Wabash River

Pollution-Abatement Needs

Recommendations, analysis and data for water conservation by pollution control between Terre Haute, Ind., and Mt. Carmel, Ill.

OHIO RIVER VALLEY
WATER SANITATION COMMISSION

OHIO RIVER VALLEY WATER SANITATION COMMISSION

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HENRY WARD
CHAIRMAN

EDWARD J. CLEARY
EXECUTIVE DIRECTOR
AND CHIEF ENGINEER

August 15, 1950

To the Chairman and
Members of the Commission:

In accordance with your resolution of July 6, 1949, an investigation has been made to determine permissible pollution limits in a 130-mile section of the Wabash River between Terre Haute, Ind. and Mt. Carmel, Ill.

It will be recalled that the request for the Commission to undertake this investigation was initiated jointly by the States of Indiana and Illinois because the Wabash River in the section under consideration is an interstate stream. Furthermore, the Wabash is a principal tributary to the Ohio River, and the quality of its waters is of concern to the Commission.

Past-chairman Joseph L. Quinn, Jr., whose home is in Terre Haute where field operations were headquartered, was especially helpful in expediting this important phase of the work. His personal interest and efforts, along with those of Commissioner Poole of Indiana and Commissioner Klassen of Illinois, are hereby acknowledged with appreciation.

As detailed elsewhere in the report, this investigation was carried out as a joint enterprise in which the Commission enjoyed the active participation of federal, state and private organizations. One of the most important contributions was made by Prof. C.J. Velz of the University of Michigan, in his analysis of stream data. Special credit is due to Robert K. Horton, staff sanitary engineer, under whose direction the work was organized and coordinated.

Respectfully submitted,

Edward J. Cleary

EDWARD J. CLEARY
Executive Director
and Chief Engineer

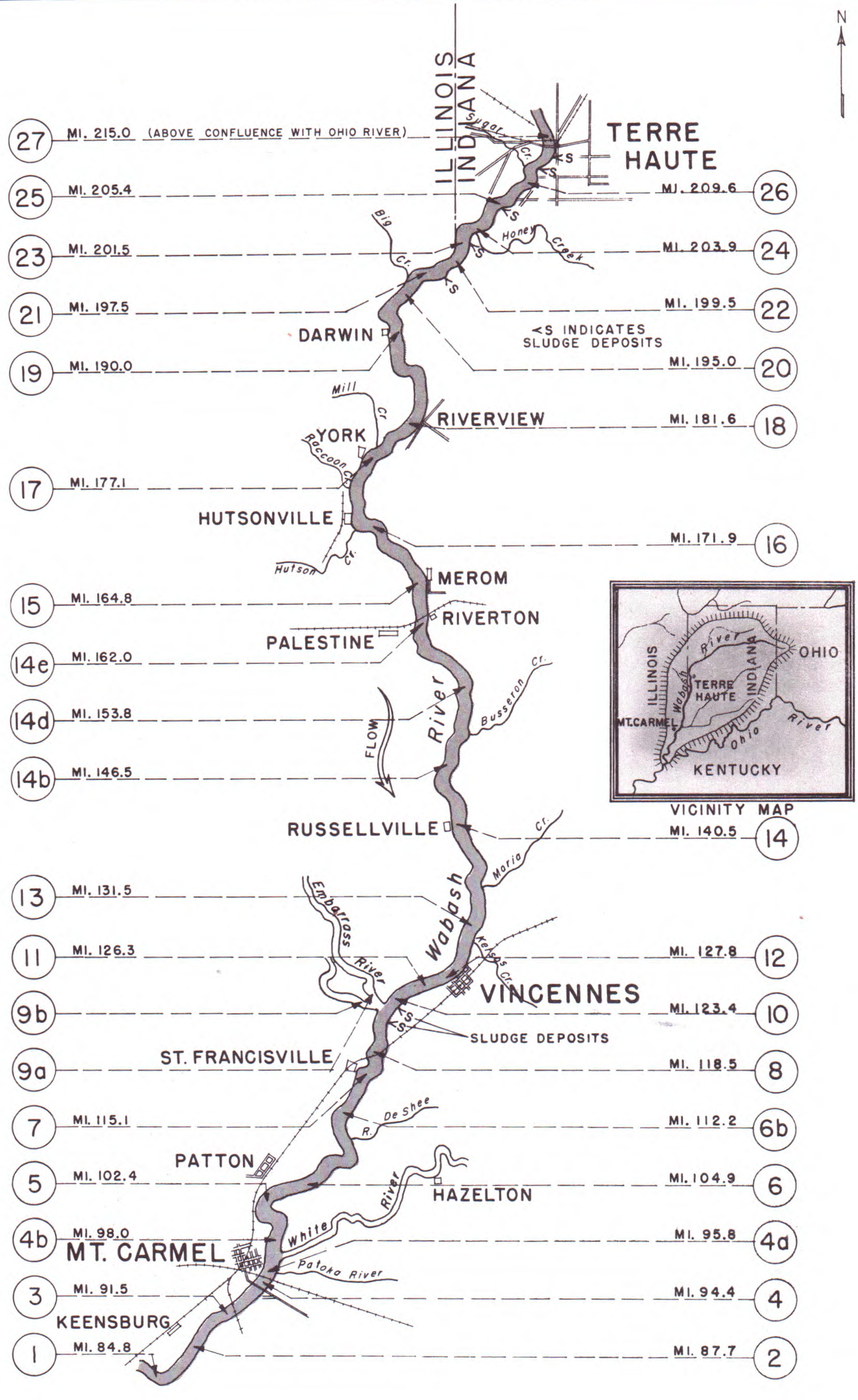

FIG. I - SAMPLING STATIONS FOR WABASH RIVER STUDY

OHIO RIVER VALLEY WATER SANITATION COMMISSION

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WABASH RIVER
POLLUTION ABATEMENT NEEDS

SYNOPSIS

The need for pollution-abatement in the Wabash River, particularly in that stretch below Terre Haute, Ind., has long been recognized. Precise information was lacking, however, with regard to natural-purification characteristics of the river under varying loads and runoff. This hindered establishment of an economical basis for present and future waste-treatment requirements.

To secure this information and thus expedite formulation of a sound program for conservation of water resources, study was authorized by the Ohio River Valley Water Sanitation Commission following a request from the States of Indiana and Illinois. These states are jointly concerned with the Wabash River, since it serves as the boundary between them. Under the direction of the Commission this study was made with the aid of seven participating agencies. Field operations began on July 18, 1949.

In effect, the investigation resolved itself into two phases: (1) collecting and analyzing hydrologic, waste-discharge and water-quality data; and (2) evaluating this information in terms of regulatory requirements.

COLLECTION OF DATA

Information secured during the survey included the following:

1. Measurement of volumes and characteristics of polluting wastes discharged at Terre Haute and Vincennes, the two major sources of pollution in the area investigated. At Terre Haute the combined municipal and industrial load was found to be 622,000 population equivalents; at Vincennes the combined load was 131,000 population equivalents.

2. Measurement of chemical and bacteriological conditions in the river resulting from existing pollution loads. In addition, supporting biological and physical data were secured.

3. River cross-sections. From these measurements it was possible

to calculate occupied-channel volume, velocity of flow, mean depth, and time-of-passage of pollution in all stretches of the river under varying conditions of runoff.

4. Runoff records. These supplied detailed information concerning river flows at the time of sampling, and in addition furnished the data required for a statistical analysis of drought probabilities.

5. River temperature data. From a quarter-century record it was possible to determine probable river temperatures during that season of the year when maintenance of desired quality objectives would be most difficult.

6. Population data. Census records for Terre Haute and Vincennes furnished information concerning growth trends at these places.

EVALUATION OF NATURAL PURIFICATION FACTORS

Basic to the establishment of treatment requirements is an analysis of the factors that influence natural-purification characteristics of the receiving body of water. Such an evaluation was made with the aid of observed data checked against calculated performance under varying conditions. In this way the capacity of the river to assimilate pollution was defined. Once this had been done, computations were made to determine the reduction in pollution loads required from waste-treatment processes in order to maintain desired quality objectives in the river.

QUALITY OBJECTIVES ESTABLISHED

The water-quality objective established with respect to dissolved-oxygen conditions in the river was:

> The average 24-hr. dissolved-oxygen content of the water shall not be less than 50 percent saturation more often than once in ten years. (during minimum week . see page 35.)

This objective meets regulations of the Indiana Stream Pollution Control Board (adopted November 8, 1945) which state: "Generally, the oxygen content of the receiving water, after being mixed with and affected by the waste, shall be no less than 50 percent saturation. A lower concentration will be tolerated temporarily only so long as it is not injurious to aquatic life, and in no case shall it fall below 25 percent saturation."

The established objective of 50 percent saturation also satisfies conditions sought by the Illinois authorities, namely assurance that fish life in the river would be protected.

In conjunction with the minimum dissolved-oxygen objective, other criteria on which treatment requirements were based included:

1. The drought flow (minimum weekly average) to be expected at Terre Haute once in ten years. This was determined to be 860 cfs.

2. The average temperature during the most critical month (August). This was determined as 26.3 deg. C.

CONCLUSIONS REGARDING TREATMENT NEEDS

On the basis of observed conditions coupled with stream analysis and in accordance with established quality objectives, the following conclusions are reached:

TERRE HAUTE

Oxygen Conditions —- Maintenance of desired dissolved-oxygen water-quality objectives requires treatment facilities for the Terre Haute pollution load capable of providing substantially complete removal of settleable solids and a total reduction of 52 percent in biochemical oxygen demand. Whenever stream flow and temperature conditions permit, an overall reduction in biochemical oxygen demand of less than 52 percent may be applied if, as a result, there is no impairment to the water-quality objective of 50 percent dissolved-oxygen saturation in the river below Terre Haute. However, under no conditions shall treatment be less than that which will provide for substantially complete removal of settleable solids and the removal of not less than forty-five percent of the total suspended solids, which is the minimum specified under the terms of the Ohio River Compact.

Bacteriological Conditions -- Chlorination of Terre Haute sewage is advisable because of the high concentration of coliform organisms discharged, the influence of which is felt as far downstream as Vincennes. Chlorination could be expected to improve the quality of water reaching the Vincennes intake, as well as enhance the recreational potentialities of the stream.

Allocation of Treatment --Allocation of treatment requirements among the various polluters at Terre Haute is a matter that commends itself for attention by the Indiana Stream Pollution Control Board. State, municipal and industrial relationships, as well as technical considerations, are involved in this decision. Among the factors to be weighed are the relative size of domestic and industrial pollution loads and the responsibility to be assigned for their reduction. The equities involved are a matter for decision by the state.

VINCENNES

At Vincennes treatment of all municipal and industrial wastes providing for substantially complete removal of settleable solids and the removal of not less than forty-five percent of the total suspended solids will be adequate to insure maintenance of desired dissolved-oxygen water-quality objectives in the Wabash River below this city.

BACKGROUND

Determination of the permissible pollution limits in a 130-mile stretch of the Wabash River between Terre Haute, Indiana, and Mt. Carmel, Illinois (see Fig. 1), was undertaken by the Ohio River Valley Water Sanitation Commission at the request of the States of Indiana and Illinois in July, 1949.

Previous surveys of the river had established the fact that it was polluted. But information was lacking to permit an analysis of the capacity of the river to assimilate pollution and still maintain water-quality objectives consistent with desired uses. It was this information that the authorities in Indiana and Illinois sought in order to promote the installation of remedial works that would most economically and most effectively meet present and anticipated needs.

The Commission was requested to undertake this investigation because the Wabash River in the stretch under consideration is interstate in character. Furthermore, the Wabash is a principal tributary to the Ohio River, and the condition of its waters as it enters the main stream is of concern to the Commission.

PURPOSE OF THE INVESTIGATION

The investigation was directed toward securing findings with regard to:

Origin, quantities and characteristics of pollutional wastes discharged into river.

Conditions in the river resulting from present pollution and a determination of the assimilative capacity of the river under varying conditions of stream flow and pollution load.

Waste-treatment measures required at Terre Haute and Vincennes in order to reach desired water-quality objectives in the river.

CONDITIONS TO BE MET

Broadly speaking, the investigation was concerned with two major objectives: (1) collecting and analyzing hydrologic, water-discharge and water-quality data; and (2) evaluating this information in terms of statutory requirements. With regard to the latter, a primary consideration was compliance with the interstate compact agreement, to which Indiana and Illinois are signatories.

The compact establishes the minimum amount of treatment for municipal sewage as that which will "provide for substantially complete removal of settleable solids, and the removal of not less than forty-five percent of the total suspended solids" (a normal accomplishment with primary treatment). However, the compact also provides that: "in specific instances such higher treatment shall be used as may be determined to be necessary by the Commission after investigation, due notice and hearing." With regard to industrial wastes the compact provides that they shall be modified or treated "to such degree as may be determined to be necessary by the Commission after investigation, due notice and hearing."

Under compact requirements, therefore, nothing less than primary treatment would be acceptable. The question then resolved itself into a determination of whether primary treatment alone would maintain the river in a condition suitable to serve intended uses.

These uses, in order of importance, are for water supply, maintenance of fish life as well as recreational values and the disposal of sewage and industrial waste.

In determining the amount of treatment that would be required it was also necessary to consider the regulations of the Indiana Stream Pollution Control Board. These regulations (see Appendix A) read in part as follows:

> "Generally, the oxygen content of the receiving water, after being mixed with and affected by waste, shall be no less than 50 percent saturation. A lower concentration will be tolerated temporarily only so long as it is not injurious to aquatic life, and in no case shall it fall below 25 percent saturation."

This regulation, therefore, fixed the allowable dissolved oxygen deficit that would be acceptable at any point in the Wabash. In so doing it also satisfied an objective sought by the Illinois authorities, namely, assurance that fish life in the stream would be protected. Depletion of fish in the river has long been a matter of complaint by both commercial and recreational fishing interests. It is claimed that species such as bass and trout have disappeared, and it is also alleged that fish taken from the river for a considerable distance below Terre Haute and in the vicinity of Vincennes are not palatable because of their poor flesh and flavor.

Another factor that had to be considered before treatment needs could be established was the minimum flow probabilities. This called for a statistical interpretation of drought data in the Wabash. From this information, it was concluded by the states of Indiana and Illinois that treatment measures be tailored to provide adequate purification at all times except during one week of lowest flow that might occur once during a period of ten years.

LOCALE AND SIDELIGHTS

The Wabash, with its tributaries, drains a basin 33,100 square miles in area. Originating in western Ohio near St. Mary's Lake it flows westerly and then southwesterly across the State of Indiana. From a point about twelve miles southwest of Terre Haute, Indiana, it forms the boundary between Indiana and Illinois. Terre Haute is 215 miles from the mouth of the Wabash, which empties into the Ohio near Mt. Vernon, Indiana. The river has a total length of 500 miles.

The section of the river with which this investigation was concerned is that extending from Terre Haute, Indiana to a point 10 miles below Mt. Carmel, Illinois, a water distance of 130 miles. With the exception of Terre Haute and Vincennes, some 85 river-miles apart, there are no major centers of population. Heavy loads of sewage and industrial wastes emanate from these centers. Agricultural pursuits characterize the principal activity in the remainder of the area.

Terre Haute draws its water supply from an intake in the river above the city sewer outlets, and the water is filtered and chlorinated prior to distribution. Vincennes likewise takes its water from the river and employs filtration and chlorination. It is reported from Vincennes that the water supply is affected by tastes and odors and these are attributed to the pollution originating in the Terre Haute area.

Because of industrial activities, pollution entering the Wabash at Terre Haute is far greater than might be anticipated from a city of this size. Population of the city is 64,000. The load from this population coupled with that from industries connected to the city sewer system produce a total municipal discharge of 210,000 population equivalents. But additional industries that discharge directly into the river contribute a further population equivalent of 412,000. Thus, the total waste discharge in the Terre Haute area has a population equivalent of 622,000.

These are the conditions and the facts that furnish the background for the Wabash River investigation. How the work was done, what the findings revealed and why certain conclusions were reached are detailed in the pages following.

HOW SURVEY WAS MADE

The Commission undertook direction of this investigation as a joint **enterprise.** Participants and the role they played in this cooperative venture were as follows:

PARTICIPATING AGENCIES

State of Indiana -- Participation of the State of Indiana was under the direction of B. A. Poole, technical secretary of the Indiana Stream Pollution Control Board. The state provided the part-time services of Ralph H. Holtje, chief, stream pollution section, who actively aided in planning field activities, the analysis of data and the preparation of this report. Indiana also furnished the services of L. A. Emelity, sanitary engineer, who was engaged as assistant project director during field investigations. Other personnel included Robert C. Rice and Roland S. Yunghans, who did the river cross-section work; H. E. Stout, who assisted in installing sewer weirs; and Stephen R. Kin, who aided in planning laboratory procedures. In addition to personnel, the state furnished sampling equipment, laboratory supplies, and an automobile.

State of Illinois -- Participation of the State of Illinois was under the direction of C. W. Klassen, chief sanitary engineer. The part-time services of William A. Hasfurther, sanitary engineer, were made available and he assisted in planning field activities as well as in the preparation of this report. Illinois also furnished the part-time services of R. M. Scott, bacteriologist, and the full-time services of Robert Schiffman, biologist. Supplies and materials provided by the state include laboratory and field equipment and an automobile.

National Council for Stream Improvement -- Through its technical director, Dr. Harry Gehm, the Council made available the consulting services of Prof. C. J. Velz of the University of Michigan and Prof. Don E. Bloodgood of Purdue University. An analysis of natural-purification capacities of the river and a statistical study of drought probabilities were made by Prof. Velz. The Council further provided the services of three laboratory technicians, and also made available the use of some precision laboratory equipment.

Terre Haute Paper Company -- With the cooperation of R. F. Burns, production manager, the company furnished laboratory space and facilities for analytical determinations and provided other assistance.

U. S. Geological Survey -- Stream-gaging information was furnished by the Survey. Personnel of this agency who participated were D. M. Corbett, district engineer, and L. W. Furness, hydrologist.

U. S. Corps of Engineers -- Detailed river maps and general background information were furnished. Corps personnel who aided in this included: Robert G. West, assistant division engineer, Ohio River Division; John W. Wiseman, sanitary engineer, Ohio River Division; Col. J. L. Persons, district engineer and Sam M. Baily, Chief of engineering division, Louisville District.

U. S. Public Health Service -- Maurice LeBosquet, sanitary engineer director, served as a consultant in the analysis and interpretation of data. J. N. Wilson, aquatic biologist, aided in planning biological sampling procedures. The Cincinnati Environmental Health Center furnished some laboratory equipment.

Ohio River Valley Water Sanitation Commission -- Robert K. Horton, staff sanitary engineer served as project director and was immediately responsible for directing and coordinating all activities and preparation of this report. The Commission paid the salaries of river samplers, laboratory helpers and a bacteriologist, and assumed other miscellaneous expenses.

Field and Laboratory Personnel

Following is a list of field and laboratory personnel, in addition to persons previously named, who were engaged on the survey. Several of those listed were employed for only a part of the time during which field operations were conducted. Personnel were: chemists - J. F. Kinnaman, N. J. Lardieri, P. W. Lin; bacteriologist - R. G. Songer; laboratory helpers - J. H. Adamson, H. R. Dierdorf, W. R. Lockhart; samplers - J. V. Green, E. W. Henderson, J. A. Klassen, K. E. Lacy, R. R. Miller, R. G. Ordeman, V. L. Sellers, J. R. Towers, D. L. Wilhelm.

COLLECTION OF DATA

All field data were collected during the period July 18 to September 30, 1949. Headquarters were maintained at Terre Haute, where laboratory facilities were established at the Terre Haute Paper Co. During the period of the maximum operation 18 persons were engaged on the field work. These included the project director, assistant project director, three chemists, a bacteriologist, a biologist, two laboratory assistants, seven samplers and two men for making river cross-sections.

SEWER LOADS

Pollution loads were measured by installing weirs in each of the outfall sewers at Terre Haute and Vincennes. Flows were measured for period varying from 48 to 96 hours. Gage readings at each weir were made at intervals of one hour. Samples were also taken hourly. Analyses were made on 24-hr. composites.

RIVER SAMPLING

Collection and analysis of river samples constituted the second portion of the field operations. A section of river, approximately 33 miles in length, was sampled intensively for four days. Three traverses were made each day, so that each station was sampled at approximately 8-hr. intervals. Traverses were staggered by two hours from day to day; this means that on any day the samples at any station were taken two hours later than they had been taken the day before. This was done so that sampling times at each station would be spaced throughout a 24-hr. period. Each successive section of the river was sampled in the same manner.

Important additional field operations were related to the location of all sludge deposits. Efforts were made to determine the size and depth of deposits.

Finally, river sampling also included plankton studies and other biological investigations which were helpful in interpreting chemical and bacteriological data.

For the most part, river samples were taken from boats; wherever available, bridges and ferries were used. Where necessary, boats were anchored at each of the river stations, and sampling crews traveled from station to station by car. To give an idea of the amount of transportation involved, it may be pointed out that when sampling in the section furthest from Terre Haute, more than 500 miles of travel a day were required. As a further indication of the size of the project it might also be pointed out that during the course of the survey more than 1,000 river samples were collected and analyzed.

ANALYSES

Analyses made on river samples are listed below. Temperatures of river water were taken at the time of sampling. Dissolved oxygen determinations were started immediately after samples had been taken and completed in the field except for final titration. All other analyses were made in the laboratory. Samples were kept on ice from time of collection until delivered to the laboratory. The following analyses were made:

Temperature	Dissolved oxygen
Hydrogen-ion concentration	MPN of coliform organisms
Biochemical oxygen demand	MPN of enterococci organisms

Chemical analyses were made in accordance with 'Standard Methods for the Examination of Water and Sewage" (ninth edition), published by the American Public Health Association.

Bacteriological analyses were made in accordance with procedure developed by the Illinois State Sanitary Water Board. These procedures are outlined as follows: (for more complete details on procedures and preparation of media see appendix B).

Coliform tests - - For the presumptive test inoculations were made into lauryl sulfate tryptose lactose broth. Double-strength lactose-broth tubes were used for 10-ml. portions of sample and single-strength tubes for portions of one ml. or less. Inoculated tubes were incubated for forty-eight hours at 37 deg. C. Tubes were read at the end of twenty-four hours and recorded as positive if any gas was contained in the round end of the fermentation tube. All tubes containing gas were submitted to the confirmed test. Tubes were read again at the end of forty-eight hours, and any remaining tubes with gas in any quantity at the end of this period were also confirmed. If no gas was formed in forty-eight hours, the test was recorded as negative.

