Monongahela River

Sewage-Treatment Considerations

Recommendations, analysis and data for water conservation by pollution control

OHIO RIVER VALLEY
WATER SANITATION COMMISSION

MONONGAHELA RIVER

Sewage-Treatment Considerations

Report prepared as a basis for Commission action regarding sewage-treatment requirements for the maintenance of satisfactory quality conditions at interstate points.

Contents

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January 10, 1959

To the Chairman and

Members of the Engineering Committee

As directed by the Commission in its Resolution No. 18-57, dated October 1, 1957, an investigation has been made of the Monongahela River and recommendations developed with regard to interstate obligations for the treatment of sewage. The following report details the staff findings and conclusions. It is presented to the Engineering Committee for review and with the request that it be transmitted to the Commission along with recommendations of the committee.

Briefly summarized, here are the highlights:

The Monongahela River originates and flows through a part of the State of West Virginia and then crosses into the political jurisdiction of the Commonwealth of Pennsylvania. At Pittsburgh it joins with the Allegheny River to form the Ohio River. The Monongahela contributes more than one-third the total annual flow of the Ohio River at Pittsburgh. Thus, the quality of the Monongahela profoundly influences the quality of the Ohio River as it begins its interstate journey.

It would appear, therefore, that the concern of our Commission is focussed primarily on sewage-treatment requirements that will satisfy Compact obligations at the West Virginia-Pennsylvania boundary line (Monongahela Mi. Pt. 91.2) as well as at the mouth of the Monongahela (Ohio River Mi. Pt. 0.0).

It is the staff conclusion that these interstate obligations would be satisfied if all communities and industries discharging sewage would provide primary treatment. Such treatment is defined in Article VI of the Compact as "substantially complete removal of settleable solids, the removal of not less than forty-five percent of the total suspended solids". Such treatment would provide at the interstate points acceptable dissolved-oxygen levels and bacterial-quality conditions.

This conclusion does not suggest, however, that either West Virginia or Pennsylvania might be satisfied with requirements that provide acceptable conditions only at interstate points. Our findings reveal that there are stretches of the West Fork and Monongahela rivers where primary treatment would fall short of producing acceptable conditions so far as intrastate interests are concerned.

It is not within the purview of our Commission, of course, to concern itself with local conditions that have no impact on interstate affairs. But it would appear quite proper to invite the State of West Virginia and the Commonwealth of Pennsylvania to utilize such findings in this report as may be useful in their determination of sewage-treatment requirements at certain communities. The findings suggest that primary treatment at these places would not suffice to satisfy intrastate aspirations.

This report is restricted to findings and conclusions with regard to sewage discharges as they affect dissolved oxygen and bacterial quality conditions. But in its review of conditions on the Monongahela River, your staff could not be unaware of the degradation suffered by the stream from mine-drainage as well as the indiscriminate discharge of other industrial wastes. It is recommended, therefore, that industrial-waste control be aggressively pursued simultaneously with the installation of sewage-treatment facilities.

Acknowledged with appreciation are the efforts of Commissioner Bern Wright of West Virginia and his staff and those of Commissioner Karl Mason of Pennsylvania and his staff. They facilitated the assembly of certain data and participated in preliminary review of the report.

The evaluation of data and the preparation of this report was carried out by Mr. Robert K. Horton, assistant director, Mr. F. W. Montanari, sanitary engineer, and Col. Harold W. Streeter, staff consultant. Mr. D. A. Robertson, Jr., engineer and hydrologist, assisted in the stream-flow analysis. Mr. Roy Reuter, University of Cincinnati cooperative-graduate student, assisted in the computations.

Respectfully submitted,

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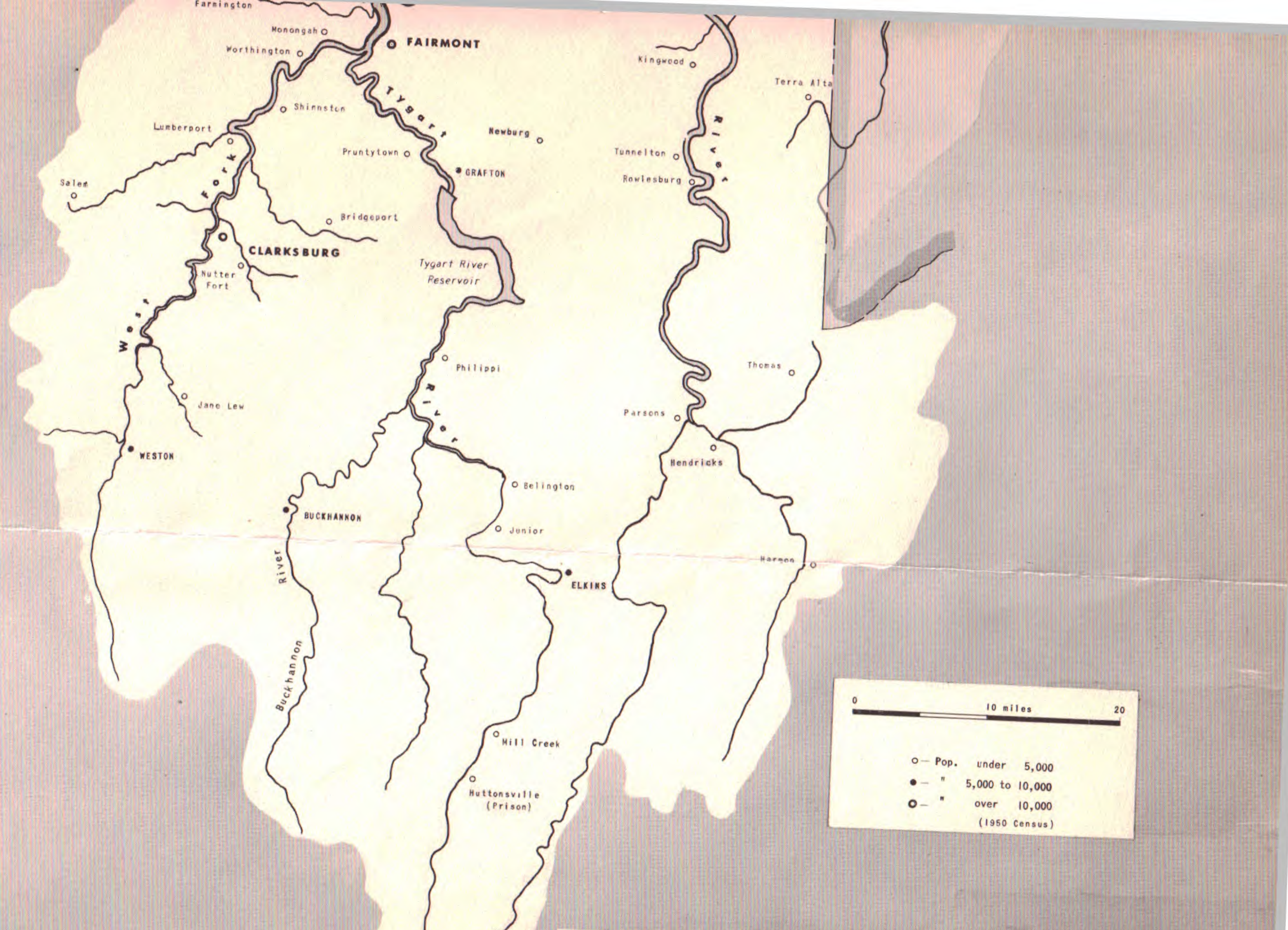

