
VALLEY PARK
KIRKWOOD
M 2
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MILES FROM MOUTH OF MERAMEC RIVER
MERAMEC RIVER

FIGURE 7

conditions were satisfactory for recreational purposes. Since the number of days were limited on which data were available concerning the number of people using the stream for recreational purposes, no definite trend could be established.

At the suggestion of Passed Assistant Sanitary Engineer R. W. Kehr of the U. S. Public Health Service, the data for each station were then arranged in numerical sequence and the median of all observations taken as representing the average condition of the stream at that point during the survey. Statistically this procedure is sound and it represented the only method possible, with the data available, by which the extremely high bacterial counts occurring during flood flows could be included without materially affecting the results of the average flows. The results obtained by using the median were quite consistent and gave a clear picture of the condition of each of the three streams studied. Figures 7 to 12, inclusive, show the results of the most probable number (M.P.N.) of coliforms per 100 ml. and the total plate counts per ml. for the Meramec, Big, and Bourbeuse Rivers, respectively. The basic data are included in Tables III and IV.

Figures 7 to 9, inclusive, show the most probable number of coliforms per 100 ml. for the Meramec, Big, and Bourbeuse Rivers, respectively, plotted against river miles above the mouth of the Meramec. The vertical lines indicate the location of the

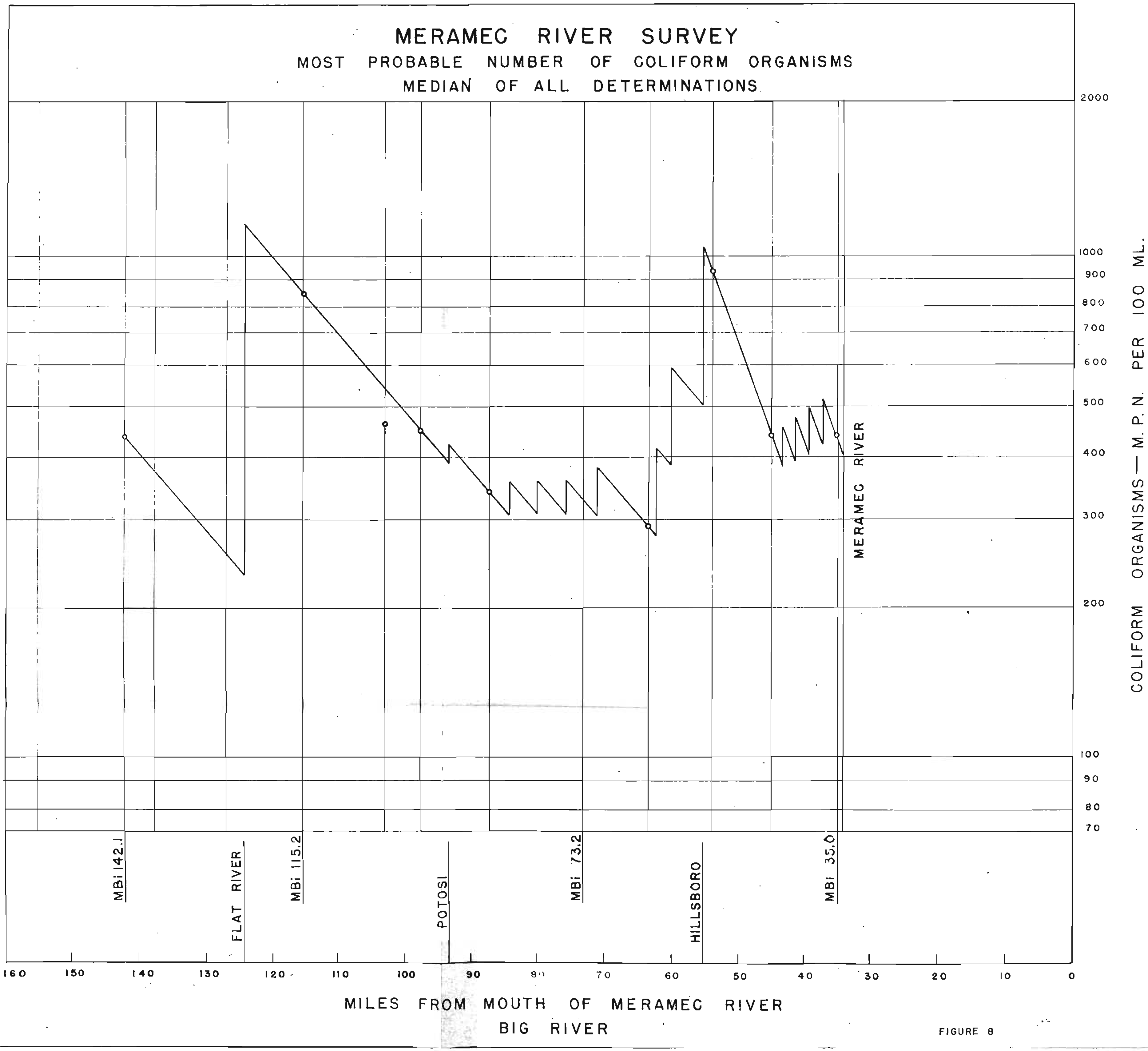
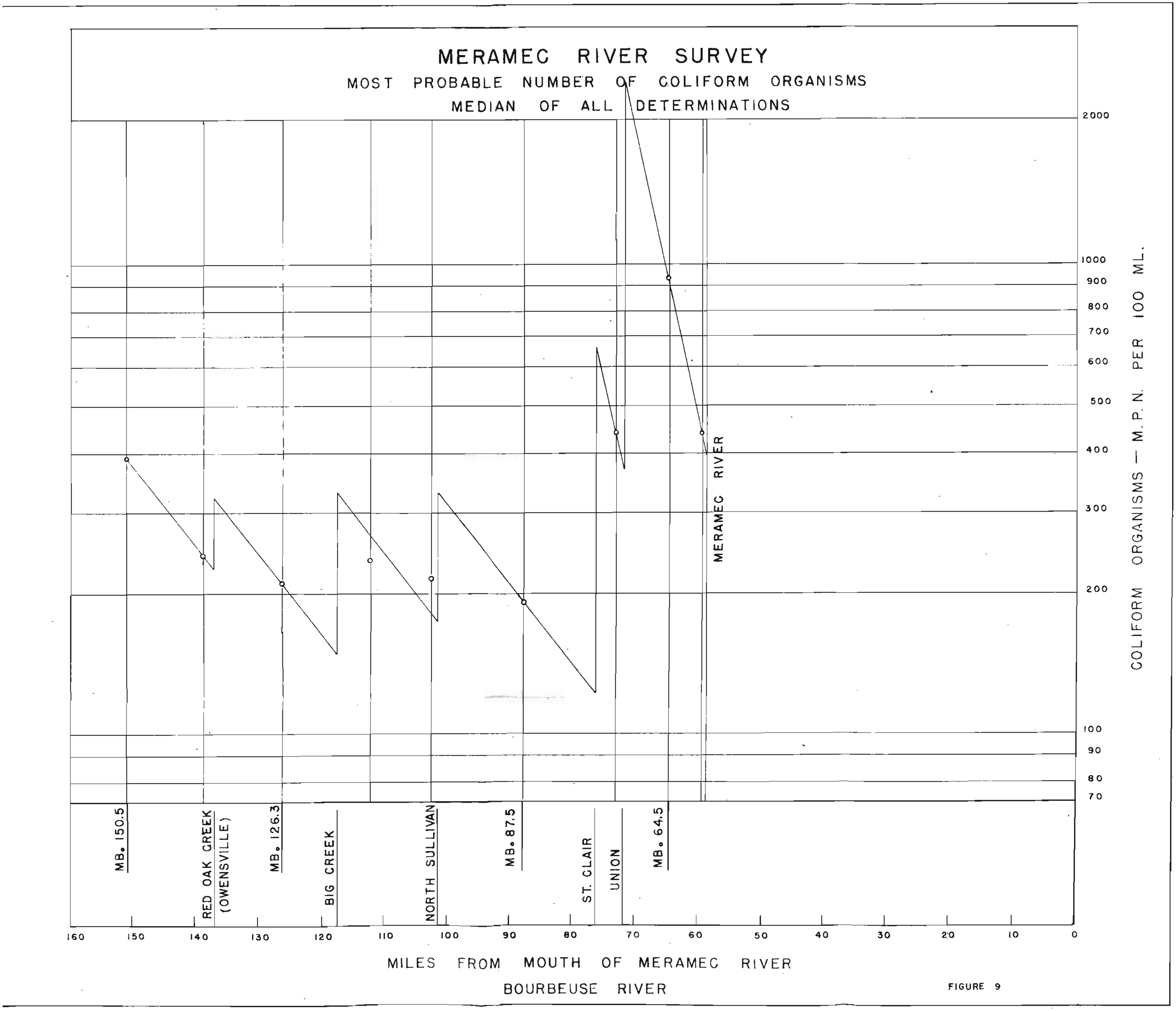