Presumptive tubes showing gas in twenty-four or forty-eight hours were confirmed in brilliant green bile broth. Confirmation tubes were incubated at 37 deg. C. for forty-eight hours. The presence of gas at the end of incubation indicated a positive confirmed test.

Enterococci tests - - For the presumptive test the media used was Winters and Sandholzer presumptive enrichment broth''. Serial dilutions of the sample were prepared and inoculated into either single-strength or double-strength broth tubes (strength of broth was governed by amount of sample used.) Inoculated tubes were incubated in a water-bath or dry-heat incubator at 45.5 deg. C. for eighteen to twenty-four hours. The presumptive test was made by observing for the presence of Turbidity and acid after incubation.

The confirmed test was applied to all presumptive tubes that were either positive or doubtful. The confirmatory media consisted of a broth portion and a solid portion in the same tube. Presumptive tubes were shaken gently and a standard loop-full of the material was inoculated into the broth and streaked across the exposed slant in the confirmatory tube. The slant-broth confirmatory tubes were incubated at 37 deg. C. for eighteen to twenty-four hours. After incubation a positive confirmed test was indicated by the following: a fine, granular turbidity in the broth, small pin-point colonies on the slant and the presence of large, ovoid gram positive cocci appearing in singles, pairs or short chains. The confirmation test was considered negative unless it met all these specifications.

F I N D I N G S

Data collected for this study were classified into six categories:

1. Measurement of pollution loads
2. River Sampling
3. River cross-sections
4. Runoff record
5. Water-temperature
6. Population data

Field investigations were required to provide information for the first three groups of data. The remaining information was compiled and tabulated from existing records. The data are presented in tabular and graphic form in a separate section of this report. Significant findings are summarized as follows:

MEASUREMENT OF POLLUTION LOADS

TERRE HAUTE

At Terre Haute there are a total of 20 sewers discharging raw wastes into the river. Ten of these sewers are privately owned and are used exclusively for the discharge of wastes from industrial plants. The remaining ten are municipal sewers, which discharge not only domestic wastes from the city but industrial wastes as well. Sewer locations are shown in Fig. 2. Results of flow measurements and B.O.D. analyses made on each sewer are given in Table I.

The load from all sewers at Terre Haute, as shown in Table I, is 622,120 population equivalents (population equivalents calculated on the basis of 0.167 lb. of 5 day B.O.D. per capita). Of this total, 210,200 population equivalents are discharged through municipal sewers, and the remaining 411,920 population equivalents through privately-owned industrial sewers.

In terms of oxygen requirements placed upon the river, the ultimate oxygen demand of wastes from municipal sewers is 51,500 lb. per day (based on total first stage oxygen demand equal to 0.245 lb. per capita), and that from industrial sewers is 101,000 lb. per day. The total ultimate demand from all wastes, therefore, is 152,500 lb. of oxygen per day.

No separate measurements were made of the volumes and B.O.D. of industrial wastes discharging into the municipal sewer system. Consequently, an exact division of the sewage and industrial wastes carried in the municipal sewers is not provided. However, an estimate of the sewered population made by Metcalf and Eddy in 1946 (1) indicates that the domestic-sewage load is in the neighborhood of 50,000 population equivalents; consequently, the industrial-wastes load is about 572,000 population equivalents.

Tests were made on the discharges from a limited number of sewer outfalls in order to obtain information concerning the suspended-solids fraction of the total B.O.D. load. These were made as follows: B.O.D. determinations were made on samples from selected sewers in the normal way; samples were then filtered through Whatman No. 4 filter paper and B.O.D. determinations made on filtrates. Differences between B.O.D. values of raw and filtered samples represented the suspended-solids fraction of the load.

Results of these tests are shown in Table II. It will be noted that for the sewer loads tested (about two-thirds of the total Terre Haute load), the population equivalent of the suspended-solids portion was 115,000 or about 30 percent ($115,000 \div 401,490 \doteq 28.6\%$) of the total B.O.D. load.

VINCENNES

At Vincennes there are four sewers discharging wastes into the river. Two of these are municipal sewers carrying combined domestic and industrial wastes, and the other two are privately-owned industrial sewers. The outfall of one of the municipal sewers, which is on the discharge side of a pumping station, is submerged; therefore, in order to determine the load from this outfall it was necessary to take measurements at two manholes upstream from the pumping station.

Location of sewers at Vincennes is shown in Fig. 3. As indicated on the map, the two sewers discharging to the pumping station have been designated V-2 and V-3. Results of flow measurements and B.O.D. analyses made on each sewer are given in Table III.

As shown in Table III, the population equivalent of all wastes at Vincennes is 131,000. Combined domestic and industrial wastes discharged through municipal sewers have a population equivalent of 32,600. The population equivalent of industrial wastes separately discharged through private sewers is 99,000. These results show that the total ultimate oxygen demand of all wastes at Vincennes is 32,300 lb. per day; the load from municipal sewers equals 8,000 lb. and that from private industrial sewers is 24,300 lb. per day.

RIVER SAMPLING

LOCATION OF SAMPLING STATIONS

On Fig. 1, which is a map of that stretch of the Wabash River under investigation, is shown the location of main-stem stations and tributaries sampled during the survey. A list of all sampling stations, including location and description, has also been prepared and is presented as Table IV.

In general, stations were located at the same sampling points used by the Indiana State Board of Health during its survey of the Wabash River in 1940. However, the stations sampled during the present survey included 17 additional stations not used in 1940. Of the total of 44 stations, 32 were located in the main stem of the Wabash and 12 were located in tributaries.

D. O. AND B.O.D. FINDINGS

River-sampling operations were begun August 22 by sampling that stretch of the river extending from Sta. 27 (Mi. 215.0) to Sta. 18 (Mi. 181.6). This stretch was sampled intensively for four consecutive days (as previously described). When this had been finished, succeeding stretches were sampled in accordance with the following schedule:

Aug. 22 - Aug. 26:	Sta. 27 to Sta. 18
Aug. 26 - Aug. 30:	Sta. 18 to Sta. 14
Aug. 31 - Sept. 3:	Sta. 14 to Sta. 6
Sept. 4 - Sept. 8:	Sta. 6 to Sta. 1

Upon completion of this phase of the program, additional sampling was done in those two stretches of the river immediately below Terre Haute and Vincennes. Since the procedure for additional sampling in the Vincennes area was exactly the same as that during the initial 4-day period, the two groups of data have been tabulated together. However, a different procedure was followed during the second period of sampling in the Terre Haute area and these findings are separately presented in Table VII.

The results of D.O. and B.O.D. analyses made on river samples, with the exception of those taken during the second sampling period in the Terre Haute area, are shown in Table V and Table VI. In Table V is shown the average D.O., B.O.D., temperature and pH during each day of sampling. Table VI shows average results of all samples taken.

The data presented in Table V have been plotted in Fig. 4 to show the general D.O. and B.O.D. characteristics of the entire river stretch during the time of sampling. As a result of the pollution load discharged at Terre Haute there is a sharp increase in B.O.D. and a drop in D.O. High runoff at the time of sampling (1,910 cfs. to 4,020 cfs., with an average of 2,420 cfs. at the Terre Haute gage) prevented any serious depletion of oxygen in the river. The lowest average D.O. observed was 70 percent saturation (5.83 ppm.); this occurred at Sta. 22. Below Sta. 22 there was a gradual improvement in D.O. content until supersaturated conditions were encountered at Sta. 14, about 13 miles above Vincennes. Below this point supersaturated conditions continued to exist at the remaining stations sampled during the survey. The data show that discharges from Vincennes and the Embarrass River had very little, if any, effect on oxygen conditions in the river.

Supersaturated oxygen values, found consistently above Terre Haute and below Sta. 14 and occasionally at other stations, indicated the influence of algae on the D.O. picture. Further evidence of large concentrations of algae were obtained during subsequent biological investigations.

As Shown in Tables V and VI, pH values throughout the river were reasonably constant. The lowest pH value observed was 7.0 and the highest 8.7.

TWO HOUR SAMPLING IN TERRE HAUTE AREA

The profound effect of algae on D.O. content of the river, as shown by the initial sampling work, indicated the need for additional sampling in the Terre Haute area on a modified schedule. To obtain a clearer picture of D.O. conditions, key stations were sampled at two-hour intervals during the period Sept. 13 to 17. The results of this sampling are presented in Table VII.

From this data curves were plotted showing the D.O. cycle throughout a 24-Hr. period. Typical curves are shown in Fig. 5. The influence of algae upon D.O. content of the water is readily apparent from these curves. Results showed that the low point in the D.O. cycle occurred in nearly every case between 4:00 A.M. and 6:00 A.M., and the high point between 4:00 P.M. and 6:00 P.M. The maximum daily variation in D.O. between low and high points was 38 percent saturation (3.6 ppm.); this occurred at Sta. 22 on Sept. 14 - 15.

Data collected during this 5-day period of two-hour sampling formed the basis for an evaluation of natural-purification characteristics (made by C. J. Velz (2)), and for determination of treatment requirements which are presented in a subsequent section of this report. By defining the influence of algae on D.O. content, these data permit more accurate determination of the effect of organic pollution on the river. In addition, river runoff during this second sampling period was less than it had been previously (average flow of 1,930 cfs. during Sept. 13 - 17 compared with 2,530 cfs. during Aug. 22 - 26). As a result the oxygen deficits were larger, and thus could be used more reliably for purposes of stream analysis.

Additional data obtained during this phase of the sampling program included 20-day B.O.D. determinations on several samples of river water. Samples for these tests were taken below Terre Haute far enough downstream to make certain that thorough mixing of river water and all waste discharges had occurred. From these tests B.O.D. rate curves, which were needed in analyzing natural-purification characteristics were established. These curves showed that deoxygenation occurred at the logarithmic rate of 0.10 at 20 deg. C. A typical curve is shown in Fig. 6.

BIOLOGICAL FINDINGS

Plankton studies showed conclusively that the Wabash River, in the stretch surveyed, contained large numbers of chlorophyllaceous algae. No plankton counts by direct methods were made because of the large amount of silt in the river. However, measurements were made of algae activity by means of chemical tests.

Briefly, these tests were made by measuring changes in D.O. in samples of river water after standing exposed to light for a period of several hours, and in samples kept in darkness for a similar period of time. The procedure was as follows: dissolved oxygen of river water was determined at the time samples were taken; half of the bottles collected were placed in an incubator where they were exposed to artificial light; the remaining bottles were wrapped in light-proof paper and placed in the same incubator; bottles were kept in the incubator for a period of either six or twelve hours, at the end of which time dissolved-oxygen determinations were made. Tests were made on samples taken at seven river stations in the Terre Haute area in the stretch between Sta. 27 and 18, and on samples taken at six river stations in the Vincennes area between Sta. 13 and 7.

From these tests the following was observed: All samples allowed to stand in light showed an increase in D.O. concentration. The amount of increase varied from 1.2 ppm. to 3.5 ppm. in six hours, and from 2.0 ppm. to 6.5 ppm. in twelve hours. These results, which give an indication of the magnitude of algae activity in the river, show that algae undoubtedly accounted for supersaturated oxygen conditions found so often throughout the sampling period.

Those samples which were kept in darkness showed, on every occasion, a decrease in D.O. concentration. The variation in the amount of decrease was from 0.3 ppm. to 1.0 ppm. in six hours, and from 0.6 ppm. to 3.5 ppm. in twelve hours.

In the study made by Velz on natural-purification characteristics it was found that the loss in D.O. of these samples far exceeded the loss that could be attributed to the normal biochemical oxidation of organic matter in a period of six to twelve hours. This loss in D.O., therefore, is attributable at least in part to the respiration of algae. The results of these tests serve to support the data collected during the two-hour sampling program on D.O. variations in the river within a 24-hr. period.

BACTERIOLOGICAL FINDINGS

Bacteriological findings are presented in Table VIII and Fig. 7. The table shows the maximum, minimum, and median values of M.P.N. of coliform organisms per 100 ml. at each station. The number of bacteriological samples taken at each station are also shown in this table. Median M.P.N. values are shown graphically in Fig. 7.

From the curve in Fig. 7 it can be seen that the concentration of coliforms just above Terre Haute (Sta. 27) was in the neighborhood of 62,000. Wastes discharging into the river at Terre Haute caused an increase in bacteriological load. This load reached a maximum between sta. 25 and 20, in which stretch the median M.P.N. value was 2,400,000. Below Sta. 20 there was a continuing decline in the number of coliforms until Vincennes was reached. At Sta. 13, which is about two miles above the Vincennes water supply intake, the median bacterial count was 6,000 coliforms per 100 ml.

Wastes from Vincennes caused a rise in the curve followed by a rather sudden drop at Sta. 10. The increase in coliforms at Sta. 8 and 7 apparently was due to the large sludge deposit completely across the Wabash River below the point of entrance of the Embarrass River. Results showed higher bacterial counts at Sta. 8 than were found either in the Embarrass or Wabash River upstream. It is also recognized that a small part of the increase was due to discharge from the Embarrass since 50 percent of the samples showed a greater bacterial M.P.N. value there than at Sta. 10.

Wastes from Mt. Carmel, which reach the river just below Sta. 4, apparently had little effect on coliform counts since the downward trend was still evident at Sta. 3 and 2 (three miles and seven miles, respectively, below Mt. Carmel). The increase in the number of coliforms shown at Sta. 1 indicated a small amount of new pollution in the area between Sta. 2 and 1 (the source of this pollution was not investigated.)

Bacteriological work done during the survey also included determinations of the number of enterococci organisms at each of the river stations. The State of Illinois, in particular, was interested in studying the correlation between enterococci and coliform counts, since some work in this direction had been done on previous pollution surveys in Illinois. Results of these enterococci investigations are also shown in Table VIII and Fig. 7.

It will be noted in Fig. 7 that the enterococci curve follows rather closely the trend of the coliform curve. Further, the ratio of M.P.N. of coliforms to M.P.N. of enterococci at most stations is in the neighborhood of 100 to 1; this ratio is in agreement with previous findings of the Illinois bacteriologists.

PHYSICAL OBSERVATIONS

Floating Material -- The outstanding physical characteristic evidencing pollution in the Wabash during the survey period was the presence of large quantities of floating tomatoes. The area most severely affected was that stretch from immediately below Terre Haute to Sta. 20. The area in the vicinity of Sta. 25 was particularly obnoxious. Here both banks of the river were lined for a distance of half a mile or more with masses of decaying tomatoes that had been washed ashore.

These tomatoes were the waste discharges from canneries at Terre Haute, which reach the river through the municipal sewer system. The canning season in Terre Haute starts each year about August 1 and lasts from six to eight weeks. Conditions similar to those observed during the 1949 survey have been observed during this same period of time in previous years by personnel of the Indiana State Board of Health.

As these waste tomatoes and tomato chunks are carried down river they disintegrate. A few miles below Terre Haute the river was literally covered with shreds of this decaying organic matter. Although few whole tomatoes were seen below Sta. 20, masses of these shreds remained in suspension much longer and, in fact, were observed as far downstream as Sta. 18, a distance of some 30 miles below Terre Haute. In those areas where tomato masses were heavily concentrated, particularly in the vicinity of Sta. 25, the sewage fungus Spaerotilus natans was also present in abundant numbers.

Canning is also done at Vincennes. As a result floating tomatoes and shredded masses of tomatoes were also found below this city for a distance of several miles. However, the river in this area was not nearly as unsightly as in the Terre Haute area.

Other physical evidence of pollution noted was the occurence of oil slicks. Specific places where slicks were observed and dates were as follows: Sta. 25 on July 29, Sta. 16 on August 3, Sta. 12 on September 28, and Sta. 9a (Embarrass River) on September 1, 2, and 3. Information from the Sanitary Water Board of Illinois indicates that perhaps the most important sources of oil pollution that might reach the Wabash are the oil fields of southern Illinois.

A final observation is that during almost the entire survey the Wabash was highly turbid, or muddy, in appearance. This means that large quantities of silt and soil are being washed into the river from the watershed. Although soil-erosion problems are outside the scope of this report it is to be noted that soil conservation measures should be promoted in order to minimize natural pollution in the Wabash.

Sludge Deposits -- Investigations were made in connection with the biological studies during August and September in order to locate sludge deposits. In the Terre Haute area deposits were found at the following places:

Immediately below sewer outfalls at Terre Haute.

About 2 miles north of Sta. 26.

At Sta. 25 and the area immediately south.

South of Sta. 23.

One mile south of Sta. 22.

Places where deposits were found are indicated on the map in Fig. 1. All these deposits were small in size, and consisted of a thin layer laid down along one side of the river. In length they varied from 1/5 to 1-1/2 miles.

In the Vincennes area sludge deposits were found at Sta. 10 and immediately south of the mouth of the Embarrass River. These deposits are also indicated on the map in Fig. 1. The deposit at Sta. 10 was located in the center of the river behind a sand bar, and covered an area of 2,000 to 3,000 sq. ft. The deposit below the mouth of the Embarrass was very much larger; it was approximately one mile in length and for most of the distance covered the entire width of the river. This deposit was particularly objectionable; there was a bad odor in the area, and bubbling in the river gave evidence of gas formation.

Studies by Velz on characteristics of natural purification in the Terre Haute area, showed that sludge deposits are a principal cause of oxygen depletion in the river. Velz determined, therefore, on the basis of hydraulic features of the river and other considerations, those areas that would be subject to sludge deposition under various runoff conditions. Field observations of sludge deposits occuring under conditions prevailing at the time of the survey confirmed Velz' findings.

RIVER CROSS-SECTIONS

An essential part of the field work undertaken during this survey included the taking of river cross-sections. The purpose of this was to permit calculation of occupied-channel volume, velocity of flow, mean depth, and time of passage of pollution in any stretch of the river, and to define other physical features. Knowledge of mean depth and time of passage, particularly, was required in order that studies on natural-purification characteristics might be made.

Cross-sections were taken in the following manner. River widths were scaled from maps supplied by the U. S. Corps of Engineers. At each section soundings were made at approximately evenly-spaced intervals across river; a total of nine to eleven soundings were taken at most sections. Soundings were referred to river stage prevailing at the time. In the Terre Haute area cross-sections were taken at 1/4 mile intervals from mile-point 215 to mile-point 180. In the Vincennes area sections were taken each 1/4 mile from mile-point 129 to mile-point 115. Elsewhere the distance between sections was approximately one mile. Additional sections were taken wherever sudden changes in width or depth occurred. The total number of sections taken in the 130 miles of river covered by the survey was 274.

Cross-sectioning started at Sta. 27 (mile-point 215) and proceeded downstream. The work began August 18 and was finished on September 7. At the time each section was taken, the type of bottom material encountered was observed in order to gain further information on the location of sludge deposits. In the Terre Haute area, although there were a few very small deposits in eddy areas, no deposits of significant size were observed inasmuch as scouring velocities existed during this period. In the Vincennes area the only deposit noted was that immediately below the mouth of the Embarrass River.

RUNOFF DATA

Hydrographs showing daily runoff during the months of August and September, 1949 are presented in Fig. 8. Two hydrographs are given to show runoff at gaging stations located at Terre Haute and Vincennes. These gaging stations are operated by the U. S. Geological Survey and the data from which the hydrographs were plotted have been supplied by that agency.

There were two periods of river sampling in the Terre Haute area; -- Aug. 22 to 26 and Sept. 13 to 17. As shown in Fig. 8 (Terre Haute curve), runoff during the first period varied from 2,690 cfs. to 2,320 cfs., with an average of 2,520 cfs. For the period Sept. 13 to 17 the average runoff was 1,980 cfs.; the range at this time was from 2,290 cfs. to 1,790 cfs.

Runoff in the Vincennes area at the time of sampling, Aug. 31 to Sept. 12, varied from a high of 4,230 cfs. to a low of 2,580 cfs.; average runoff for the entire period was 3,050 cfs.

DROUGHT PROBABILITIES

One of the factors governing treatment requirements is the minimum drought flow for which selected quality objectives will be maintained. For example, treatment requirements to maintain selected objectives for a drought flow occurring once in 20 years would be greater than those to maintain the same objectives for a flow occurring once in 10 years.

Drought flows may be considered as the minimum average flow occurring during a period of a day, a week, a month, or some other time interval, Drought severity becomes greater as the time interval over which runoff is averaged is shortened. To illustrate this, the following figures from the report by Velz are given: In a 10-year period at Terre Haute average flow during the minimum month would be 1,050 cfs.; during the minimum week average flow would be 860cfs.; and during the minimum day average flow would be 820 cfs.

In these studies drought expectancies based on minimum weekly average flows have been used in determining treatment requirements. A weekly period is considered the most reasonable time interval to be used, since at low flow a week approximates the time of passage of pollution through the critical reaches of the river.

Employing the statistical theory of extreme values, Velz investigated drought expectancies at Terre Haute. These investigations are based on the continuous runoff record at the Terre Haute gage for the period 1928-1948. From these findings a curve of drought frequencies, shown in Fig. 9, has been prepared. The severity of a drought, in terms of minimum weekly average flow, that will occur at any frequency can be determined readily from this curve. For example, the curve shows that the drought flow occurring in 90 percent of the years will be equal to or greater than 860 cfs.; or stated in other terms, this means that once every ten years the drought flow will be equal to or less than 860 cfs.

WATER TEMPERATURE DATA

From the Public Service Company of Indiana a record of river water temperature from 1924 to 1949 was obtained. This record, showing daily temperatures throughout the 26-yr. period, was compiled at the Dresser Power Plant, located five miles downstream from Terre Haute. From this record a summary tabulation has been prepared (See Table IX) showing for each year of record, the minimum daily temperature, maximum daily temperature, and monthly average temperature recorded during each of the three most critical months, July, August, and September.

As shown in Table IX, the hottest month of record was July, 1934; the average temperature during this month was 29.0 deg. C. The maximum daily temperature recorded, occurring in August, 1947, was 32.8 deg. C.

Averages of the monthly average temperatures are shown in Table IX, The average July temperature for the years of record is 26.8 deg. C; the average for August is 26.3 deg. C; and for September, 22.9 deg. C.

In his statistical analysis of drought expectancies, Velz investigated the probability of droughts occurring in specific months. He found that severe drought conditions would occur most frequently in August and September. Because of the combination of low flows and high temperatures occurring in

August (average temperature in August is only 0.5 deg. C. less than average in July, the hottest month), August is the most critical month from the standpoint of maintaining suitable stream quality. Therefore, in determining treatment requirements it would appear proper to use the average water temperature prevailing during August, 26.3 deg. C.