MERAMEC RIVER SURVEY
MOST PROBABLE NUMBER OF COLIFORM ORGANISMS
MEDIAN OF ALL DETERMINATIONS
COLIFORM ORGANISMS — M. P. N. PER 100 ML.
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
MERAMEC RIVER
MBi 142.1
FLAT RIVER
MBi 115.2
POTOSI
MBi 73.2
HILLSBORO
MBi 35.0
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MILES FROM MOUTH OF MERAMEC RIVER
BIG RIVER

FIGURE 8

various sampling stations, a few of which have been designated as described in the section "Location of Sampling Stations". It will be noted that when the bacteriological results are plotted on a logarithmic scale, the rate of reduction of organisms between sources of pollution appears to follow a straight line. A review of bacteriological studies of the Illinois, Ohio, and Mississippi Rivers (9) shows that the rate of reduction is actually a curve, but for relatively short times of flow between sources of pollution such as occur throughout the Meramec Basin, the rate of reduction of organisms approximates a straight line. These studies have shown that the rate of reduction of bacteria is primarily a function of time and temperature. Since the Meramec study was conducted under summer conditions without any appreciable change in the average temperature, it is to be expected that the rate of reduction would be fairly constant except for time of flow. The change in slope indicating a more rapid rate of reduction of organisms, noted in Figures 7, 8, and 9, as the streams near their mouth is probably due to backwater and to the wider and deeper pools previously mentioned near the mouth of each of the streams and to a consequent increase in the time of flow. This effect is not so pronounced in Figures 10, 11, and 12. In fact, the slope appears to be flatter on the Big and Bourbeuse Rivers although this may be due to the many small streams which come in between stations with the result that only in the upper reaches is there


MERAMEC RIVER SURVEY
MOST PROBABLE NUMBER OF COLIFORM ORGANISMS
MEDIAN OF ALL DETERMINATIONS
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
COLIFORM ORGANISMS — M. P. N. PER 100 ML.
MERAMEC RIVER
MB. 150.5
RED OAK CREEK (OWENSVILLE)
MB. 126.3
BIG CREEK
NORTH SULLIVAN
MB. 87.5
ST. CLAIR
UNION
MB. 64.5
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MILES FROM MOUTH OF MERAMEC RIVER
BOURBEUSE RIVER
FIGURE 9

any indication of the slope which shows the rate of reduction. The pollution assumed to come from cottages and camps located above station M 25.0 on Figure 7, and above stations M Bi 35.0, M Bi 54.0, M Bi 64.4, and M Bi 73.2 on Figure 8 has been shown as a series of short vertical rises. The steeper slope generally noted on Figures 10, 11, and 12 is believed to be due to the greater concentration of organisms. The slope on these Figures is not as well defined as on Figures 7, 8, and 9 due to the many small tributaries between the various stations. Since there are no concentrations of population on many of these small tributary watersheds, no increase in pollution would be expected. However, a considerable number of soil bacteria might be contributed by a stream even though no pollution was present. Such a condition would increase the total plate count without affecting the coliform determination.

In general, it is felt that the results obtained are quite good and present a representative picture of conditions during the survey. Except for the lower reaches of all rivers and the Big River below Flat River, the coliform concentrations are all below 500 per 100 ml. The total bacteria as indicated by the plate counts run much higher but are generally below 1000 per ml.