POPULATION DATA

Population data for Terre Haute and Vincennes, obtained from the Census Bureau, are given in Table X and also in Figures 10 and 11.

From Table X and Fig. 10 it can be seen that for the period 1920 to 1940 there was a decline in population at Terre Haute from 66,083 to 62,693, or a decrease of 5.1 percent. However, since 1940 the trend has been upward; the 1950 census shows an increase of 2.2 percent over that in 1940.

Since the trend is not defined any prediction concerning population at future dates calls for great caution. In view of this, treatment needs for municipal wastes at Terre Haute were confined in these studies on the basis of population at the present time.

Data in Table X and Fig. 11 indicate that there has been a levelling-off in population at Vincennes. Here the increase in population during the past 30 years has amounted to only 9.5 percent. It would appear then that during the next two decades the Vincennes population will show only a moderate amount of change from the present figure (18,798).

COMPUTATIONS

Evaluation of the natural-purification characteristics of the stream is basic to the establishment of treatment requirements. With the field and laboratory data secured by the Commission, coupled with information from previous studies, an analysis was made by Professor Velz. From this analysis a series of curves was prepared showing oxygen conditions in the river below Terre Haute under varying pollution loads and at varying runoff levels. Three of these curves are reproduced in this report (see Figs. 12, 13, and 14).

The first of these (Fig. 12) shows the relationship at a constant pollution load between runoff and dissolved oxygen at the critical or lowest point in the oxygen sag. The second curve (Fig. 13) shows the relation at constant runoff between pollution load and dissolved oxygen at the critical point. The third curve (Fig. 14) shows the relation at constant load and constant runoff between critical dissolved oxygen and temperature.

Each of these curves was calculated with the effect of sludge deposits eliminated. It should be observed, however, that Velz found that "the primary cause of critical oxygen conditions in the Wabash River is sludge deposits." In his study, therefore, detailed consideration was given to the formation of sludge deposits and their effect on oxygen balance in the river.

With the aid of these curves, which define the capacity of the river to assimilate pollution by natural-purification processes, computations were made to determine the reduction in pollution loads that would maintain desired quality-objectives in the river. These computations have been limited to that stretch of the river immediately below Terre Haute. Furthermore, they are based on the condition that deposition of sludge in the river will not occur. Since the minimum requirement of the Ohio River Compact is that all wastes shall be so treated as to provide for substantially complete removal of settleable solids, virtual freedom from sludge-deposit formation should be achieved by installation of treatment facilities for all wastes at Terre Haute.

In determining treatment requirements, principal interest is in the low point on the oxygen sag--curve, namely, the worst oxygen conditions that might prevail at any time. The low point on the sag does not always occur at the same geographic position in the stream, but will move up or downstream as temperature, runoff, and other factors vary. However, it is the magnitude of this critical oxygen condition rather than its position that is of major concern.

Studies made by Maurice LeBosquet, sanitary-engineer director of the U. S. Public Health Service and a member of the Commission's Engineering Committee, have established a relationship that can be usefully employed at this point. Lebosquet has shown (3) that with constant load (and under certain other conditions) the relation between oxygen deficit at the critical or low point and runoff is hyperbolic.

Expressed mathematically, this may be stated as follows:

$$D \times Q = K \qquad \text{(a)}$$

D = critical oxygen deficit in ppm.

Q = runoff in cfs.

K = a constant

Although, this relation is mathematically exact only when the initial oxygen deficit is zero, it is sufficiently accurate for practical design purposes. Results obtained by using the formula certainly fall within the range of accuracy of sampling data.

Furthermore, the accuracy of the method is corroborated in the Velz analysis. It should be noted that the curve in Figure 12 demonstrates the hyperbolic relationship between critmcal dissolved oxygen and runoff.

The oxygen deficit in pounds per day at the critical point may be calculated by the following formula:

$$\text{Deficit in lb. per day} = D \times Q \times 5.4 \qquad \text{(b)}$$

Where 5.4 is the factor converting ppm x cfs. to lb. per day of oxygen; thus

$$\text{Deficit} = D \text{ in } \frac{\text{parts}}{1{,}000{,}000 \text{ parts}} \times Q \text{ in } \frac{\text{cu.-ft.}}{\text{secs.}} \times \frac{62.4 \text{ lb.}}{\text{cu.-ft.}} \times \frac{86{,}400 \text{ sec.}}{\text{day}}$$

$$= D \times Q \times \frac{62.4 \times 86{,}400}{1{,}000{,}000} \text{ lb. per day}$$

It is evident, then, from Equations (a) and (b) that with the same pollution load the critical dissolved-oxygen deficit in pounds per day is constant.

Since it is necessary to calculate treatment requirements at temperature different from the average temperature occuring at the time of sampling, consideration must be given to the effect of temperature on critcal oxygen deficit. As shown by LeBosquet (3), the critical oxygen deficit in ppm. is practically constant despite variations in temperature. This conclusion is substantially supported by the findings of Velz (calculations made on the basis of the curve shown in Fig. 14, show that there is a variation of only 0.10 to 0.17 ppm. in critical deficit in the temperature range with which these studies are concerned). For all practical purposes, therefore the critical deficit that would occur at the design temperature of 26.3 deg. C (see page 28)) has been taken as the same as that occurring at 23 deg. C, the temperature used by Velz in his studies on natural-purification characteristics.

Before proceeding with calculations of treatment requirements it was necessary to determine the value of the critical oxygen-deficit in pounds per day produced in the river by the present pollution load, but with the effect of sludge deposits eliminated. In the analysis made by Velz, the value of this deficit was found to be nearly 40,000 lbs. per day.

A typical calculation showing how this value was obtained follows: From Fig. 12 it can be determined that the critical oxygen deficit is 40 percent saturation at a runoff of 1,000 cfs. and with a pollution load equal to 70 percent of the 1949 load. The deficit in pounds with the full 1949 load is:

$$60\% \times 8.68 \times 1{,}000 \times \frac{1}{70\%} \times 5.4 = 40{,}000 \text{ lbs. per day}$$

where 60% = deficit in percent saturation (100% - 40%)

8.68 = dissolved oxygen saturation in ppm. at 23 deg. C

1,000 = runoff in cfs.

$\frac{1}{70\%}$ = to convert to full 1949 load

5.4 = conversion factor

Similar calculations made on the basis of other curves prepared by Velz give essentially the same figure.

Reasoning, then, that a reduction or increase in the 1949 pollution load will produce a proportional change in the critical dissolved-oxygen deficit in pounds (4), Equation (b) above may be used for calculating the amount of treatment needed to maintain a selected dissolved-oxygen level at the critical point under varying conditions of drought flow. The method of making these calculations is as follows:

If the minimum allowable D.O. at the critical point is taken as 50 percent saturation, then, the allowable critical oxygen deficit in ppm. equals:

(100% - 50%) x D.O. saturation value (in ppm) at selected temperature

The temperature that has been selected for design purposes is 26.3 deg. C. Dissolved-oxygen saturation value at this temperature is 8.17 ppm. Therefore the allowable critical oxygen deficit in ppm. is:

$$50\% \times 8.17 = 4.09 \text{ ppm.}$$

At a drought flow of 1,000 cfs., for example, the allowable critical oxygen deficit in pounds, from Equation (b), would be:

$$4.09 \times 1,000 \times 5.4 = 22,100 \text{ lb.}$$

Since the 1949 load produces a critical deficit of 40,000 lb., then the reduction in this load required to maintain 50 percent saturation at 1,000 cfs. would be:

$$40,000 - 22,100 \quad 17,900 \text{ lb.}$$

Or, amount of treatment required is:

$$\frac{17,900}{40,000} = 45\%$$

Calculations were made to determine treatment needs at other drought flows. Results of these calculations are plotted in Fig. 15.

The manner in which Fig. 15 is used can be illustrated in this fashion: If it is desired to maintain a minimum D.O. of 50 percent saturation at the critical point, and the drought flow occurring once in ten years (860 cfs.) is used as a basis for design, then from Fig. 15 the amount of reduction in the 1949 load required is 52 percent. For a drought flow occurring once in five years (1,125 cfs.), the amount of treatment for the same load is 38 percent. If the design is based on a ten percent increase in 1949 load, then Fig. 15 shows that to maintain 50 percent saturation at the critical point for a drought occurring once in 10 years the required treatment is 57 percent.

TREATMENT NEEDS

TERRE HAUTE

OXYGEN CONDITIONS

The criteria employed as representative of the desired dissolved-oxygen objective in the critical stretch of the Wabash River below Terre are these:

1. The average 24-hr. dissolved oxygen content of the water will be not less than 50 per cent saturation, except during that period of minimum weekly low flow which has a probability of occurence of once in ten years.

2. Only once in ten years will there be an expected summer drought severity during which minimum weekly average flow in the river will fall below 860 cfs.

3. The average temperature during August, the most critical month with respect to severe drought conditions and high temperature, is 26.3 deg. C.

With these criteria applied to the analysis of natural-purification loads, this conclusion is reached:

> Maintenance of desired dissolved-oxygen water-quality objectives requires treatment facilities for the Terre Haute pollution load capable of providing substantially complete removal of settleable

solids and a total reduction of 52 per-
pent in biochemical oxygen demand. An overall reduction in biochemical oxygen demand of less than 52 percent could be applied whenever stream flow and temperature conditions are such that there would be no impairment to the water-quality objective of 50 percent dissolved-oxygen saturation in the river below Terre Haute. Under no conditions, however, could treatment be less than that which will provide for substantially complete removal of settleable solids and the removal of not less than forty-five percent of the total suspended solids, which is the minimum specified under the terms of the Ohio River Compact.

To indicate the frequencies at which varying degrees of treatment will be adequate during drought flow to maintain the selected dissolved-oxygen objective, Fig. 16 has been prepared. For example, the curve in this figure, based on the probability of drought flows and a summer temperature of 26.3 deg. C., shows that 35 percent reduction in B.O.D. of the 1949 load will be adequate, on the average, during drought flows that occur 78 percent of the years. Or stated another way (see vertical scale on right side), this amount of B.O.D. reduction would be inadequate about once every five years.

The lowest drought (minimum weekly average) occurring at Terre Haute during the period of record (1928 to 1948) is 732 cfs. With 52 percent reduction in the 1949 load the 24-hour average D.O. at the critical point at this drought flow will be 41 percent saturation (3.4 ppm.). Because of the effect of algae on the D.O., values less than the 24-hour average will occur momentarily. Data presented in a preceding section (see page 20) indicates that the low point on the D.O. cycle may be from 1 to 2 ppm. less than the 24-hour average D.O.

Therefore, for the minimum flow-of-record the instantaneous minimum D.O. would be expected to be 1.4 to 2.4 ppm. (1 to 2 ppm. less than the 24-hour average D.O. of 3.4 ppm.). However, as shown in Fig. 5, this low D.O. would be expected to last only for one to two hours. The effect of this short period of serious oxygen depletion on fish life is believed to be within the limits of survival (or range of escape), particularly since it occurs only in a small stretch of the river represented by the critical zone.

BACTERIOLOGICAL CONDITIONS

Bacterial counts revealed by the survey indicated that the effects of Terre Haute sewage were evident at the Vincennes water intake, some 80 miles downstream.

Detailed data given in Table VIII showed that bacterial population in the river at Terre Haute was equivalent to that found in dilute sewage. A progressive decline in numbers of both coliform and enterococci bacteria occurred in the passage downstream to Vincennes. However, at Station 13, located two miles above the Vincennes intake, the median coliform count was in excess of the allowable limit established by the Indiana Stream Pollution Control Board for waters used as a source of supply. Regulations of the Indiana Board (see Appendix A) require that a raw water supply shall have an M.P.N. of coliform organisms of not greater than 5,000 per 100 ml. Of eleven analyses made at Sta. 13, five samples had an M.P.N. of 4,500 or less, whereas the M.P.N. of the remaining six samples was 6,000 or greater.

It should be observed that these bacteriological conditions were encountered during a period of relatively low flow and high temperature. Increased flows and lower temperatures would mean: (1) a reduction in the time of passage between Terre Haute and Vincennes and (2) a slower rate of bacterial die-away. Therefore, with larger flows and lower temperatures (which conditions may be expected throughout much of the year) there would be even higher bacterial concentrations at Vincennes.

In view of these considerations, chlorination of Terre Haute sewage is deemed advisable. Chlorination would not only reduce bacterial numbers at the Vincennes water intake, but would enhance the recreational potentialities of the river as well. A further consideration commending the use of chlorine is that it will provide additional reduction in B.O.D. of the Terre Haute pollution load.

TASTES AND ODORS

No phenols were detected in tests of the water at Vincennes during the course of the survey. However, it is reported that phenolic tastes are noted on occasion. This statement and the alleged poor flavor of fish taken from the river suggest that consideration be given to requirements for industrial waste treatment at Terre Haute to curtail the discharge of taste and odor producing substances.

ALLOCATION OF TREATMENT NEEDS

Because the industrial pollution load going directly to the river is twice that of the pollution load emanating from the municipal sewers at Terre Haute, a question of allocation of treatment requirements presents itself. Simply stated, it is this: How much of the purification capacity of the stream should be available for the individual industries and how much for the municipality? Since municipal and industrial relationships as well as technical considerations are involved, this is a question that commends itself for decision by the Indiana Stream Pollution Control Board.

It can be pointed out, however, that a formula for the allocation of treatment requirements may be designed on one or the other of the following bases: installation of facilities capable of an overall reduction in total load of exactly 52 percent, the reduction found to be necessary for present loadings under critical flow conditions; or installation of facilities capable of an overall reduction of some percentage higher than 52 percent in order to provide a cushion for municipal and industrial expansion. Because of the difficulty in revising treatment allocations once they are established, it would appear that the more practical course in making initial allocations would be to provide for additional demands on water resources so that future growth can be accommodated. Obviously this is a matter on which the Indiana Stream Pollution Control Board is most competent to make a decision.

VINCENNES

At Vincennes detailed studies on natural-purification characteristics of the river were not considered essential. Observations indicated that because of similar physical characteristics the capacity of the river to assimilate pollution in this stretch would be at least equal to that in the Terre Haute area. Furthermore, a 12 percent larger drainage area (13,700 sq. mi. vs. 12,200 sq. mi.) provides greater runoff and dilution at this point than at Terre Haute.

The pollution load at Vincennes measured during the survey was 131,600 population-equivalents. This is equal to 21 percent of the Terre Haute load. With a loading of this magnitude, studies at Terre Haute show that if the suspended-solids fraction of the load is sufficiently removed to insure against sludge deposits, natural-purification capacities of the river would be adequate to maintain an oxygen level of not less than 50 percent saturation with a stream flow as low as 380 cfs. The probability of such a low flow occurring at Vincennes is so remote that it may be ignored.

Therefore, the conclusion is reached that treatment of all municipal and industrial wastes providing for substantially complete removal of settleable solids and the removal of not less than forty-five percent of total suspended solids will be adequate to insure maintenance of desired dissolved-oxygen water quality objectives in the Wabash River below this city.

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TABLES AND FIGURES

TABLE I

POLLUTION LOAD AT TERRE HAUTE

1949

Sewer No.	Location	Dates of Measurement	Avg. Flow m.g.d.	Avg. 5-day B.O.D. p.p.m.	Population Equivalents
MUNICIPAL SEWERS:					
T-4	Walnut St.	Aug. 2-8	1.804	291	26,200
T-5	Turner St.	Aug. 1-9	1.130	468	26,400
T-11	Hulman St.	Aug. 25-27	3.290	240	39,500
T-13	Oak St.	Aug. 12-21	0.169	204	1,720
T-14	U. S. Penitentiary	Aug. 21-23	0.349	38	660
T-15	Tayler St.	Aug. 18-21	1.720	102	8,780
T-16	Crawford St.	Aug. 18-21	0.925	68	3,140
T-17	Poplar St.	Aug. 24-27	0.281	961	13,500
T-18	Eagle St.	Aug. 24-27	3.660	382	70,000
T-19	Ohio St.	Aug. 24-27	1.730	235	20,300
PRIVATELY OWNED INDUSTRIAL SEWERS:					
T-1	Valentine Packing Co.	Aug. 1-8	0.015	22	20
T-2	" " "	Aug. 1-10	0.079	454	1,790
T-3	" " "	Aug. 1-8	0.070	60	210
T-6	Indiana Wood Preserving	Aug. 1-9	0.081	428	1,740
T-7	Commercial Solvents	Aug. 12-17	2.140	402	43,000
T-8	" "	Aug. 14-15	0.454	7,440	168,900
T-9	" "	Aug. 12-17	2.116	356	37,700
T-10	" "	Aug. 12-17	1.025	24	1,230
T-12	Terre Haute Paper Co.	Aug. 12-17	4.076	743	151,400
T-20	Merchants Distilling Co.	Aug. 21-23	3.040	39	5,930
				Total	622,120

TABLE II

FRACTION OF TERRE HAUTE B.O.D. LOAD
IN FORM OF SUSPENDED SOLIDS
1949

Sewer No.	Location	% of 5-Day B.O.D. In Suspended Solids Form	Load in Population Equivalents	
			Total	Suspended Solids Fraction
T - 2	Valentine Packing Co.	28.6	1,790	510
T - 5	Turner Street	14.4	26,400	3,800
T - 8	Commercial Solvents	33.8	168,900	57,000
T - 11	Hulman Street	27.2	39,500	10,750
T - 12	Terre Haute Paper Co.	24.8	151,400	37,600
T - 17	Poplar Street	39.6	13,500	5,350
		Total	401,490	115,010

TABLE III

POLLUTION LOAD AT VINCENNES

1949

Sewer No.	Location	Dates of Measurement	Avg. Flow m.g.d.	Avg. 5-day B.O.D. p.p.m.	Population Equivalents
MUNICIPAL SEWERS:					
V-2	2nd & Willow St.	Aug. 31-Sept. 2	1.212	380	23,000
V-3	1st & DuBois St.	Aug. 31-Sept. 2	0.966	185	9,000
V-5	St. Clair St.	Sept. 1-2	0.102	113	600
PRIVATELY OWNED INDUSTRIAL SEWERS:					
V-1	Ft. Wayne Paper Co.	Aug. 31-Sept. 2	1.158	1220	70,500
V-4	Central Fibre Prod. Co.	Aug. 31-Sept. 2	1.980	288	28,500
				Total	131,600

TABLE IV

RIVER SAMPLING STATIONS

Location and Description
1949

Main Stem Stations Station No.	Main Stem Stations Miles Above Mouth	Tributary Stations Station No.	Description
27	215.0		Wabash River at N. Y. Central R. R. bridge in Terre Haute.
		26 a	Sugar Creek 3,000 ft. up stream from Wabash River.
26	209.6		Wabash River about 1 mile below Terre Haute.
25	205.4		Wabash River at Dresser power plant.
24	203.9		Wabash River at mouth of Honey Creek.
		23 a	Honey Creek about 2 mi. up stream from Wabash River.
23	201.5		Wabash River about 10 mi. below Terre Haute.
22	199.5		Wabash River at Indiana-Illinois state line about 12 mi. below Terre Haute
21	197.5		Wabash River about 14 mi. below Terre Haute.
20	195.0		Wabash River about 17 mi. below Terre Haute.
		19 a	Big Creek 200 ft. up stream from Wabash River.
19	190.0		Wabash River at Darwin, Ill. Ferry.
18	181.6		Wabash River at Riverview, Ind.
		17 a	Mill Creek 2,000 ft. up stream from Wabash River.
17	177.1		Wabash River at York, Ill., ferry.
		16 a	Racoon Creek 300 ft. up stream from Wabash River.
16	171.9		Wabash River at Hutsonville, Ill., bridge.
		15 a	Hutson Creek 300 ft. up stream from Wabash River.
15	164.8		Wabash River at Merom, Ind.
14 e	162.0		Wabash River at Riverton, Ind.
14 d	153.8		Wabash River about 8 mi. below Riverton, Ind.
		14 a	Busseron Creek 0.7 mi. up stream from Wabash River.