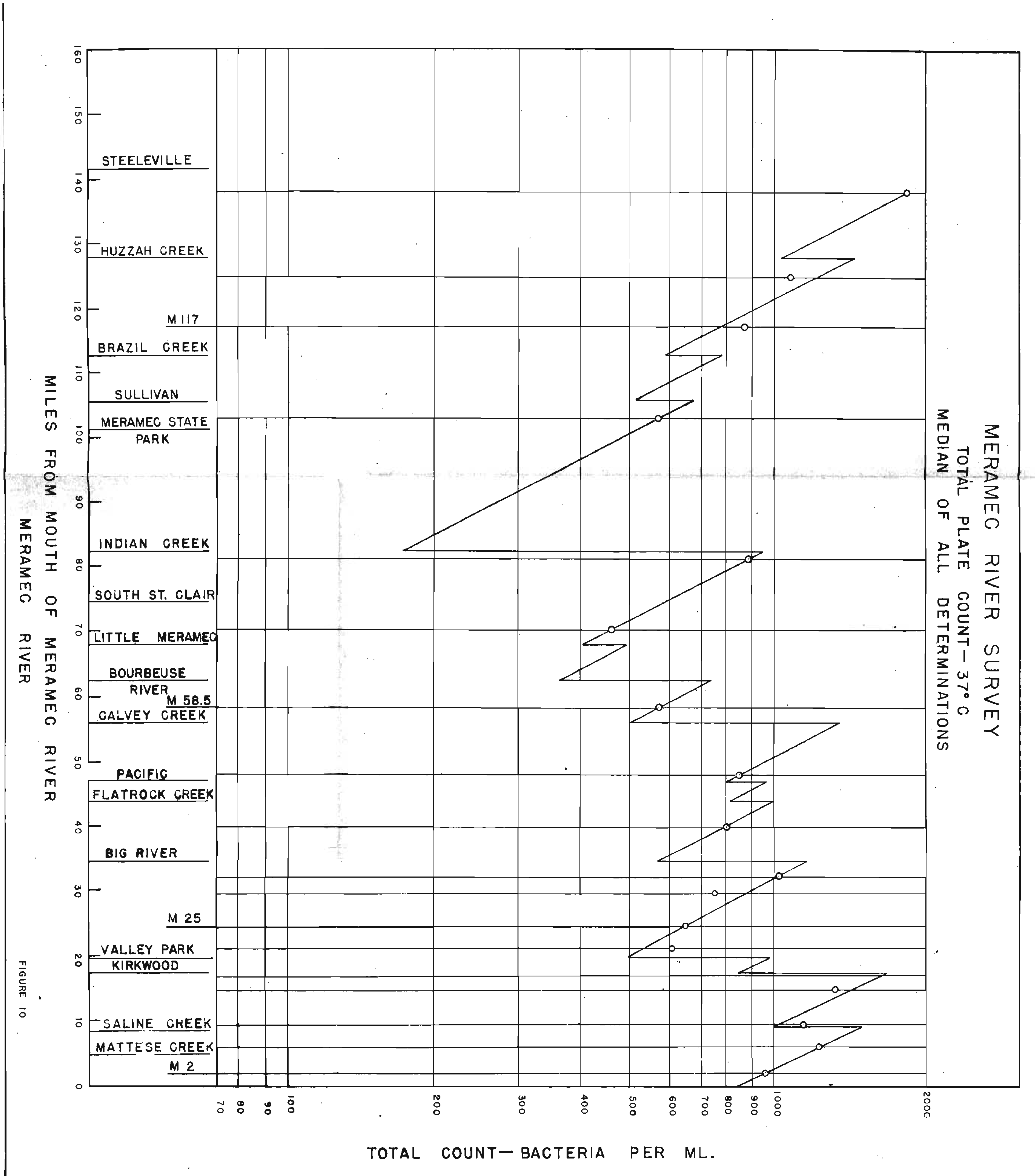

MERAMEC RIVER SURVEY
TOTAL PLATE COUNT—37° C
MEDIAN OF ALL DETERMINATIONS
MILES FROM MOUTH OF MERAMEC RIVER
MERAMEC RIVER
TOTAL COUNT—BACTERIA PER ML.
STEELEVILLE
HUZZAH CREEK
M 117
BRAZIL CREEK
SULLIVAN
MERAMEC STATE PARK
INDIAN CREEK
SOUTH ST. CLAIR
LITTLE MERAMEC
BOURBEUSE RIVER
M 58.5
CALVEY CREEK
PACIFIC
FLATROCK CREEK
BIG RIVER
M 25
VALLEY PARK
KIRKWOOD
SALINE CREEK
MATTESE CREEK
M 2
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
70
80
90
100
200
300
400
500
600
700
800
900
1000
2000

FIGURE 10

TABLE III

SUMMARY OF BACTERIOLOGICAL AND CHEMICAL DETERMINATIONS
MERAMEC RIVER

Sampling Station	Coliforms* MPN per 100 ml.	Total Count* per ml. - 37°C	D.O. ppm.	D.O. % Sat.	Turbidity p.p.m.	Alkalinity p.p.m. $CaCO_3$
M 2.0	230	948	7.67	87	32	160
M 5.8	430	1238	7.25	84	33	162
M 9.6	930	1150	7.73	85	33	164
M 14.8	930	1332	7.34	85	33	165
M 21.0	230	608	7.74	92	33	166
M 25.0	230	649	7.64	90	39	166
M 29.5	230	743	8.34	93	32	172
M 32.0	335	1015	7.76	85	30	171
M 40.0	230	805	7.90	91	37	159
M 48.0	230	835	7.47	86	40	158
M 58.5	230	572	7.44	87	53	146
M 70.5	150	460	7.51	87	32	153
M 81.2	92	785	7.29	84	26	159
M 103.1	220	571	7.32	83	26	157
M 117.0	230	850	7.19	80	24	165
M 125.0	330	1075	7.15	79	14	173
M 138.8	430	1840	7.07	77	48	145

*Median of all determinations. All others are arithmetic averages.