TABLE IV (Continued)

Main Stem Stations Station No.	Main Stem Stations Miles Above Mouth	Tributary Stations Station No.	Description
14 b	146.5		Wabash River about 5 mi. up river from Russellville, Ill.
14	140.5		Wabash River at Russellville, Ill., ferry.
		13 a	Maria Creek about 2 mi. up stream from Wabash River.
13	131.5		Wabash River about 3 mi. above Vincennes.
		12 a	Kelsos Creek 1 mi. up stream from Wabash River.
12	127.8		Wabash River at U.S. 50 highway bridge in Vincennes.
11	126.3		Wabash River about 1 mi. below Vincennes.
10	123.4		Wabash River about 4 mi. below Vincennes.
		9 a	Embarrass River about 1.3 mi. up stream from Wabash River.
		9 b	Old channel of Embarrass River about 2 mi. up stream from Wabash River.
8	118.5		Wabash River at C.C.C. and St. L. R.R. bridge above St. Francisville, Ill.
7	115.1		Wabash River at St. Francisville, Ill., Ferry.
6 b	112.2		Wabash River about 3 mi. below St. Francisville, Ill.
		6 a	Deshee River about 0.5 mi. up stream from Wabash River.
6	104.9		Wabash River about 10 mi. below St. Francisville, Ill.
5	102.4		Wabash River about 13 mi. below St. Francisville, Ill.
4 b	98.0		Wabash River about 17 mi. below St. Francisville, Ill.
4 a	95.8		Wabash River just above mouth of White River.
4	94.4		Wabash River at highway bridge (Ind. stat route 64) in Mt. Carmel, Ill.
3	91.5		Wabash River at C.C.C. & St. L. R.R. bridge about 3 mi. below Mt. Carmel,
2	87.7		Wabash River about 7 mi. below Mt. Carmel
1	84.8		Wabash River about 10 mi. below Mt. Carme

TABLE V

ANALYSES OF RIVER SAMPLES

Sampling at Eight-Hour Intervals
1949

River Station No.	Date	Average Results of Three Analyses Per Day: B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
27	8/22-8/23	5.4	10.8	124	23.3	7.6
	8/23-8/24	6.2	11.5	136	24.6	7.8
	8/24-8/25	4.6	10.8	129	25.0	7.4
	8/25-8/26	9.7	11.1	134	25.6	7.0
26 a	8/22-8/23	3.9	9.3	95	20.7	7.6
	8/23-8/24	1.7	8.3	96	22.6	7.9
	8/24-8/25	4.9	8.5	98	22.1	7.9
	8/25-8/26	2.0	13.6	166	27.8	7.5
26	8/22-8/23	11.9	8.9	103	23.1	7.6
	8/23-8/24	12.2	8.9	105	24.6	7.8
	8/24-8/25	12.1	8.6	106	25.0	8.1
	8/25-8/26	13.0	8.6	103	25.0	8.0
25	8/22-8/23	10.2	7.2	84	23.7	7.5
	8/23-8/24	9.0	8.2	97	24.4	7.7
	8/24-8/25	9.9	7.8	99	24.8	7.9
	8/25-8/26	9.2	6.0	70	24.4	8.0
24	8/22-8/23	11.2	7.1	85	24.5	7.6
	8/23-8/24	8.0	7.8	94	25.0	7.7
	8/24-8/25	8.9	7.7	92	25.2	7.9
	8/25-8/26	8.4	6.5	78	24.5	8.2
23 a	8/22-8/23	1.4	8.1	92	21.7	7.6
	8/23-8/24	1.8	8.5	96	22.0	7.6
	8/24-8/25	2.6	8.0	92	22.8	7.9
	8/25-8/26	1.9	7.4	84	22.2	8.0
23	8/22-8/23	7.3	7.1	84	24.3	7.6
	8/23-8/24	7.9	7.5	92	25.5	7.8
	8/24-8/25	8.0	6.5	78	25.1	7.8
	8/25-8/26	6.7	5.9	71	26.1	7.7
22	8/22-8/23	7.3	6.7	78	23.9	7.4
	8/23-8/24	6.8	7.0	84	25.5	7.8
	8/24-8/25	6.2	4.5	55	24.8	7.8
	8/25-8/26	6.6	5.1	62	25.6	7.9

TABLE V (Continued)

River Station No.	Date	Average Results of Three Analyses Per Day B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
20	8/22-8/23	7.7	8.8	103	23.9	7.7
	8/23-8/24	5.8	7.3	89	26.1	-
	8/24-8/25	5.4	4.9	59	25.8	7.7
	8/25-8/26	5.3	4.8	58	26.1	8.2
19 a	8/22-8/23	2.4	9.0	109	25.6	7.6
	8/23-8/24	2.3	9.1	112	26.6	7.7
	8/24-8/25	0.8	9.8	123	27.8	8.1
	8/25-8/26	2.5	7.2	-	-	8.0
19	8/22-8/23	5.7	7.1	84	24.4	7.6
	8/23-8/24	4.6	5.9	71	22.2	7.7
	8/24-8/25	5.4	6.2	73	25.2	7.7
	8/25-8/26	-	7.8	94	25.6	8.5
18	8/22-8/23	4.5	7.8	93	24.2	7.6
	8/23-8/24	4.4	6.8	81	21.3	7.7
	8/24-8/25	4.9	7.4	90	25.5	7.9
	8/25-8/26	5.7	10.5	125	25.0	7.5
	8/26-8/27	3.4	5.4	66	26.1	7.0
	8/27-8/28	3.4	4.2	50	24.4	7.3
	8/28-8/29	2.3	4.6	62	24.1	7.1
	8/29-8/30	3.6	8.0	97	25.2	7.7
17 a	8/26-8/27	2.3	7.1	79	20.7	7.4
	8/27-8/28	3.7	6.2	68	20.9	7.4
	8/28-8/29	3.8	7.5	86	23.0	7.5
	8/29-8/30	0.6	7.4	84	22.2	7.0
17	8/26-8/27	5.4	7.5	91	26.1	7.1
	8/27-8/28	2.9	4.8	57	24.2	7.4
	8/28-8/29	5.5	5.5	65	23.9	7.6
	8/29-8/30	3.4	7.8	88	22.5	7.5
16 a	8/26-8/27	3.2	5.8	67	21.8	7.5
	8/27-8/28	2.9	5.8	64	21.1	7.4
	8/28-8/29	1.4	6.6	74	20.6	7.8
	8/29-8/30	1.3	6.7	80	23.0	7.5
16	8/26-8/27	5.1	7.8	95	25.2	7.7
	8/27-8/28	3.0	4.8	55	23.9	7.6
	8/28-8/29	5.9	6.0	69	23.7	7.6
	8/29-8/30	4.0	7.8	92	24.4	7.7

TABLE V (Continued)

River Station No.	Date	Average Results of Three Analyses Per Day B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
15 a	8/26-8/27	3.9	5.6	62	21.6	7.7
	8/27-8/28	2.3	4.9	52	19.4	7.3
	8/28-8/29	2.4	5.1	56	21.1	7.6
	8/29-8/30	2.1	5.2	57	20.5	7.6
15	8/26-8/27	4.1	6.5	86	25.6	7.4
	8/27-8/28	2.5	5.1	60	25.1	7.4
	8/28-8/29	3.3	6.6	79	25.2	7.4
	8/29-8/30	2.3	6.4	76	24.2	-
14 e	8/26-8/27	4.4	7.8	96	25.9	7.8
	8/27-8/28	5.6	5.9	71	25.2	7.5
	8/28-8/29	2.3	5.9	70	25.0	7.5
	8/29-8/30	1.7	6.7	80	25.4	-
14 d	8/26-8/27	4.0	8.6	105	26.6	8.0
	8/27-8/28	3.3	7.6	91	25.3	7.6
	8/28-8/29	3.0	7.2	84	25.0	7.5
	8/29-8/30	1.8	8.0	95	24.4	8.7
14	8/26-8/27	4.1	8.3	101	25.6	-
	8/27-8/28	3.8	9.1	109	20.3	7.8
	8/28-8/29	3.0	8.0	97	25.3	-
	8/29-8/30	3.0	11.4	126	25.6	-
	8/31-9/1	4.1	10.2	118	23.0	7.5
	9/1-9/2	3.6	10.9	128	24.7	8.0
	9/2-9/3	5.3	11.9	140	24.2	8.0
	9/3-9/4	4.2	10.4	108	22.2	7.5
	9/8-9/9	4.7	9.7	108	22.7	8.2
	9/9-9/10	4.4	8.0	91	22.2	7.7
	9/10-9/11	9.5	9.5	108	22.2	8.1
	9/11-9/12	4.0	7.9	90	21.9	7.6
13 a	8/31-9/1	2.6	6.5	71	19.6	7.6
	9/1-9/2	1.9	7.8	82	17.8	7.8
	9/2-9/3	1.1	7.8	87	21.7	7.8
	9/8-9/9	1.4	8.0	85	21.8	7.6
	9/9-9/10	1.6	7.8	84	18.6	7.6
	9/10-9/11	1.2	8.1	93	22.8	8.1
	9/11-9/12	4.0	7.5	80	18.9	7.6
12 a	8/31-9/1	5.5	6.4	72	17.5	7.5
	9/1-9/2	2.7	6.7	72	19.5	7.7
	9/2-9/3	1.7	7.0	75	19.1	7.6
	9/8-9/9	1.4	8.0	83	17.3	8.2
	9/9-9/10	2.1	7.7	82	18.3	7.4
	9/10-9/11	1.6	8.8	94	18.9	8.2
	9/11-9/12	1.9	7.0	72	17.5	7.6

TABLE V (Continued)

River Station No.	Date	Average Results of Three Analyses Per Day B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
12	8/31-9/1	3.6	9.0	106	23.6	7.5
	9/1-9/2	5.4	11.5	134	23.7	7.8
	9/2-9/3	4.0	10.2	118	23.5	7.8
	9/8-9/9	5.2	9.8	111	22.0	8.2
	9/9-9/10	4.4	9.5	108	22.4	7.7
	9/10-9/11	4.8	9.6	109	22.2	8.2
	9/11-9/12	3.9	7.6	84	20.3	7.9
11	8/31-9/1	4.1	8.7	114	23.9	7.6
	9/1-9/2	6.1	10.7	126	24.4	7.8
	9/2-9/3	6.2	10.5	113	23.5	7.9
	9/8-9/9	6.3	10.7	121	21.9	8.2
	9/9-9/10	5.3	9.8	112	22.0	7.7
	9/10-9/11	4.3	9.9	113	22.2	8.0
	9/11-9/12	6.2	7.4	83	21.4	7.7
10	8/31-9/1	3.9	11.4	136	24.1	7.7
	9/1-9/2	6.6	13.0	150	23.4	8.0
	9/2-9/3	4.8	10.7	126	24.0	7.8
	9/8-9/9	6.0	11.5	122	22.8	8.0
	9/9-9/10	4.3	9.8	112	22.4	7.8
	9/10-9/11	4.2	10.4	118	22.2	8.1
	9/11-9/12	3.8	7.4	83	21.6	7.7
9 a	8/31-9/1	4.0	5.4	63	22.8	7.4
	9/1-9/2	4.9	7.0	80	20.3	7.7
	9/2-9/3	3.0	6.8	80	24.2	7.9
	9/3-9/4	2.4	6.3	73	23.3	8.1
	9/8-9/9	3.1	6.0	69	22.4	7.5
	9/10-9/11	3.2	6.3	73	23.3	7.9
	9/11-9/12	3.9	4.2	47	21.6	7.7
9 b	8/31-9/1	2.6	7.2	85	25.0	8.3
	9/1-9/2	5.2	3.6	39	20.0	7.4
	9/8-9/9	2.0	4.8	51	18.3	7.8
8	8/31-9/1	4.2	9.0	106	23.3	7.6
	9/1-9/2	6.2	10.9	127	23.7	8.0
	9/2-9/3	6.2	11.1	129	23.5	7.8
	9/8-9/9	5.6	9.2	104	21.7	8.2
	9/9-9/10	5.0	10.0	117	23.3	7.7
	9/10-9/11	4.1	10.1	115	22.2	8.1
	9/11-9/12	4.2	7.2	81	21.6	7.7

TABLE V (Continued)

River Station No.	Date	Average Results of Three Analyses Per Day B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
7	8/31-9/1	4.4	8.8	104	23.3	7.8
	9/1-9/2	4.3	10.5	122	23.3	8.3
	9/2-9/3	6.0	10.1	116	23.9	8.0
	9/8-9/9	3.7	9.8	111	22.2	8.3
	9/9-9/10	4.8	9.4	107	22.0	7.9
	9/10-9/11	4.5	9.6	109	22.2	8.1
	9/11-9/12	4.5	7.8	88	21.6	-
6 b	9/8-9/9	5.3	9.7	107	20.7	8.3
	9/9-9/10	5.6	9.9	112	22.0	8.0
	9/10-9/11	4.7	8.8	100	22.2	8.1
	9/11-9/12	6.2	8.0	89	21.1	7.8
6 a	8/31-9/1	1.4	7.0	79	20.6	7.5
	9/1-9/2	2.1	7.6	81	19.3	8.0
	9/2-9/3	0.9	7.8	84	20.2	7.7
	9/3-9/4	0.9	6.5	73	21.1	8.2
	9/8-9/9	1.0	8.0	85	18.5	8.1
	9/9-9/10	0.9	7.8	85	19.6	7.5
	9/10-9/11	1.0	7.4	77	17.8	7.8
	9/11-9/12	0.8	7.1	75	18.3	7.7
6	8/31-9/1	4.0	9.4	110	22.8	7.7
	9/1-9/2	3.8	10.0	120	23.5	7.9
	9/2-9/3	4.9	9.8	113	23.1	7.9
	9/3-9/4	3.0	10.5	127	25.6	7.9
	9/4-9/5	3.6	9.2	110	24.8	7.7
	9/5-9/6	4.7	10.1	120	24.5	7.7
	9/6-9/7	3.8	9.5	113	24.4	-
	9/7-9/8	3.5	8.1	95	23.9	-
	9/8-9/9	5.1	9.4	110	22.0	8.2
	9/9-9/10	5.2	9.7	109	21.8	7.8
	9/10-9/11	5.3	9.2	105	22.2	7.9
	9/11-9/12	4.6	8.5	96	21.6	-
5	9/4-9/5	3.4	9.8	116	24.6	7.8
	9/5-9/6	5.8	12.3	149	25.6	-
	9/6-9/7	3.9	9.7	115	24.4	-
	9/7-9/8	4.4	8.7	102	23.5	-
4 b	9/4-9/5	3.8	10.4	126	25.6	7.6
	9/5-9/6	4.6	9.8	117	24.5	8.1
	9/6-9/7	4.8	10.2	120	24.4	-
	9/7-9/8	4.5	9.3	108	23.9	-

TABLE V (Continued)

River Station No.	Date	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
		Average Results of Three Analyses Per Day				
4 a	9/4-9/5	3.8	9.6	116	23.9	7.7
	9/5-9/6	5.0	9.5	112	24.7	7.9
	9/6-9/7	4.4	8.6	100	23.6	-
	9/7-9/8	4.4	8.6	100	23.6	-
4	9/4-9/5	3.3	9.2	110	24.4	7.9
	9/5-9/6	3.9	9.1	106	23.9	7.8
	9/6-9/7	4.0	9.3	109	23.7	-
	9/7-9/8	4.5	8.7	100	23.1	-
3	9/4-9/5	2.9	9.8	115	24.4	7.8
	9/5-9/6	3.0	9.2	107	23.3	7.9
	9/6-9/7	3.7	9.6	114	24.1	-
	9/7-9/8	3.7	8.6	100	22.5	-
2	9/4-9/5	2.4	9.9	116	24.2	7.8
	9/5-9/6	2.8	7.9	104	23.3	7.8
	9/6-9/7	2.3	9.4	110	23.9	-
	9/7-9/8	3.0	8.7	100	22.7	-
1	9/4-9/5	2.7	10.3	122	24.6	7.8
	9/5-9/6	3.4	9.9	115	23.7	7.6
	9/6-9/7	3.3	10.1	118	24.1	-
	9/7-9/8	4.2	9.2	103	22.8	-

TABLE VI

SUMMARY OF RESULTS OF ANALYSES
MADE ON RIVER SAMPLES

Sampling at Eight-Hour Intervals
Aug. 22 - Sept. 12, 1949

River Station No.	Average Results of All Analyses During Indicated Period				
	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
27	6.5	11.1	131	24.6	7.5
26 a	3.1	9.9	114	23.3	7.7
26	12.3	8.8	104	24.4	7.9
25	9.6	7.3	88	24.3	7.8
24	9.1	7.3	87	24.8	7.9
23 a	1.9	8.0	91	22.2	7.7
23	7.5	6.8	81	25.2	7.7
22	6.7	5.9	70	24.9	7.7
20	6.1	6.5	77	25.4	7.9
19 a	2.0	8.7	115	26.7	7.9
19	5.2	6.8	81	24.3	7.9
18	4.0	6.8	83	24.6	7.5
17 a	2.6	7.1	79	20.2	7.3
17	4.3	6.4	75	24.0	7.4
16 a	2.2	6.2	71	21.6	7.6
16	4.5	6.6	78	24.3	7.9
15 a	2.7	5.2	57	20.7	7.8
15	3.1	6.2	75	25.0	7.4
14 e	3.5	6.6	79	25.0	7.5
14 d	3.0	7.9	94	25.3	8.0
14 a	1.7	8.3	100	26.1	8.5
14	4.5	9.5	110	23.6	7.9
13 a	1.9	7.5	83	20.2	7.7
12 a	2.6	7.2	77	19.1	7.8
12	4.4	9.5	109	22.9	7.9
11	5.5	9.8	112	23.0	7.9
10	4.7	10.9	125	23.2	7.9
9 a	3.6	6.0	69	22.8	7.8
9 b	3.3	5.2	58	21.1	7.9
8	5.0	9.6	110	23.0	7.8
7	4.6	9.5	108	22.9	8.0
6 b	5.5	9.1	102	21.6	8.1
6 a	1.1	7.5	80	19.8	7.8
6	4.3	9.4	111	23.5	7.8
5	4.2	10.1	120	24.5	8.0

TABLE VI (Continued)

River Station No.	Average Results of All Analyses During Indicated Period				
	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temp. °C	pH
4 b	4.4	9.4	134	24.6	7.9
4 a	4.4	9.3	111	24.5	7.9
4	3.9	9.1	106	23.9	7.9
3	3.3	9.3	109	23.7	7.9
2	2.6	9.0	108	23.6	7.8
1	3.4	9.9	115	23.9	7.6

TABLE VII

RESULTS OF ANALYSES MADE ON RIVER SAMPLES
IN TERRE HAUTE AREA

Sampling at Two-Hour Intervals
September 13-17, 1949

River Station No.	Date 1949	Time	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temperature °C
24	9-14	2:00 P.M.	5.2	6.9	73	18.3
		4:00 P.M.	4.8	6.9	75	18.3
		6:00 P.M.	5.3	7.1	75	18.3
		8:00 P.M.	4.6	6.4	68	18.3
		10:00 P.M.	5.2	6.4	68	18.3
		12:00 A.M.	5.1	5.9	62	18.3
	9-15	3:00 A.M.	4.8	5.1	54	18.9
		5:00 A.M.	5.0	5.2	55	18.9
		6:15 A.M.	4.2	5.7	61	18.9
		8:20 A.M.	4.8	5.7	61	18.9
		10:00 A.M.	4.0	5.6	61	20.0
		12:00 P.M.	5.0	6.6	70	18.9
	9-16	2:00 P.M.	7.1	8.5	93	20.0
		4:00 P.M.	7.2	7.7	84	20.0
		6:00 P.M.	8.2	9.1	98	19.4
		8:00 P.M.	9.4	6.7	72	18.9
		10:00 P.M.	6.4	7.5	80	18.9
		12:00 A.M.	6.4	7.0	75	18.9
	9-17	2:00 A.M.	6.8	6.8	73	18.9
		4:00 A.M.	6.8	6.6	71	19.4
		6:00 A.M.	6.8	6.5	70	19.4
		8:00 A.M.	6.8	6.6	71	19.4
		10:00 A.M.	6.0	7.2	79	20.0
		12:00 P.M.	6.8	8.5	94	20.6
23	9-14	2:40 P.M.	5.5	6.8	72	18.3
		4:40 P.M.	5.3	6.6	70	18.3
		6:40 P.M.	4.7	5.5	58	18.3
		8:40 P.M.	4.0	6.3	66	18.3
		10:40 P.M.	4.3	4.9	52	18.3
	9-15	0:40 A.M.	3.8	4.7	50	18.3
		3:30 A.M.	4.5	4.2	45	18.9
		5:15 A.M.	3.8	4.6	49	18.9
		6:45 A.M.	4.2	4.1	44	18.9
		9:00 A.M.	5.0	4.3	46	18.9
		10:30 A.M.	4.2	4.8	51	18.3

TABLE VII (Continued)

River Station No.	Date 1949	Time	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temperature °C
23	9-16	2:40 P.M.	5.9	7.7	84	20.0
		4:40 P.M.	6.9	8.3	89	19.4
		6:40 P.M.	6.6	8.5	92	19.4
		8:40 P.M.	7.3	7.8	83	18.9
		10:40 P.M.	6.4	7.4	79	18.9
	9-17	0:40 A.M.	6.3	7.4	79	18.9
		2:35 A.M.	5.0	6.1	67	20.0
		4:40 A.M.	4.8	5.8	63	19.4
		6:40 A.M.	7.2	5.8	63	19.4
		8:45 A.M.	-	5.9	64	19.4
		10:30 A.M.	5.0	6.7	72	19.4
		12:30 P.M.	6.2	7.7	85	20.6
22	9-14	3:15 P.M.	4.5	6.9	73	18.3
		9:15 P.M.	4.2	4.6	49	18.3
		11:15 P.M.	2.8	3.6	38	18.3
	9-15	1:15 A.M.	3.7	4.8	51	18.9
		4:15 A.M.	6.0	3.3	35	18.9
		5:50 A.M.	4.2	3.4	36	18.9
		7:20 A.M.	3.0	3.5	37	18.9
		9:25 A.M.	3.8	3.6	38	18.9
		11:00 A.M.	5.0	3.9	42	19.4
		1:00 P.M.	5.8	5.4	58	19.4
	9-16	3:15 P.M.	5.7	6.7	72	19.4
		5 15 P.M.	5.8	7.2	78	19.4
		7:15 P.M.	5.6	6.9	74	18.9
		9:15 P.M.	5.7	6.3	67	18.9
		11:15 P.M.	-	7.0	75	18.9
	9-17	1:15 A.M.	4.9	6.2	66	18.9
		3:15 A.M.	4.8	5.9	64	20.0
		5:15 A.M.	4.5	5.1	56	20.0
		7:10 A.M.	4.2	5.1	55	19.4
		9:20 A.M.	-	5.6	60	19.4
		11:10 A.M.	3.8	6.1	67	20.0
		1:15 P.M.	5.0	6.7	74	20.6
20	9-13	2:00 P.M.	3.9	4.7	52	20.6
		4:45 P.M.	3.6	4.8	53	20.6
		7:30 P.M.	1.4	5.4	57	18.3
		10:30 P.M.	2.4	4.4	46	18.3

TABLE VII (Continued)

River Station No.	Date 1949	Time	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temperature °C
20	9-14	2:00 A.M.	3.2	3.5	38	19.4
		5:00 A.M.	2.6	3.7	39	18.3
		10:45 A.M.	4.2	3.4	36	18.3
	9-15	2:00 P.M.	3.5	4.9	54	20.6
		4:00 P.M.	3.8	5.6	62	20.6
		6:00 P.M.	3.8	5.7	61	18.9
		8:00 P.M.	3.6	4.9	51	17.8
		10:00 P.M.	3.3	5.6	58	17.2
		12:00 A.M.	3.2	5.7	60	17.8
	9-16	2:00 A.M.	2.4	3.6	39	19.4
		4:00 A.M.	3.2	2.8	30	18.9
		6:00 A.M.	2.7	2.6	28	18.9
		8:00 A.M.	3.5	3.5	38	19.4
		9:50 A.M.	3.2	4.4	47	19.4
		12:00 P.M.	3.5	4.2	46	20.0
	9-17	2:00 P.M.	5.0	6.3	70	21.1
		4:00 P.M.	4.7	6.8	76	21.1
		6:00 P.M.	3.8	6.0	67	21.1
		8:00 P.M.	3.1	4.4	49	21.1
		12:00 P.M.	2.9	5.1	58	22.2
	9-18	8:30 A.M.	5.2	5.1	58	22.2
		10:40 A.M.	5.4	5.5	62	21.6
		12:10 P.M.	6.5	6.4	71	21.1
19	9-13	2:40 P.M.	3.0	3.6	40	20.6
		5:40 P.M.	2.9	4.0	44	20.0
		8:15 P.M.	2.7	4.3	45	17.8
		11:30 P.M.	2.3	4.4	46	18.3
	9-14	2:45 A.M.	3.3	3.2	34	18.3
		5:45 A.M.	1.8	4.0	42	18.3
		9:00 A.M.	1.7	4.0	42	18.3
		11:45 A.M.	3.2	4.2	44	18.3
	9-15	3:00 P.M.	3.8	5.5	61	20.6
		5:00 P.M.	3.7	5.6	62	20.6
		7:00 P.M.	3.4	5.4	56	17.8
		9:00 P.M.	3.0	5.1	53	17.8
		11:00 P.M.	3.3	5.0	51	16.7

TABLE VII (Continued)

River Station No.	Date 1949	Time	B.O.D. p.p.m.	D.O. p.p.m.	D.O. % Sat.	Temperature °C
19	9-16	1:00 A.M.	2.9	5.0	52	17.2
		3:30 A.M.	2.7	5.0	52	17.8
		5:00 A.M.	3.2	4.3	46	18.9
		6:45 A.M.	2.5	4.3	46	18.9
		9:15 A.M.	2.6	4.8	52	19.4
		10:30 A.M.	2.8	4.9	53	20.0
		2:40 P.M.	3.6	4.7	52	20.6
	9-17	3:00 P.M.	4.1	5.9	67	22.2
		5:00 P.M.	4.4	5.3	60	21.6
		7:00 P.M.	3.5	5.8	65	21.1
		9:00 P.M.	3.6	5.1	56	20.6
		11:00 P.M.	-	-	-	
	9-18	1:00 A.M.	3.8	5.1	56	20.0
		9:30 A.M.	4.3	5.9	67	22.2
		11:30 A.M.	4.8	6.3	71	21.6
		1:00 P.M.	5.7	7.3	82	21.6
18	9-13	3:15 P.M.	2.0	5.6	62	20.6
		6:30 P.M.	1.8	4.8	50	17.8
		9:30 P.M.	1.6	4.3	46	18.9
	9-14	0:45 A.M.	3.0	5.5	59	18.9
		3:45 A.M.	2.2	3.6	38	18.3
		6:45 A.M.	1.7	4.5	47	17.8
		9:45 A.M.	1.6	4.8	51	18.3
		1:00 P.M.	3.5	4.8	51	18.3

TABLE VIII

RESULTS OF BACTERIOLOGICAL ANALYSES

1949

Station No.	Analyses Made During Period	No. Samples	Coliforms - MPN per 100 ml			Enterococci - MPN per 100 ml		
			Min.	Max.	Median	Min.	Max.	Median
27	7/28-9/13	9	2,300	240,000+	62,000	60	69,000	235
26 a	7/28-9/13	9	2,300	240,000+	6,200	210	23,000	655
26	7/28-9/13	19	69,000	2,400,000+	1,200,000	130	240,000+	154,500
25	7/28-8/25	18	130,000	24,000,000	2,400,000	690	2,400,000	240,000
24	7/28-9/17	21	21,000	69,000,000	2,400,000	20	6,900,000	23,000
23 a	7/28-9/13	9	600-	24,000,000	240,000	45-	2,400+	62
23	7/28-9/17	11	6,200	6,200,000	2,400,000	130	69,000	23,000
22	7/28-9/17	11	69,000	69,000,000	2,400,000	690	240,000+	23,000
20	8/23-9/16	9	240,000	2,400,000+	2,400,000	2,300	130,000	6,200
19	7/28-9/14	13	23,000	2,400,000	430,000	210	69,000	690
18	7/28-9/14	19	62,000	6,900,000	430,000	23	6,200	690
17 a	8/2-8/30	8	6,000	2,400,000	62,000	4	6,900	230
17	8/2-8/30	8	23,000	2,400,000+	376,000	6	6,900	240
16 a	8/2-8/30	8	230	690,000	14,000	4	24,000+	230
16	8/2-8/30	8	21,000	620,000	62,000	62	6,900	230
15 a	8/2-8/30	7	620	62,000	6,000	23	2,400	62
15	8/2-8/30	7	6,200	2,400,000+	62,000	23	24,000	620
14	8/2-9/12	12	2,300	690,000	62,000	6	6,900	130
13	8/2-9/12	11	600	62,000	6,000	23	6,900	130

TABLE VIII (Continued)

Station No.	Analyses Made During Period	No. Samples	Coliforms - MPN per 100 ml Min.	Max.	Median	Enterococci - MPN per 100 ml Min.	Max.	Median
12 a	8/31-9/11	9	2,300	240,000	62,000	60-	2,300	146
12	8/31-9/12	10	2,300	2,400,000+	23,000	60	2,300	146
11	9/1-9/19	11	23,000	690,000	210,000	60	69,000	620
10	8/31-9/12	10	2,300	230,000	36,500	23	620	95
9 a	8/31-9/12	11	2,300	690,000	23,000	23	6,200	620
8	8/31-9/12	8	23,000	2,400,000+	240,000	23	24,000	620
7	8/31-9/12	10	6,000	24,000,000	240,000	23	6,200	130
6 a	8/31-9/12	9	2,300	690,000	23,000	13	1,300	230
6	8/31-9/11	15	2,400	690,000	69,000	6	6,200	62
5	9/5-9/8	5	6,200	240,000+	24,000	6	62	43
4	9/5-9/8	6	2,300	24,000	6,200	5	62	43
3	9/5-9/8	6	60	6,200	1,200	23	62	56
2	9/5-9/8	5	230	2,300	620	23	62	23
1	9/5-9/8	6	230	6,200	2,300	23	62	23

TABLE IX

TEMPERATURE OF WABASH RIVER BELOW TERRE HAUTE

River Temperature In Degrees Centigrade

Year	July			August			September		
	Daily Min.	Daily Max.	Monthly Avg.	Daily Min.	Daily Max.	Monthly Avg.	Daily Min.	Daily Max.	Monthly Avg.
1924	21.1	26.6	-	22.8	27.2	-	15.5	23.9	-
1925	-	-	25.0	-	-	25.1	-	-	24.1
1926	-	-	26.1	-	-	25.5	-	-	24.0
1927	-	-	24.8	-	-	22.7	-	-	22.4
1928	-	-	25.5	-	-	25.4	-	-	19.9
1929	-	-	24.8	-	-	24.0	-	-	20.6
1930	-	-	26.9	-	-	25.5	-	-	22.7
1931	26.3	32.2	28.7	22.6	31.2	26.4	18.2	27.5	24.3
1932	22.9	30.7	27.4	24.0	28.5	26.0	17.9	28.2	21.8
1933	24.3	29.2	26.3	22.9	28.8	25.3	19.8	27.8	23.5
1934	25.5	32.6	29.0	21.7	30.7	26.2	16.0	23.9	21.0
1935	25.5	29.6	27.3	21.1	30.1	26.7	16.0	25.2	21.4
1936	25.2	31.6	28.3	24.6	30.1	27.7	16.0	27.8	23.3
1937	22.9	28.6	26.0	25.9	28.7	27.1	17.4	28.2	22.0
1938	22.6	27.9	26.5	24.3	29.5	26.9	18.0	27.2	23.4
1939	23.4	28.8	26.6	23.4	28.7	25.8	18.9	26.8	25.8
1940	23.4	31.6	27.3	23.2	30.6	27.2	17.9	26.4	22.6
1941	23.8	31.8	27.8	23.9	32.4	27.0	18.3	28.3	23.9
1942	23.9	29.4	26.7	23.3	30.0	25.6	12.8	26.6	22.2
1943	23.9	28.9	26.7	24.4	28.9	26.7	17.2	27.2	21.1

TABLE IX (Continued)

River Temperature In Degrees Centigrade

Year	July			August			September		
	Daily Min.	Daily Max.	Monthly Avg.	Daily Min.	Daily Max.	Monthly Avg.	Daily Min.	Daily Max.	Monthly Avg.
1944	26.1	30.6	28.3	22.2	31.7	28.3	21.1	27.8	23.9
1945	23.3	28.3	25.5	23.3	30.0	26.6	17.8	27.8	22.8
1946	24.5	28.9	27.2	20.5	29.4	25.5	19.4	27.8	23.9
1947	22.2	28.3	25.5	26.1	32.8	30.0	16.7	30.0	24.4
1948	23.9	28.9	26.6	22.8	31.1	26.7	18.3	27.8	23.9
1949	26.1	31.1	28.9	23.9	30.5	27.2	17.2	27.2	22.8
		Average	26.8			26.3			22.9

Data from Public Service Company of Indiana

TABLE X

POPULATION OF TERRE HAUTE AND VINCENNES

Year	Population	
	Terre Haute	Vincennes
1850	4,051	2,070
1860	4,543	3,960
1870	7,509	5,440
1880	26,042	7,680
1890	30,217	8,853
1900	36,673	10,249
1910	58,157	14,895
1920	66,083	17,160
1930	62,810	17,564
1940	62,693	18,228
1950 (provisional)	64,097	18,798

Data from Census
Bureau

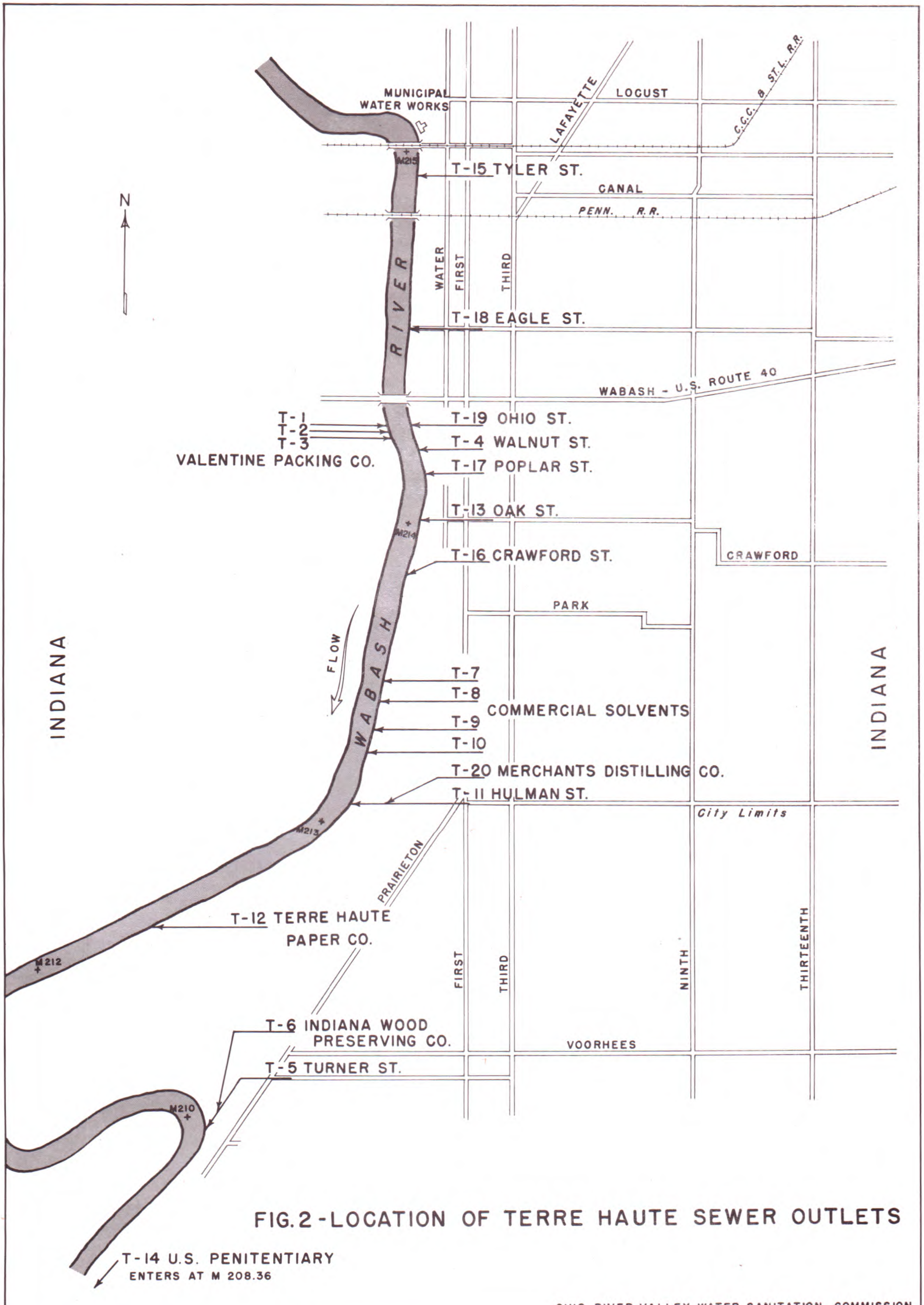


FIG. 2 - LOCATION OF TERRE HAUTE SEWER OUTLETS

OHIO RIVER VALLEY WATER SANITATION COMMISSION

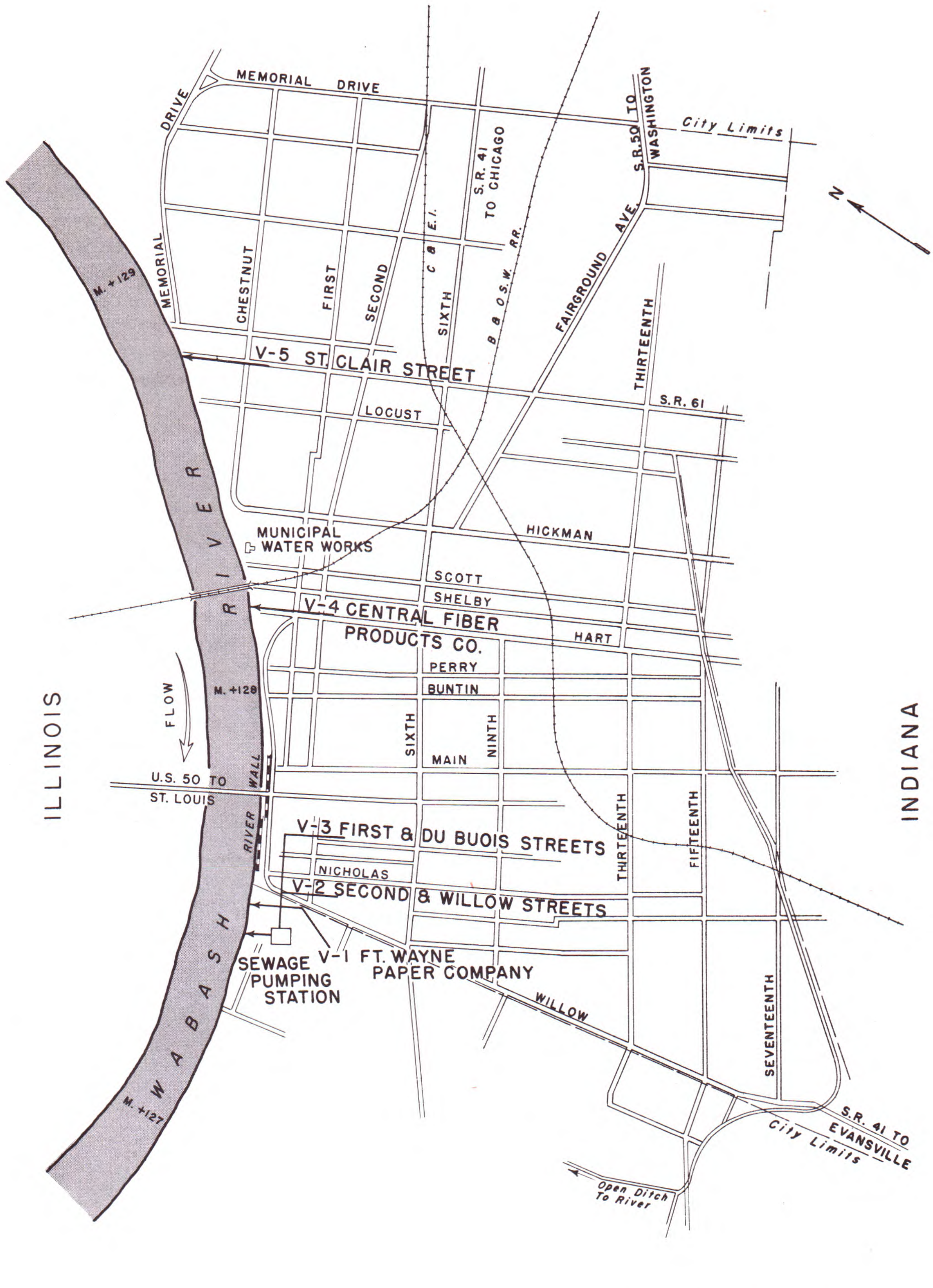
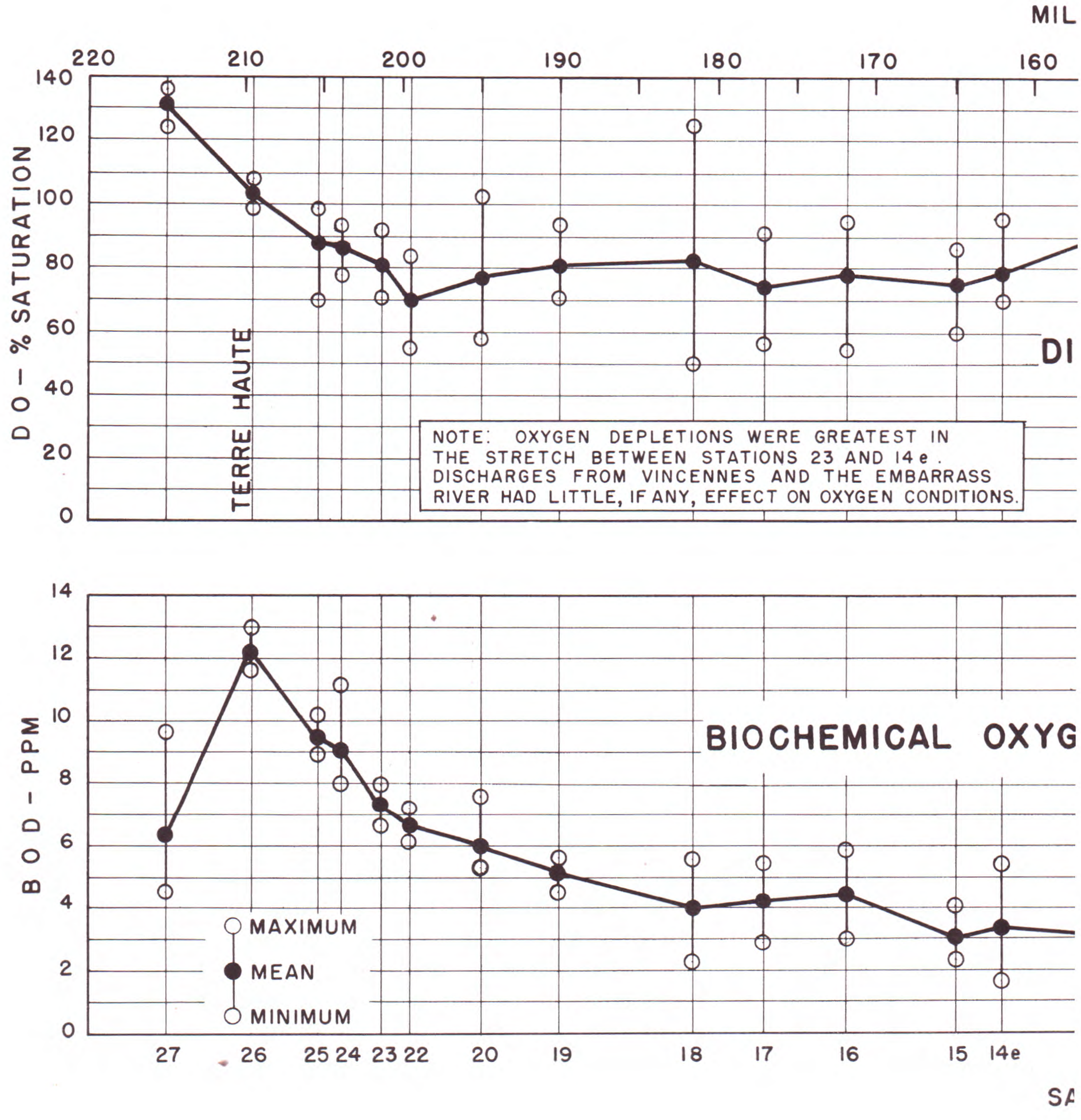


FIG. 3 - LOCATION OF VINCENNES SEWER OUTLETS


MIL
220
210
200
190
180
170
160
140
120
100
80
60
40
20
0
D O – % SATURATION
TERRE HAUTE
DI
NOTE: OXYGEN DEPLETIONS WERE GREATEST IN THE STRETCH BETWEEN STATIONS 23 AND 14e. DISCHARGES FROM VINCENNES AND THE EMBARRASS RIVER HAD LITTLE, IF ANY, EFFECT ON OXYGEN CONDITIONS.
14
12
10
8
6
4
2
0
B O D – PPM
BIOCHEMICAL OXYG
MAXIMUM
MEAN
MINIMUM
27
26
25 24
23 22
20
19
18
17
16
15
14e
SA