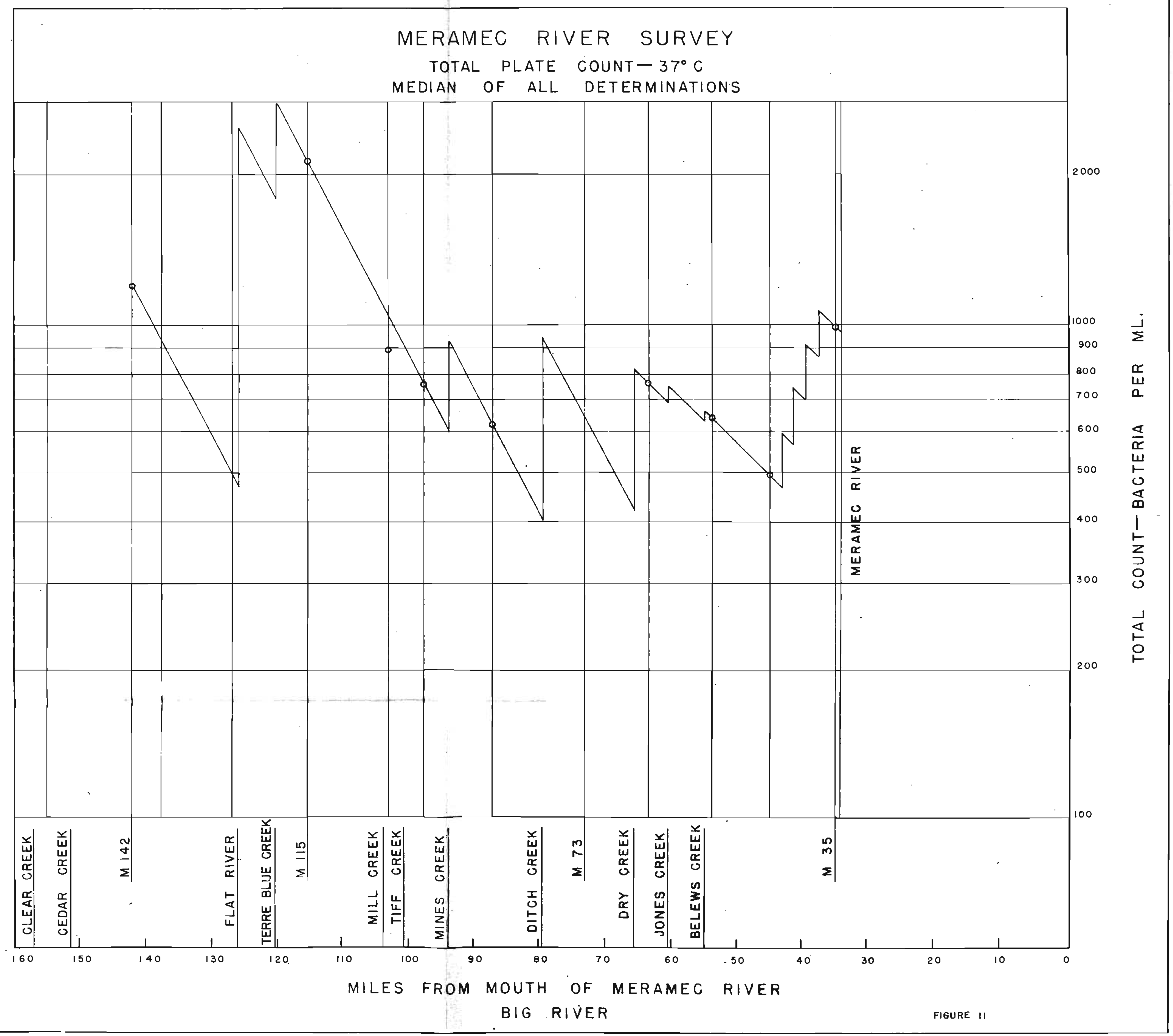
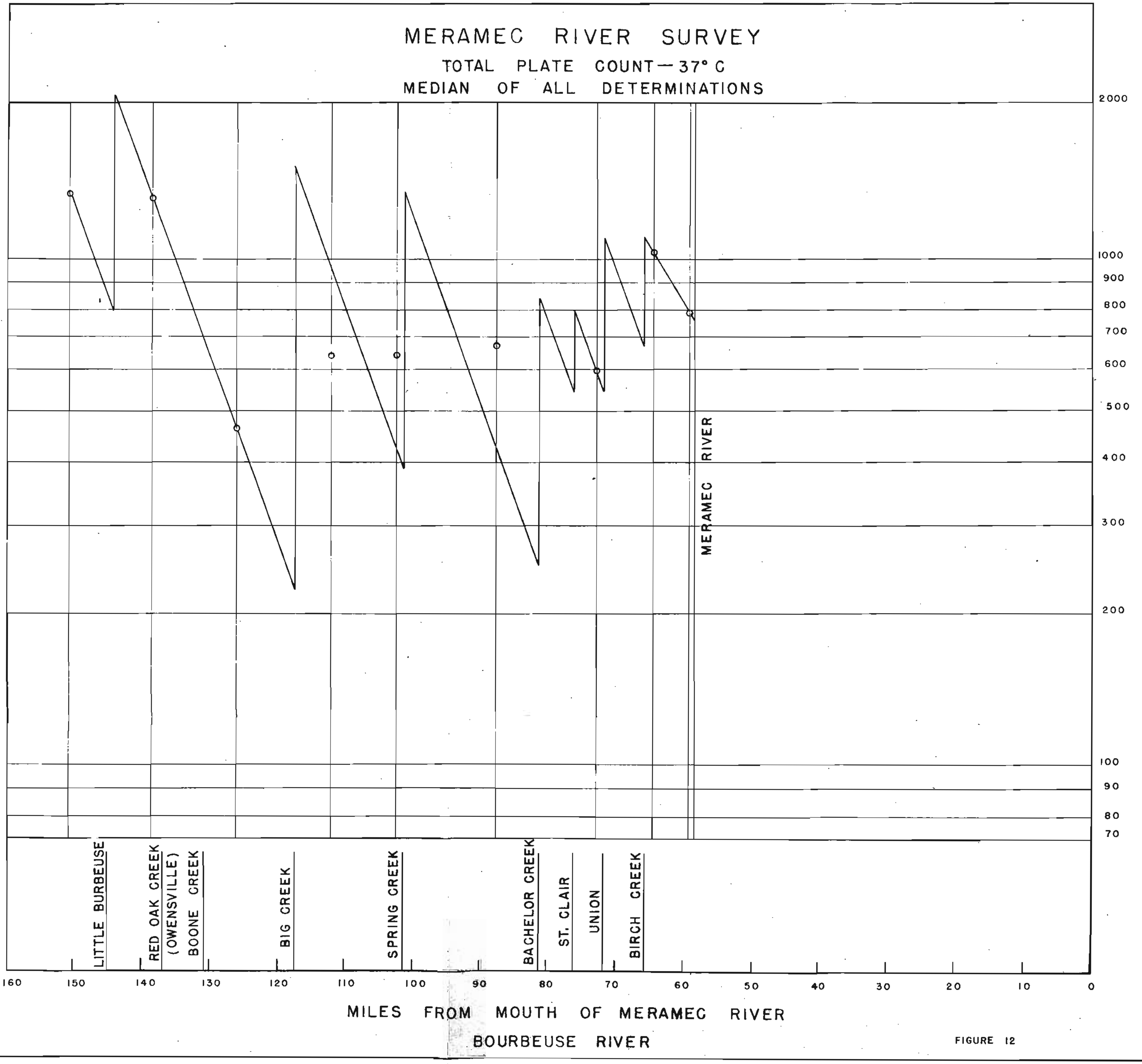

MERAMEC RIVER SURVEY
TOTAL PLATE COUNT—37° C
MEDIAN OF ALL DETERMINATIONS
CLEAR CREEK
CEDAR CREEK
M 142
FLAT RIVER
TERRE BLUE CREEK
M 115
MILL CREEK
TIFF CREEK
MINES CREEK
DITCH CREEK
M 73
DRY CREEK
JONES CREEK
BELEWS CREEK
M 35
MERAMEC RIVER
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
2000
TOTAL COUNT—BACTERIA PER ML.
MILES FROM MOUTH OF MERAMEC RIVER
BIG RIVER
FIGURE 11

TABLE IV

SUMMARY OF BACTERIOLOGICAL AND CHEMICAL DETERMINATIONS
BIG & BOURBEUSE RIVERS

Sampling Station	Coliforms* MPN per 100 ml.	Total Count* per ml. - 37°C	D.O. ppm.	D.O. % Sat.	Turbidity p.p.m.	Alkalinity p.p.m. $CaCO_3$
BIG RIVER						
M Bi 35.0	430	988	7.51	87	36	189
45.0	430	490	7.27	84	46	185
54.0	930	635	7.70	88	53	187
64.4	290	761	7.03	79	55	190
86.9	335	620	7.21	81	68	189
97.7	445	753	6.97	77	75	188
103.0	460	881	6.93	76	49	184
115.2	840	2143	6.99	77	63	183
142.1	430	1195	6.70	72	48	169
BOURBEUSE RIVER						
M Bo 59.3	430	797	6.45	75	86	107
64.5	930	1031	6.41	72	90	105
72.7	430	596	6.70	73	81	107
87.5	190	668	6.68	76	64	105
102.3	215	635	6.25	71	64	94
112.1	230	635	6.28	70	75	89
126.3	210	461	6.23	69	87	96
138.5	240	1305	5.51	60	76	89
150.5	390	1340	5.64	61	80	78

*Median of all determinations. All others are arithmetic averages.



MERAMEC RIVER SURVEY
TOTAL PLATE COUNT — 37° C
MEDIAN OF ALL DETERMINATIONS
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
TOTAL COUNT — BACTERIA PER ML.
MERAMEC RIVER
LITTLE BURBEUSE
RED OAK CREEK
(OWENSVILLE)
BOONE CREEK
BIG CREEK
SPRING CREEK
BACHELOR CREEK
ST. CLAIR
UNION
BIRCH CREEK
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MILES FROM MOUTH OF MERAMEC RIVER
BOURBEUSE RIVER

FIGURE 12

RESULTS OF CHEMICAL ANALYSES

A summary of the results of the chemical analyses is given in Tables III and IV with the bacteriological results. The determination of the alkalinity and dissolved oxygen of the samples collected was a precaution against the possible existence of greater pollution than was anticipated. As indicated on Figure 2, the cities of Union and Valley Park have no sewage treatment facilities, and the primary treatment plant at Flat River was not in operation during the survey period. The absence of any appreciable dissolved oxygen sag below each of these cities tends to bear out the original assumption that the dilution provided is sufficient to prevent the occurrence of any critical conditions and to maintain a satisfactory oxygen balance. However, from the standpoint of public health, complete treatment and chlorination of the sewage from these areas is definitely indicated if the Meramec Basin is to continue to serve as a recreational area.

The turbidity of each of the three streams involved was generally low except during surface runoff. The inclusion of the high turbidities in the averages shown in Tables III and IV has resulted in generally higher turbidities than would probably exist at average flows. The generally higher turbidities on the Bourbeuse have been referred to previously in this report.