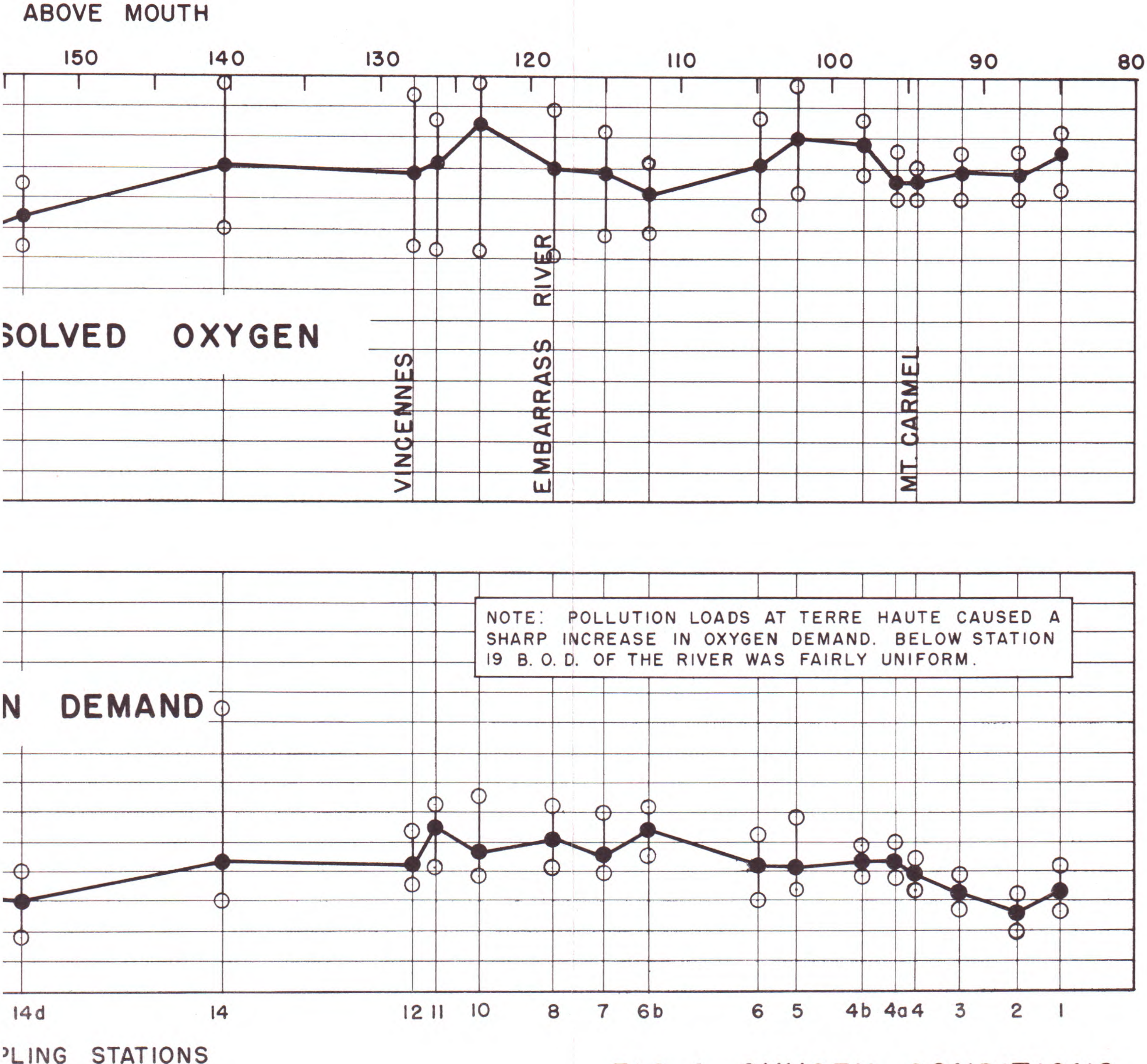
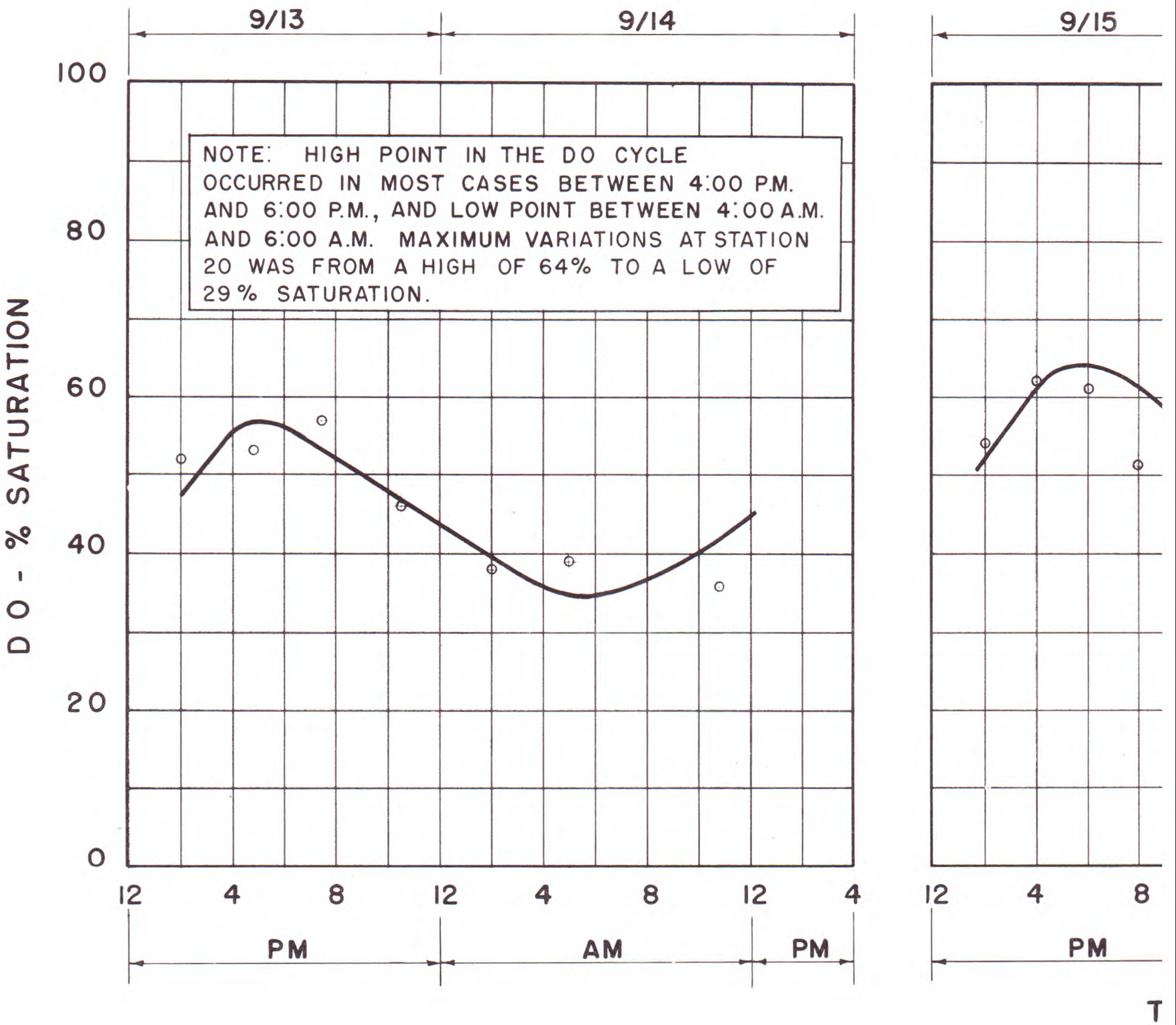


FIG. 4 - OXYGEN CONDITIONS IN WABASH RIVER

TERRE HAUTE TO MT. CARMEL
AUG. 22 - SEPT. 12, 1949


9/13
9/14
9/15
100
80
60
40
20
0
DO - % SATURATION
NOTE: HIGH POINT IN THE DO CYCLE OCCURRED IN MOST CASES BETWEEN 4:00 P.M. AND 6:00 P.M., AND LOW POINT BETWEEN 4:00 A.M. AND 6:00 A.M. MAXIMUM VARIATIONS AT STATION 20 WAS FROM A HIGH OF 64% TO A LOW OF 29% SATURATION.
12
4
8
12
4
8
12
4
12
4
8
PM
AM
PM
PM
T

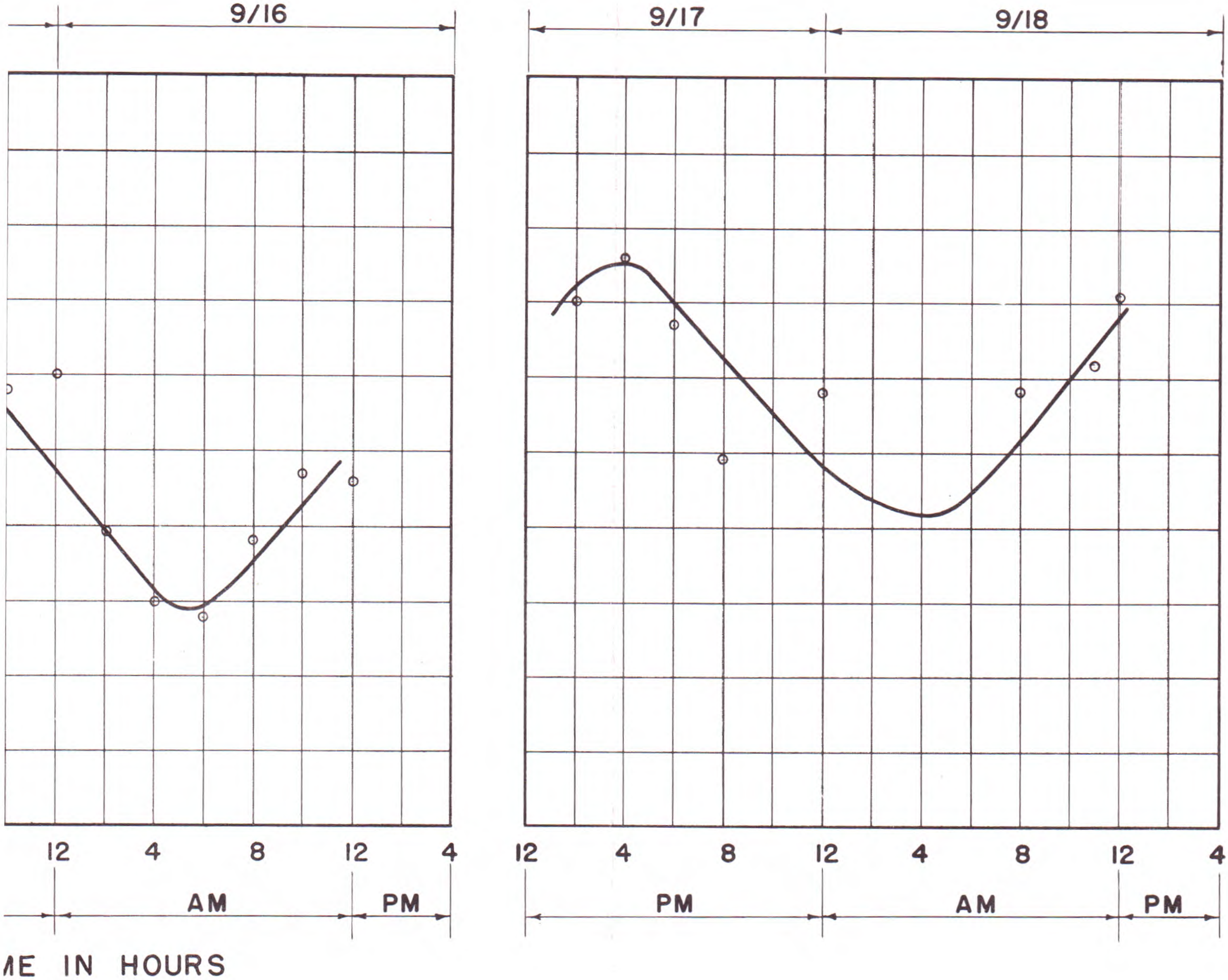


FIG. 5 - EFFECT OF ALGAE ON DISSOLVED OXYGEN

SAMPLING STATION 20

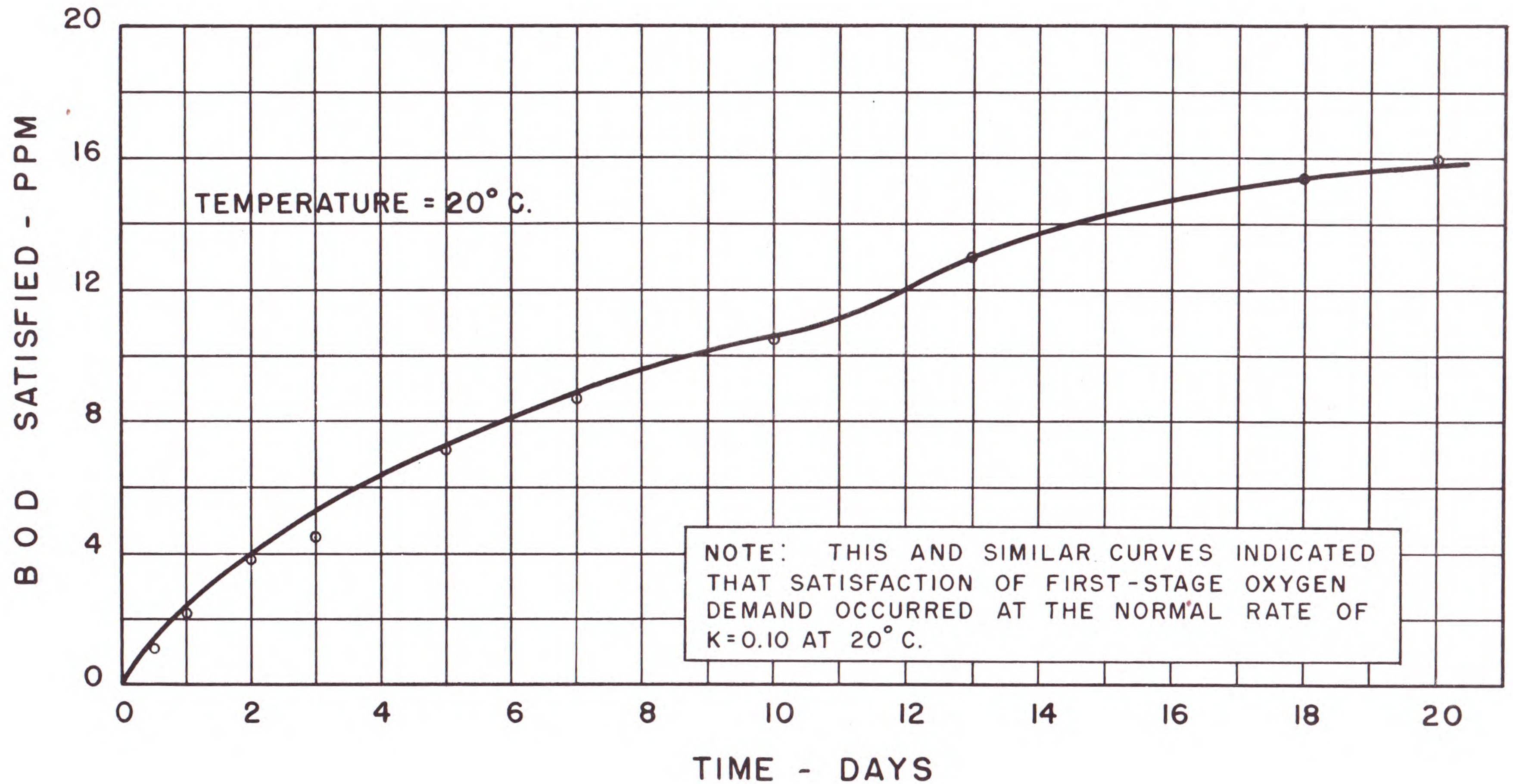
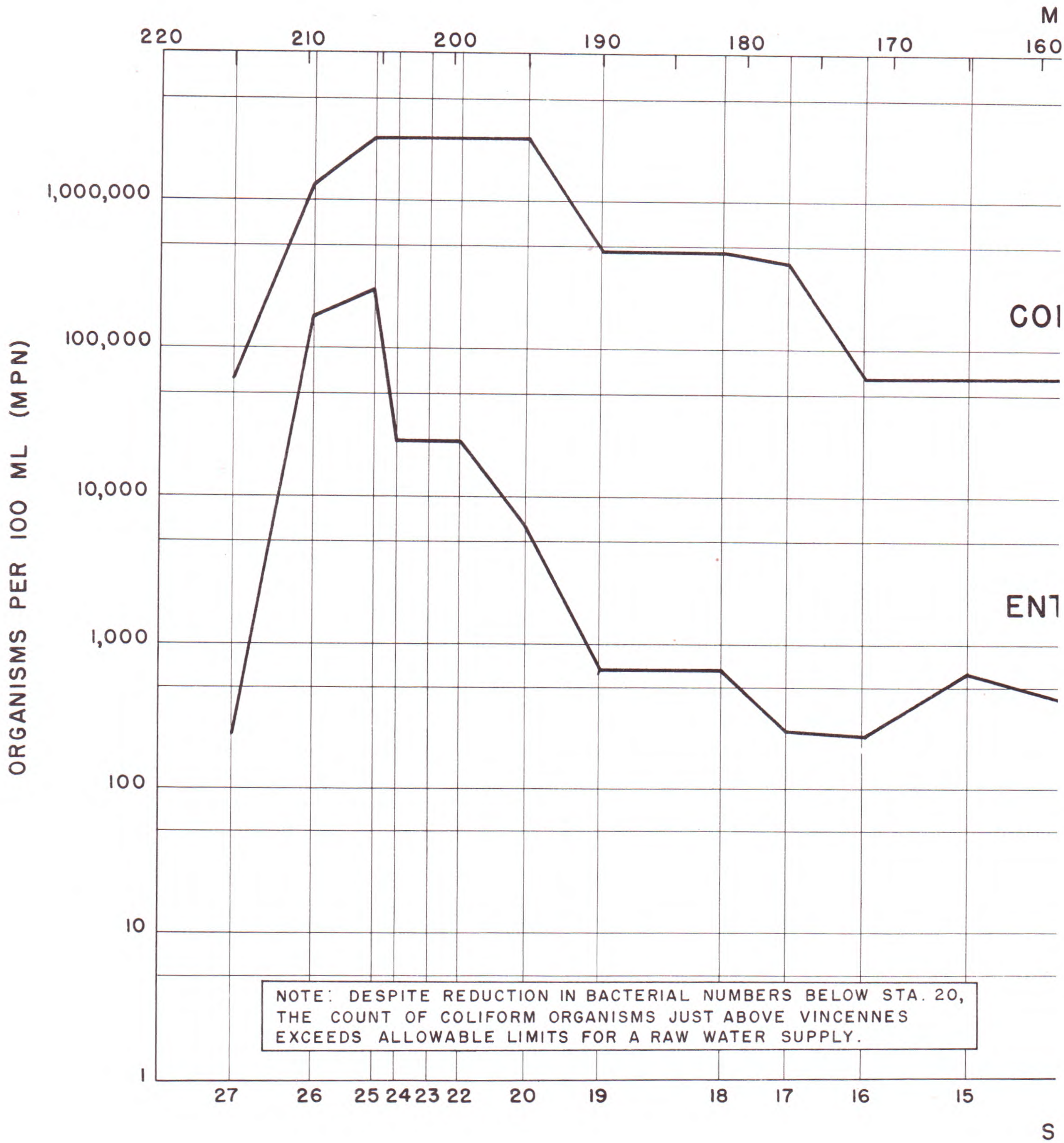


FIG. 6 - RATE AT WHICH B O D OF RIVER WATER AND TERRE HAUTE POLLUTION LOAD IS SATISFIED



M
220
210
200
190
180
170
160
1,000,000
100,000
10,000
1,000
100
10
1
ORGANISMS PER 100 ML (MPN)
COI
ENT
NOTE: DESPITE REDUCTION IN BACTERIAL NUMBERS BELOW STA. 20, THE COUNT OF COLIFORM ORGANISMS JUST ABOVE VINCENNES EXCEEDS ALLOWABLE LIMITS FOR A RAW WATER SUPPLY.
27
26
25 24 23 22
20
19
18
17
16
15
S

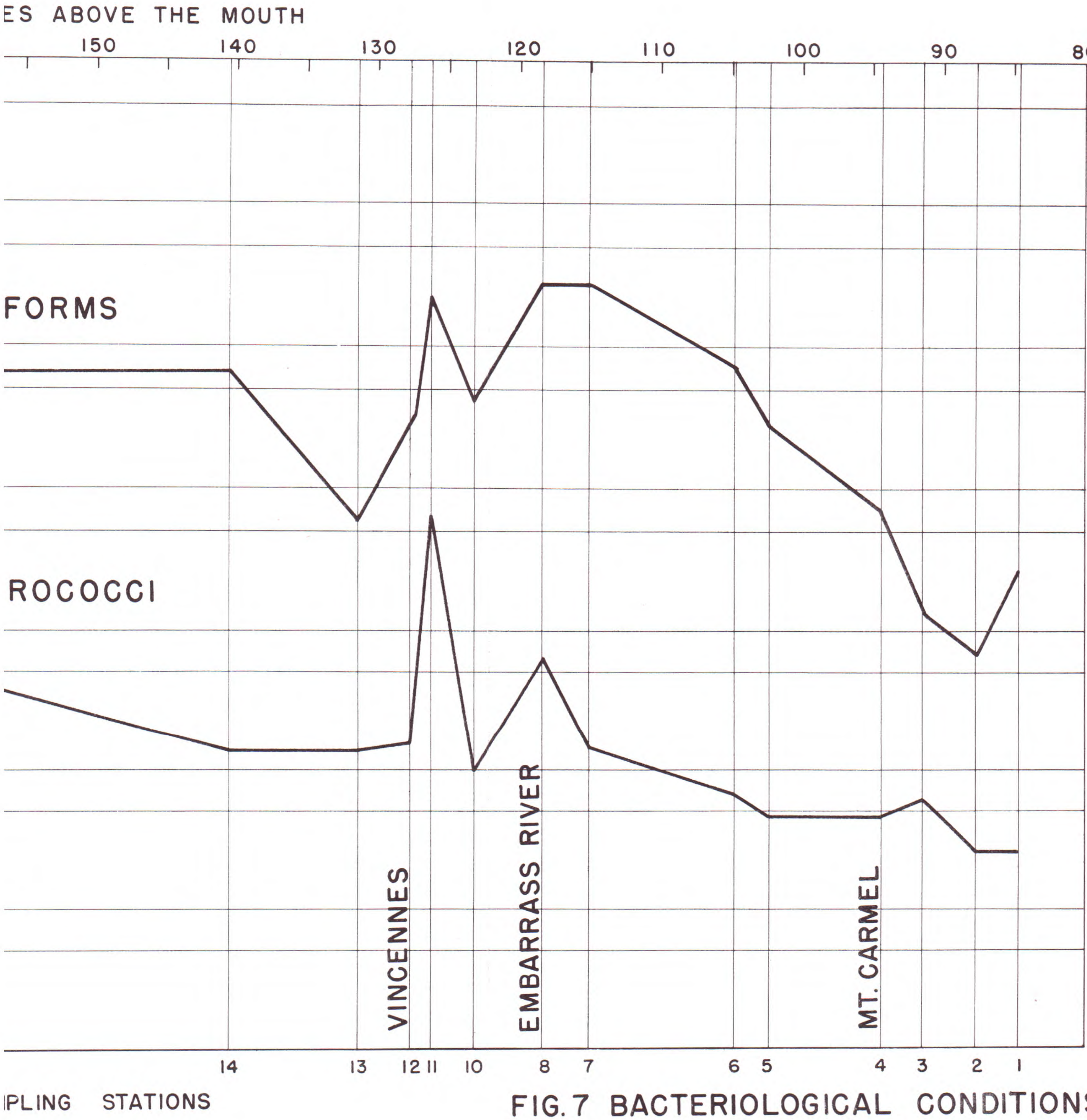


FIG. 7 BACTERIOLOGICAL CONDITIONS IN WABASH RIVER
TERRE HAUTE TO MT. CARMEL
AUG. 22 — SEPT 12, 1949

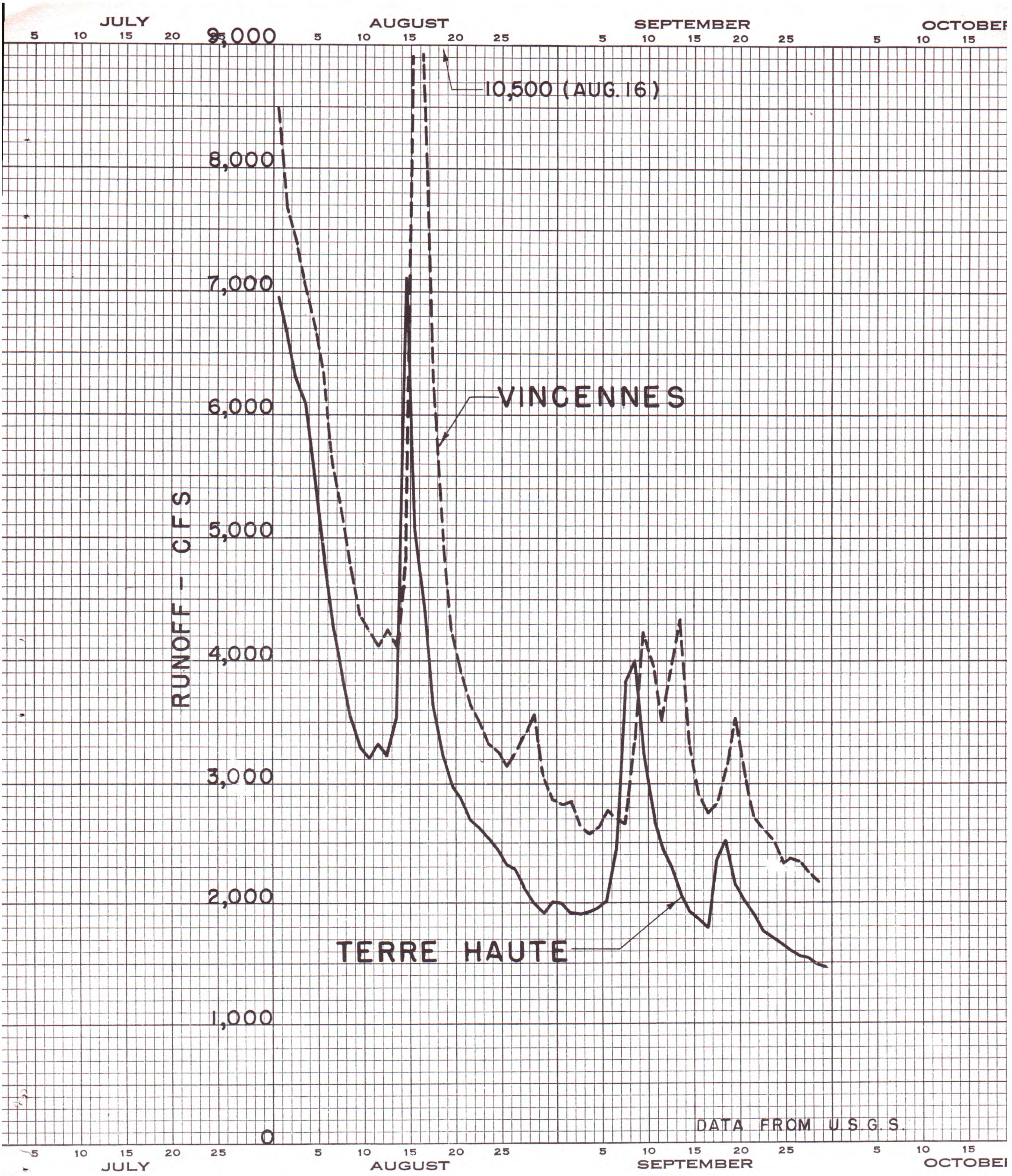


FIG. 8 - DAILY AVERAGE RUNOFF OF WABASH RIVER AT TERRE HAUTE AND VINCENNES (1949)

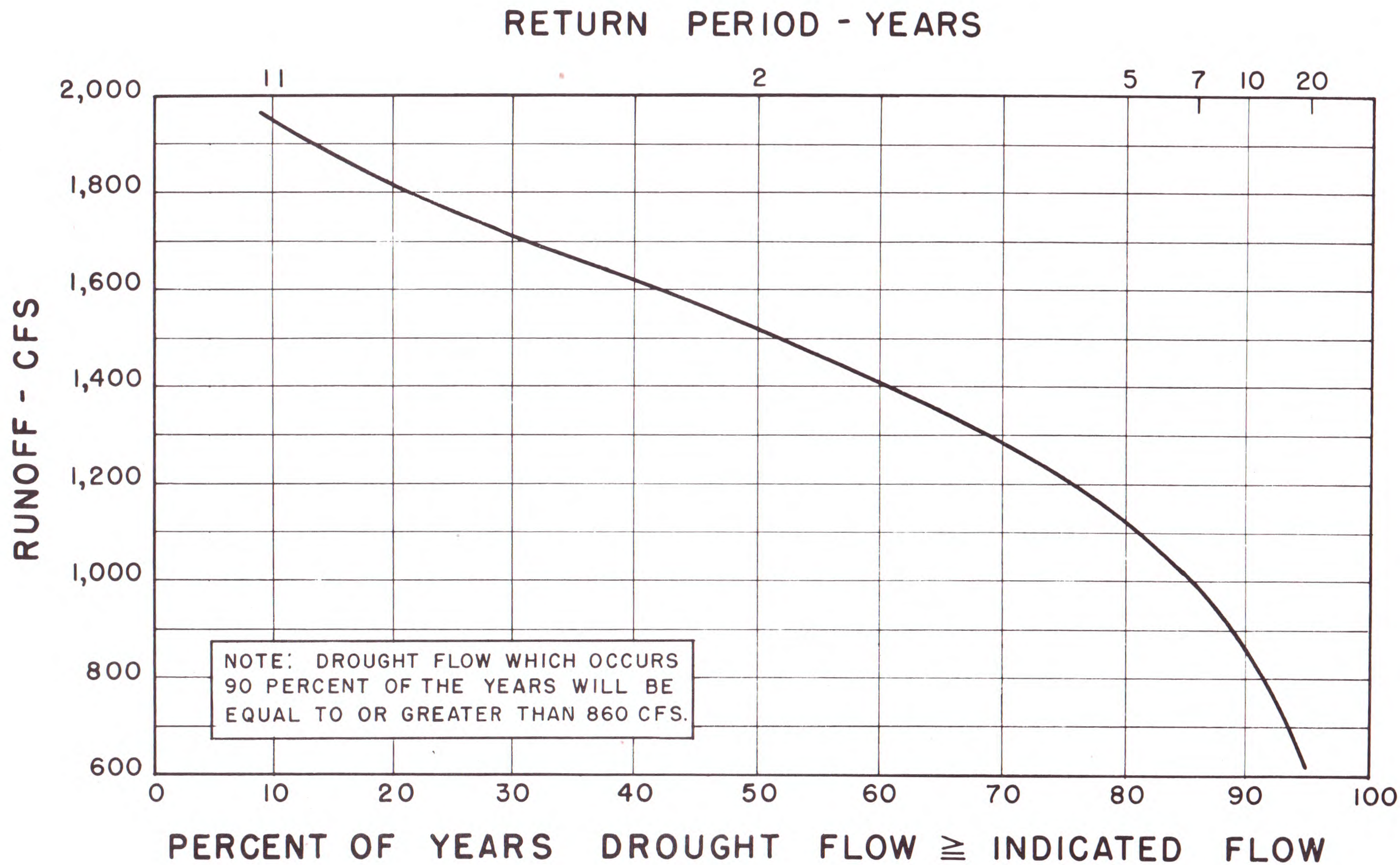


FIG. 9 – FREQUENCY OF DROUGHTS AT TERRE HAUTE

(MINIMUM WEEKLY AVERAGE FLOW)