The alkalinities shown in Tables III and IV are the arithmetic averages of all determinations and it is believed that they are representative of conditions during the survey period. The generally low alkalinity existing along the Bourbeuse River is believed to be due to the fact that most of the flow is from surface runoff, whereas the Big and Meramec Rivers are composed of a higher percentage of spring water. This is confirmed by the results of a few hardness determinations made during the survey which show that the non-carbonate hardness in the Bourbeuse River is low when compared to results from the Big and Meramec Rivers. Should the low alkalinities be the result of acid mine drainage or similar wastes, the non-carbonate hardness would have been much higher.

SUMMARY OF CONCLUSIONS

General

The use of the term "pollution" in describing the study which is outlined herein is, perhaps, a misnomer, since the word "pollution" in its common usage is associated with a low oxygen balance generally accompanied by nuisance conditions. At no point were there any such indications on any of the streams studied.

The general condition of the three streams studied, as indicated by the chemical analyses made, was considered to be satisfactory. The fact that no appreciable oxygen depletion was noted indicates clearly the absence of any gross pollution during the survey period. The normal alkalinity present at all times indicated that no appreciable quantities of acid wastes were reaching the streams.

The condition of the streams as indicated by bacteriological determinations appeared to be reasonably satisfactory except for the Big River below Flat River, and the lower reaches of the Big, Bourbeuse, and Meramec Rivers where the coliform content may be excessive in view of the trend of present standards of stream purity toward low coliform concentrations.

A Suggested Program for the Meramec Basin

If the Meramec Basin is to continue in use as a major recreational area, the following program should be undertaken in the interest of safeguarding the public health:

1. All municipalities using the Meramec River or any of its tributaries for the disposal of sewage wastes should provide complete treatment and effective chlorination for such wastes.

2. Detailed studies should be made of the sewage disposal facilities of all cabins, camps, and bathing beaches adjacent to the Meramec or any tributary, and the owners required to provide satisfactory treatment, including chlorination of all wastes reaching the stream.

3. Provision should be made for the frequent collection and analysis, both chemical and bacteriological, of samples from various points on the principal streams to provide a continuous check on their condition and suitability for recreational purposes.

Proposed Standards of Purity for the Meramec River

Many suggested classifications have been proposed for streams which are used for recreational purposes. In 1934, Streeter (10) suggested the classification of streams into three groups according to their use, with a fourth group for streams or stream zones used for bathing and sport fishing. A summary of other standards, some of which are in effect, is given in the Sewage Works Journal for September, 1942 (11). There seems to be considerable variation as to the maximum coliform content permissible, but in most cases the allowable average is 50 to 100 coliforms per 100 ml. with not more than 1000 per 100 ml. in any individual sample. In most cases no attempt is made to limit the total number of bacteria present.

The establishment of any standards of stream purity must be made with a reasonable understanding of local conditions. Further, careful consideration must necessarily be given to factors which cannot be controlled. The presence of large concentrations of population upon any watershed would naturally be expected to increase the average coliform concentrations. Further, if determinations on samples taken during periods of surface runoff are included, both geometric and arithmetic averages will be increased. It would seem, therefore, that any attempt to establish such standards for any given stream should involve the determination of the minimum concentrations of coliforms which might be expected, and should make provision for the exclusion in some manner of unusually high counts made during surface runoff.

With the above in mind, the following tentative standards are suggested for the Meramec Basin with the full expectation that some revision will be necessary if, and when, the previously mentioned program has been carried out and the results of these improvements are available:

1. The number of coliforms present as indicated by monthly records and determined as under (a) or (b) shall not exceed 500 per 100 ml.

(a) If all samples from a single sampling station during a given month are taken at times when the stream flow, temperature, and turbidity are such that the stream is suitable for recreational use, the geometrical average of all determinations shall be used.

(b) If any of the samples from a given station are taken at a time while the effects of surface runoff, as indicated by the turbidity and flow, are clearly evident, the median of all determinations for that month shall be used.

2. The dissolved oxygen and alkalinity of all streams, subject to normal variation, should be maintained as nearly as feasible at levels which existed during the survey period.

The use of medians instead of arithmetic or geometric averages when data are included which reflect the effect of surface wash should be given further consideration. It is hoped that future investigators will give such consideration to their use when conditions are present which warrant such a procedure.

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(2) Ibid., Page 15.

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(11) G. J. Schroepfer. An Analysis of Stream Pollution and Stream Standards. Sewage Works Journal, Volume XIV, No. 5, Page 1044, September 1942.

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