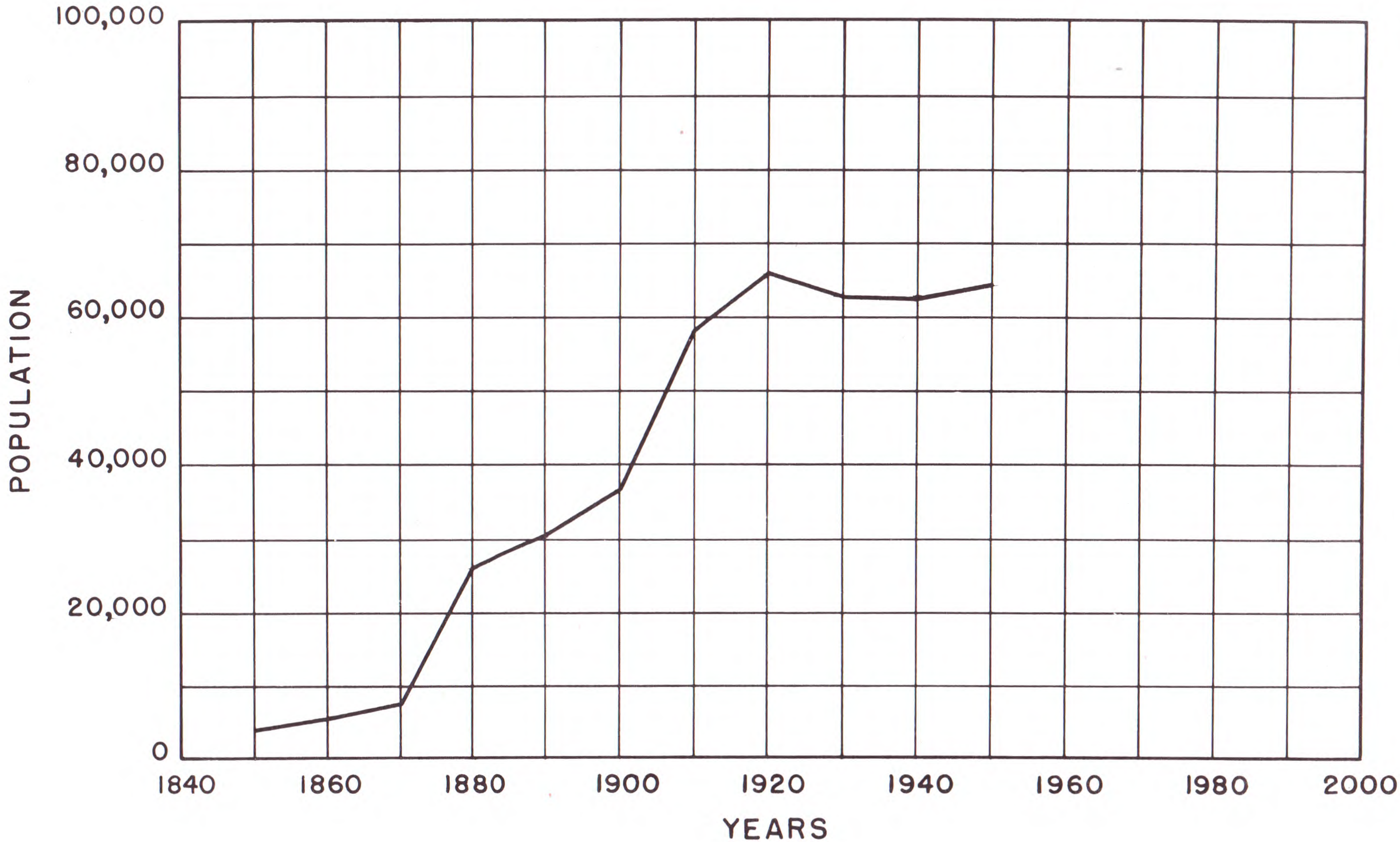


FIG.10-POPULATION OF TERRE HAUTE

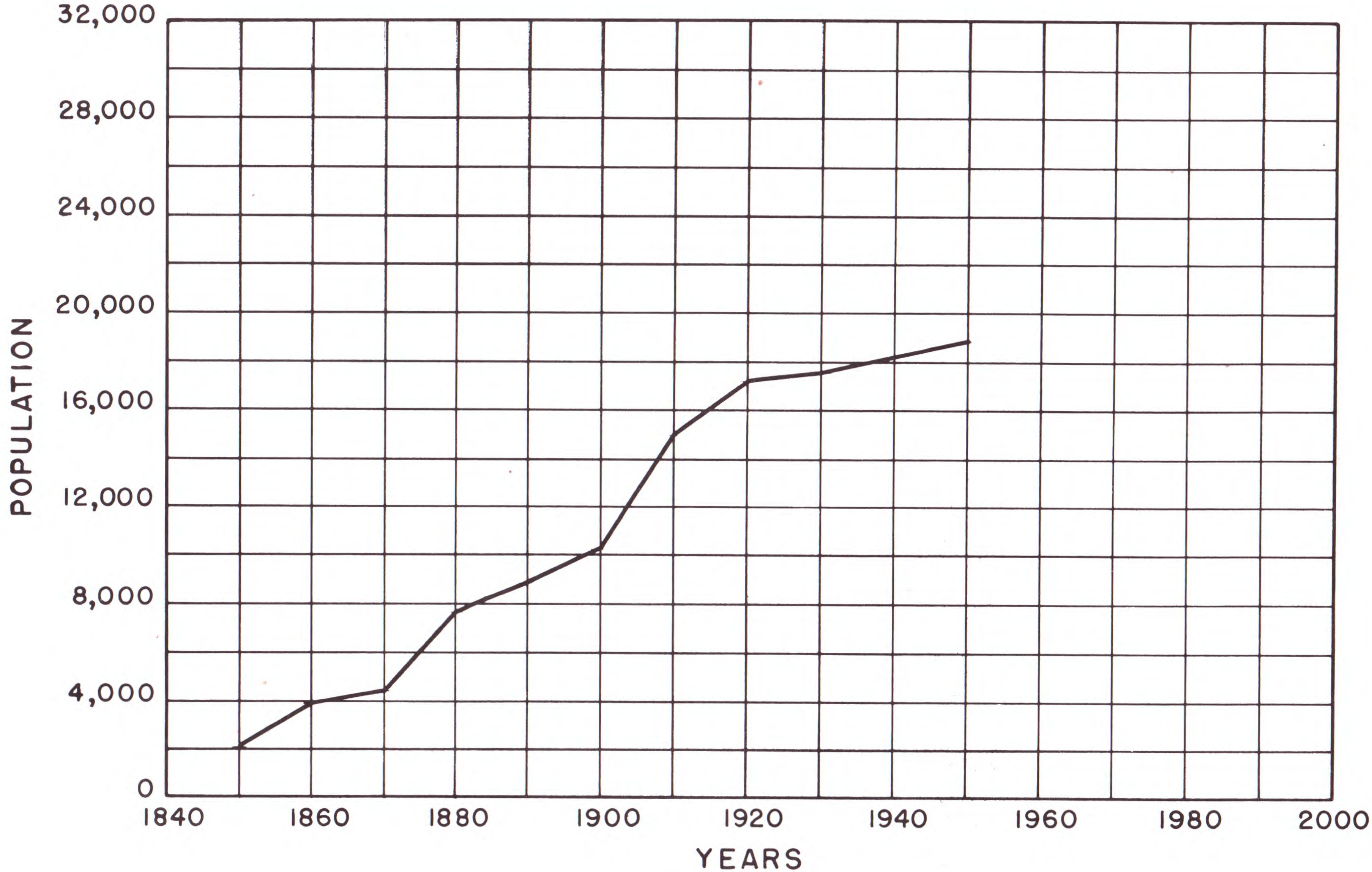


FIG. 11-POPULATION OF VINCENNES

OHIO RIVER VALLEY WATER SANITATION COMMISSION

DATA FROM CENSUS BUREAU

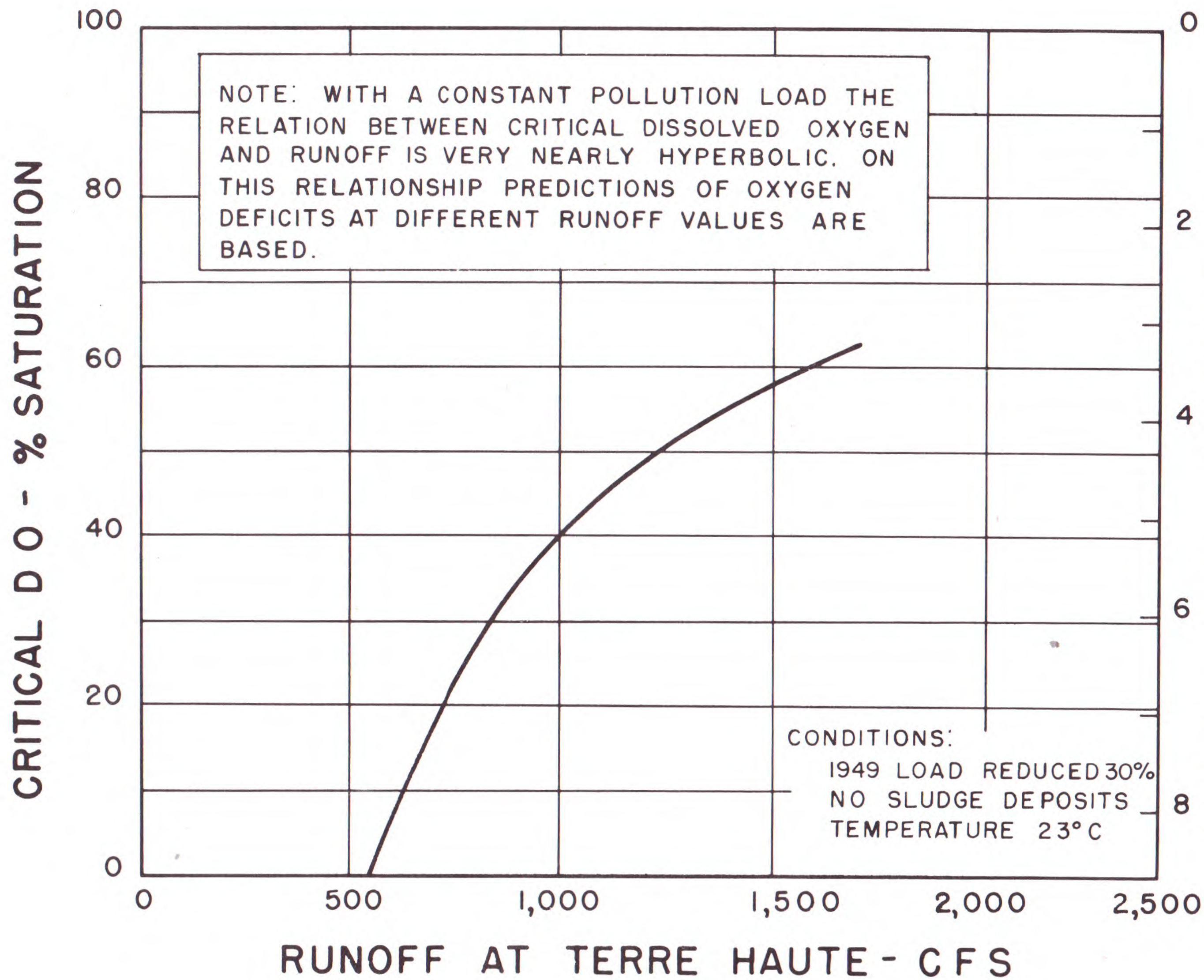


FIG.12-RELATION BETWEEN CRITICAL DISSOLVED OXYGEN AND RUNOFF

OHIO RIVER VALLEY WATER SANITATION COMMISSION

FROM ANALYSIS MADE BY C. J. VELZ

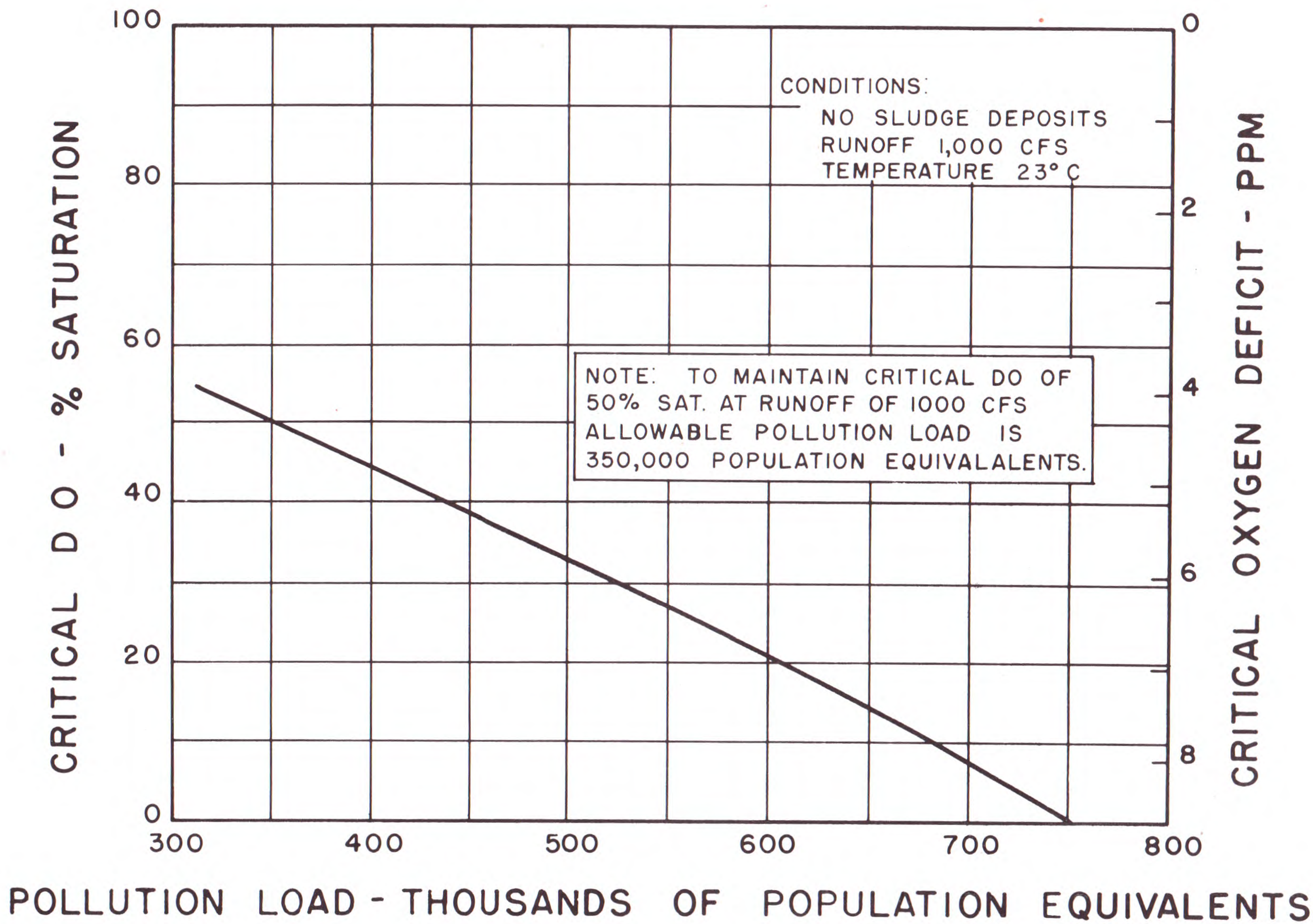


FIG. 13 - RELATION BETWEEN CRITICAL DISSOLVED OXYGEN AND POLLUTION LOAD

OHIO RIVER VALLEY WATER SANITATION COMMISSION FROM ANALYSIS MADE BY

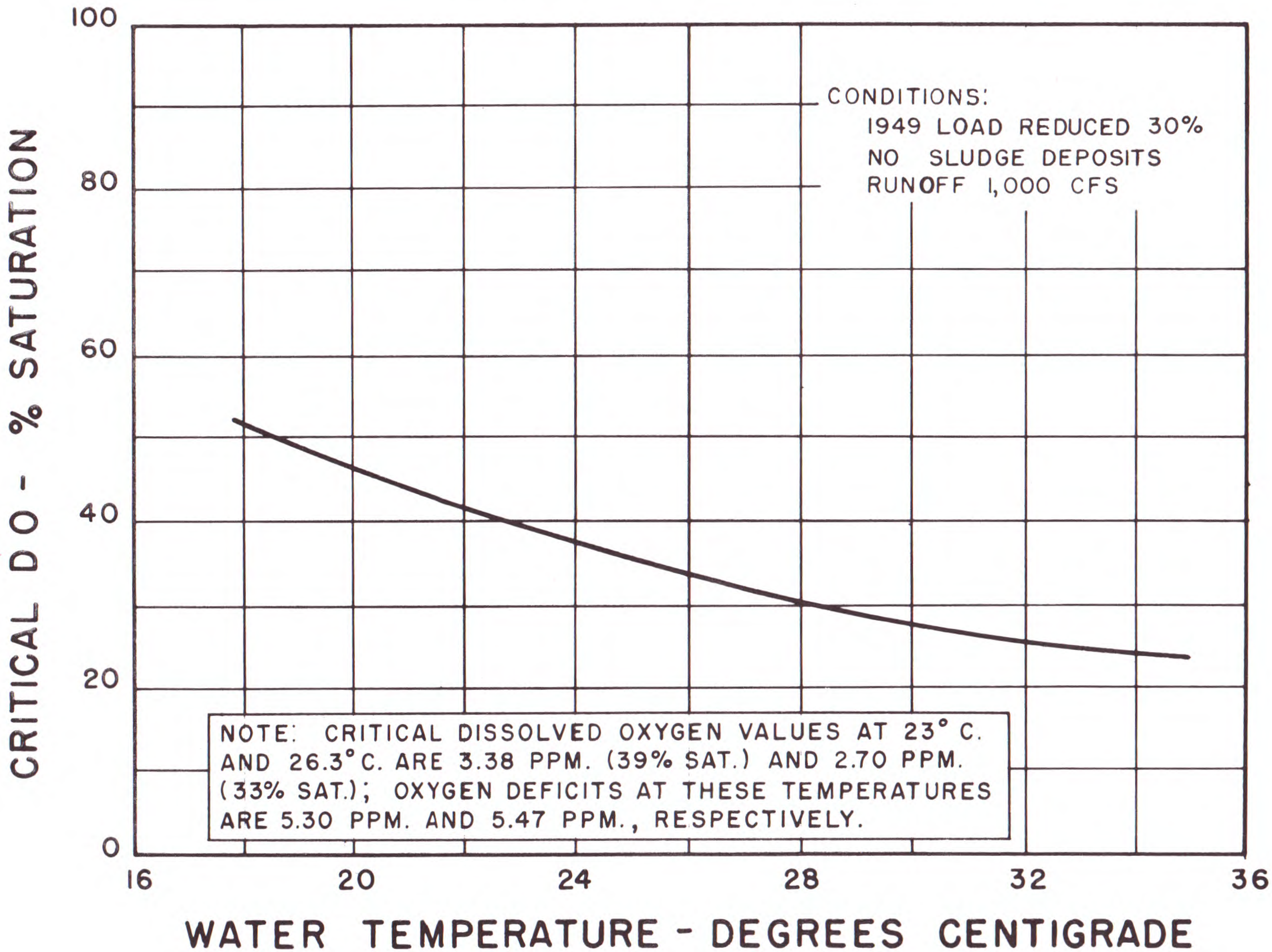


FIG.14-RELATION BETWEEN CRITICAL DISSOLVED OXYGEN AND TEMPERATURE OF RIVER WATER

OHIO RIVER VALLEY WATER SANITATION COMMISSION

FROM ANALYSIS MADE BY C. LVELZ

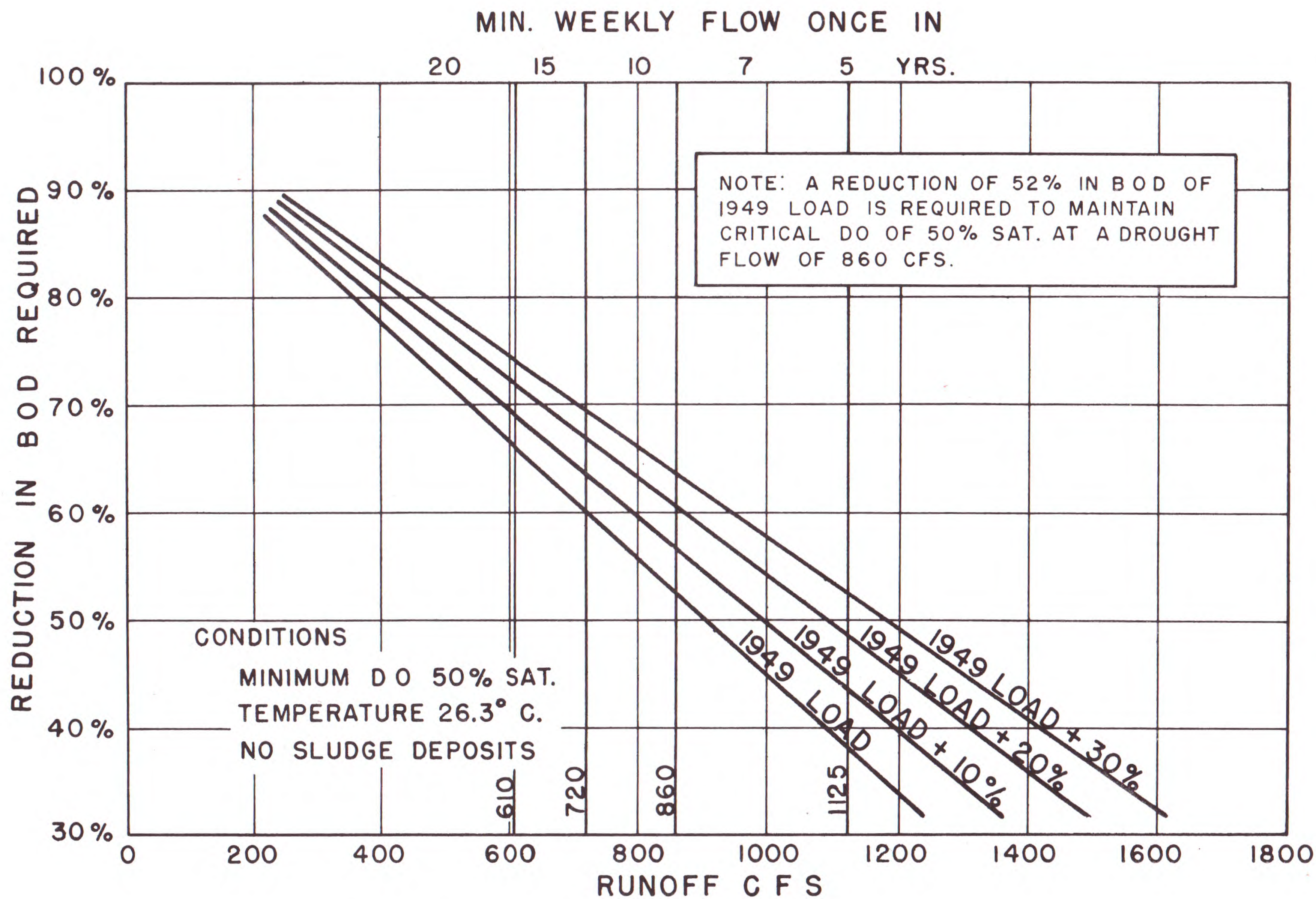


FIG. 15 - DEGREE OF TREATMENT REQUIRED AT TERRE HAUTE FOR VARYING DROUGHT FLOWS

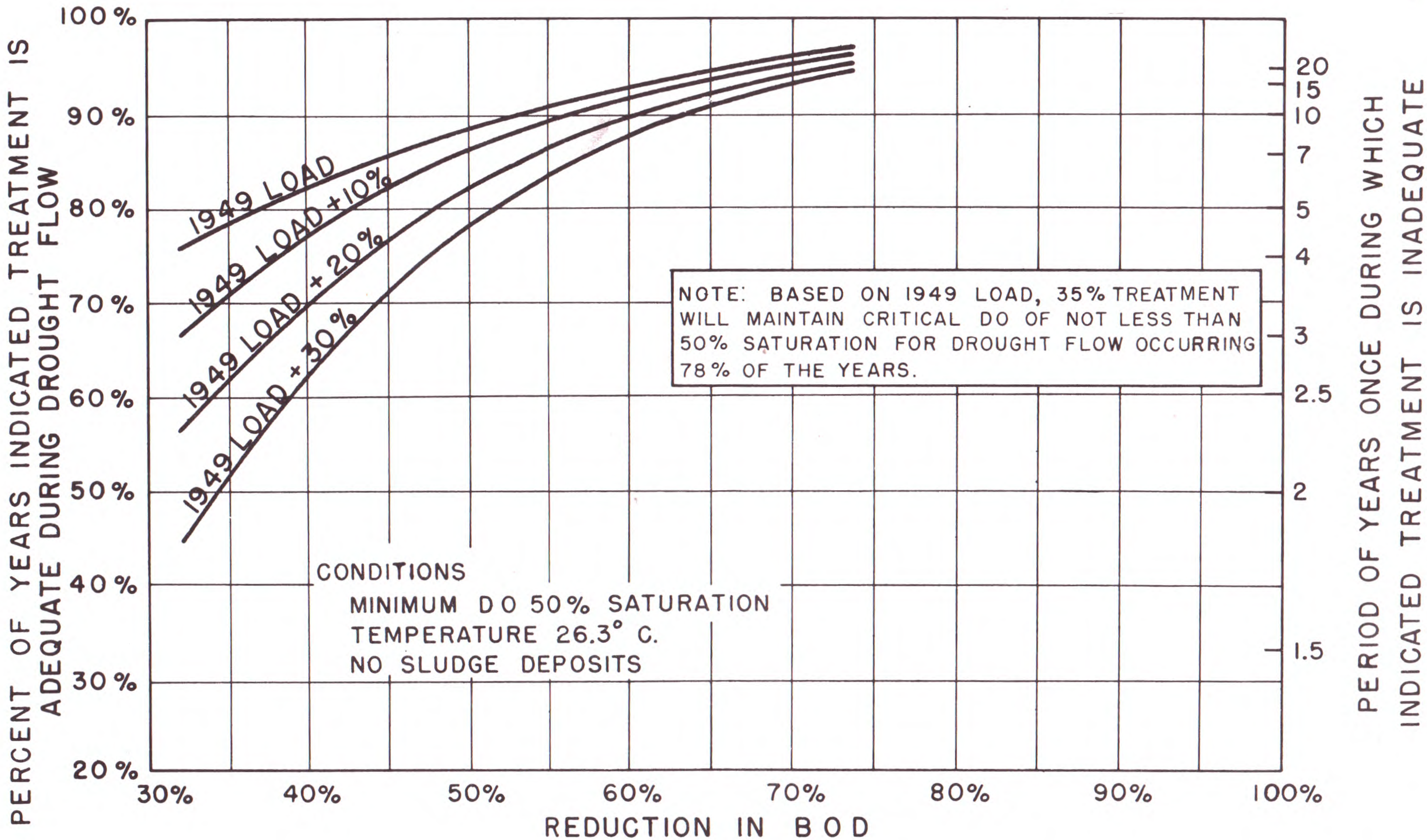


FIG. 16 - PERCENT OF YEARS VARYING DEGREES OF TREATMENT ARE ADEQUATE AT TERRE HAUTE

APPENDIX A

REGULATION SPC-1 OF THE INDIANA STREAM POLLUTION CONTROL BOARD

Pursuant to due publication of notice and public hearing required by the provisions of Chapter 120 of the Acts of the General Assembly of Indiana of 1945, the Stream Pollution Control Board of the State of Indiana at its regular meeting held at 1098 West Michigan Street, Indianapolis, Indiana, the Indiana State Board of Health Building, on November 8, 1945, at which a quorum of said Board was present, unanimously adopted the following regulation:

REGULATION SPC 1

WHEREAS, the Stream Pollution Control Board of the State of Indiana has the power under Section 7, Chapter 214, Acts of 1943, to determine what qualities and properties of water shall indicate a polluted condition of such water in any of the streams or waters of this State, and

WHEREAS, the Board recognizes the fact that the character of all surface water is affected by the mode of life of the people and the activities of industry, and that both the people and industry are dependent on said surface water to a greater or lesser extent, and

WHEREAS, it is recognized that concentrations of population may exist on small streams where diluting water is insufficient to maintain suitable concentrations of oxygen by the use of known and reasonable methods of waste treatment, and

WHEREAS, there is a fair economic balance between cost of treatment of waste and benefits received beyond which it is not reasonable to expend money for treatment, and the cost of treatment and the benefits to be derived must be considered in determining the extent of corrective treatment to be applied, and

WHEREAS, natural purifying agencies in the stream should be reasonably utilized, these agencies consisting primarily of the biology of the stream which is affected by the depth of the water, the velocity of the current, etc., and

WHEREAS, the necessary degree of purity of surface waters depends on the subsequent use which varies on different watersheds and at different points on the same watershed, and

WHEREAS, for the above-named reasons, each stream presents a separate problem and standards may need to be modified to fit specific cases,

BE IT RESOLVED, that in general the following regulations and standards shall be applicable to all receiving waters, and any water which does not meet such standards and properties shall be deemed and considered as in a polluted condition.

1. Floating material including grease and oil shall not be discharged into any surface water in deleterious amounts, or in amounts sufficient to affect injuriously fish life, fur bearing or domestic animal or the general biology of the water, or plant life in or in the vicinity of such water.

2. Waste which is discharged into any water shall contain nothing which will deposit in a stream or a lake to form putrescent or otherwise objectionable sludge banks.

3. Waste which is discharged into any water shall contain no materials in concentrations sufficiently high to affect adversely public health fish life, fur bearing or domestic animals, or plant life in or in the vicinity of such water.

4. Generally the oxygen content of the receiving water, after being mixed with and affected by the waste, shall be no less than 50 per cent saturation. A lower concentration will be tolerated temporarily but only so long as it is not injurious to aquatic life, and in no case shall it fall below 25 per cent saturation.

5. Receiving waters shall be considered unsuitable for bathing if the coliform concentration exceeds 1000 per 100 ml. (MPN.) If the receiving water is used as a source of water supply, a coliform density greater than 5000 per 100 ml. (MPN.) shall not exist at or in the vicinity of the intake. Also in the case of wastes, bearing or producing substances objectionable from a taste or odor standpoint which are discharged into waters which are used as a source of water supply such wastes shall be so treated as to render them unobjectionable before discharge into the stream or lake.

The Technical Secretary is hereby directed to submit three (3) copies of the aforesaid rules to the Attorney General of Indiana, for his approval as to the legality of the same, and to then submit said copies to the Governor of Indiana, for his approval of the same, and thereafter file the original approved copy and one (1) duplicate thereof with the Secretary of State of the State of Indiana, and one (1) duplicate approved copy thereof with the Legislative Bureau of the State of Indiana.

APPENDIX B

PROCEDURES OF ILLINOIS SANITARY WATER BOARD FOR DETERMINATION OF COLIFORMS AND ENTEROCOCCI

COLIFORM TESTS

Presumptive Medium: Lauryl sulfate tryptose lactose broth shall be prepared from Difco dehydrated medium. The final concentration of the broth shall be as described in Standard Methods (9th Ed.) after addition of water sample. For example, a 10 ml. portion of water shall be inoculated into 10 ml. of double strength lactose broth and one ml. or less of sample shall be inoculated into 10 ml. of standard lactose broth (single strength).

Confirmatory Medium: Brilliant Green Bile broth (2%) (Difco dehydrated) shall be used as the confirmatory medium.

Size of Portions: Two 10 ml. portions of sample shall be planted direct and serial dilutions of two tubes each shall be used for as many dilutions as shall be necessary to obtain a satisfactory MPN.

Dilution Water: Standard phosphate dilution water as described in Standard Methods (8th Ed.) p. 156, or Public Health Report 48 - June 16, 1933 pp 81-91.

Dilution Bottles: Bottles conforming to specifications of p. 183, Standard Methods (9th Ed.). The closure may be rubber stoppers, ground-glass or screw top.

Pipettes: Standard 10 ml. transfer pipettes for transferring 10 ml. portions. For 1 ml. and 0.1 ml. portions and for dilutions, pipettes graduated for 1 and 1.1 ml. shall be used.

Presumptive Procedure: Dilutions as explained above shall be inoculated into lauryl sulfate tryptose lactose broth and incubated for 48 hours at 37° C. They shall be read at 24 hours and recorded as + if any gas is contained in the round end of the fermentation tube. Any tube containing gas (or bubble) shall be submitted to the confirmed test. Tubes containing no gas shall be incubated another 24 hours. Any remaining tubes with gas in any quantity at the end of 48 hours are to be confirmed in Brilliant Green lactose bile broth. If no gas is formed in 48 hours, the test is recorded as negative.

Confirmed Test: Presumptive tubes showing gas in 24 or 48 hours shall be confirmed in Difco dehydrated Brilliant Green Bile broth, beginning with the first highest dilution with a solid bank of positives on up. Gas in any amount produced in 48 hours or less incubation at 37° C. shall be recorded as positive (+) and discarded. Absence of gas at the end of 48 hours incubation is a negative test on confirmation.

ENTEROCOCCI TESTS

Media: Consists of the Presumptive Enrichment Medium and the Confirmatory Medium with the latter consisting of a broth portion and a solid part in the same tube. The composition of the media are:

	Presumptive Broth	Confirmatory Slant Broth	Confirmatory Slant Agar
Dextrose	0.5%	0.5%	0.5%
Tryptone	0.5%	0.5%	0.5%
Yeast Extract	0.5%	0.5%	0.5%
Sodium Azide	0.04%	0.04%	0.04%
Sodium Chloride	---	6.5%	---
Methylene Blue	---	0.001%	0.001%
Bromthymol Blue	0.0032%	---	---
Agar	---	---	1.5%

In order to secure uniformity in all participating laboratories, the above media shall be obtained from the Difco Laboratories, Detroit, Michigan as a dehydrated preparation. In the preparation of media from the Difco product, the following quantities of dried ingredients are used per 1000 ml.

Presumptive Broth, single strength	15.4 Gms.
Presumptive Broth, double strength	30.8 Gms.
Confirmatory agar	30.4 Gms.
Confirmatory broth	80.4 Gms.

All media are complete, with the exception of 65 Oxford units per 100 ml. of confirmatory broth.

Presumptive broth of normal strength is tubed in 10 ml. and double strength in 10 ml. quantities. Confirmatory agar is tubed for long slants. The confirmatory broth is sterilized in 50 ml. or 100 ml. quantities.

All media is sterilized at 15 pounds for fifteen minutes.

Add, with aseptic technique, enough confirmatory broth to cover from one-third to one-half of the slant. Inoculate immediately or store in ice box not to exceed one day.

Presumptive Test: The same serial dilutions shall be used as for the coliform tests. Ten ml. of sample shall be planted in 10 ml. of double strength broth. One ml. or less of sample shall be inoculated into 10 ml. of single strength broth.

The media used is Winters and Sandholzer "presumptive enrichment broth".

Presumptive tests shall be incubated at 45.5° C water bath or dry heat incubator for 18-24 hours. The presumptive test is observed for the presence of turbidity and acid in the tube. At times the turbidity is slight and will require careful observation with proper adjustment of transmitted light. Certain acid waters will cause a change of the indicator to the acid range at time of planting. In such cases, turbidity is the single indication of growth. All tubes showing acid and turbidity shall be recorded as positive (+) presumptive test. Those with no growth are negative and the test is completed.

Confirmed Test: The confirmed test is applied to all positive tubes plus any that may be doubtful. The tubes of the positive presumptive test are gently shaken and a standard loop-full of the material inoculated into the confirmatory broth and streaked across the exposed slant. As an alternate procedure, the positive presumptive tube may be refrigerated for about an hour to precipitate the sediment, the supernatent liquid decanted, and the sediment streaked.

The slant-broth confirmatory medium is incubated 18-24 hours at 37° C. A positive test consists of a fine, granular turbidity in the broth, small pin-point colonies on the slant and the presence of large, ovoid gram positive cocci appearing in singles, pairs or short chains. The confirmation is negative unless it meets all these specifications.

The MPN shall be determined in the same way as for the coliform group.