FIG. 1- MONONGAHELA RIVER BASIN MAP.

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PURPOSE AND SCOPE

This report is concerned with an investigation of pollution conditions in the Monongahela River resulting from sewage discharges and with the development of recommendations regarding corrective measures. The investigation was undertaken in accordance with a Commission directive, as set forth in Resolution No. 18-57, adopted October 1, 1957.

The Monongahela River is formed by the confluence of the West Fork and Tygart rivers at Fairmont, W.Va. From this point the river flows in a northerly direction through parts of West Virginia and Pennsylvania for a distance of 129 miles to its mouth at Pittsburgh. The river crosses the West Virginia-Pennsylvania state line at a point 91.2 miles from the mouth. Total area of the Monongahela watershed is about 7,380 square miles.

Major tributaries to the Monongahela, other than the West Fork and Tygart rivers, are the Cheat and Youghiogheny rivers. A map of the basin, showing tributaries and municipal sources of pollution is shown in Fig. 1.

The Monongahela and West Fork rivers serve as a source of water supply for 29 communities with a total population of 644,600 (see Table I). In addition, there are 30 communities with a population of 140,100 using other surface streams in the basin for water supply.

Sewage from a population of 362,700 is discharged directly to the Monongahela and West Fork rivers. Furthermore, these rivers receive discharges from industries and from communities on tributaries whose pollution load is estimated to be equivalent in strength to sewage from another 301,100 persons (see Table II).

Dissolved-oxygen and bacterial conditions evaluated

This investigation was directed toward: (a) an evaluation of quality conditions in the Monongahela -- in terms of dissolved-oxygen levels and coliform-bacterial densities -- under existing pollution loads; and (b) an appraisal of changes in quality that may be expected if all sewage discharges are treated in accordance with the statutory minimum requirements of the Ohio River Valley Water Sanitation Compact.

Acid pollution, which is caused primarily by drainage from coal mines, exerts a marked influence on oxygen levels and bacterial concentrations in the river. The effects of acid conditions, therefore, were taken into consideration in reaching conclusions regarding waste-control measures.

Recommended corrective measures apply only to the control of sanitary-sewage discharges (as referred to in the second paragraph of Article VI of the Compact). Evaluation of detailed requirements relating to the control of pollution from industrial-waste discharges beyond those basic requirements established by the Commission on April 6, 1955 (IW-1) is a matter that requires separate study.

In evaluating conditions in the Monongahela consideration was given to pollutional loads going directly to the river and to the effect of pollution that might reach the river through its tributaries. On most tributaries the major pollution loads are located quite some distance from where the tributary enters the main stem. These loads, therefore, exert only a limiting influence on quality conditions in the Monongahela. For this reason, detailed analysis of each tributary was not considered necessary for the purposes of this report. One exception is the West Fork River, whose condition has a profound influence on the quality of the upper Monongahela River.

In view of the large pollutional loads that are discharged to the West Fork River at Weston and Clarksburg, and because there are times when the flow in the West Fork is extremely small, quality conditions in this stream were evaluated.

From the viewpoint of Commission responsibilities, the primary concern is with the quality of water in the Monongahela at interstate points. One of these is the West Virginia-Pennsylvania state line at mile 91.2. Another is the mouth, because of the effect the Monongahela has on quality conditions in the Ohio River.

DILUTION WATER AVAILABILITY

Stream-flow records from the following U.S. Geological Survey gaging stations were used to determine the quantity and variability of dilution water.

River	Gage	Miles from mouth of Monongahela River	Drainage Area square miles
West Fork	Butcherville, W.Va.	190.0	181
West Fork	Enterprise, W.Va.	141.0	759
Monongahela	Hoult, W.Va.	124.6	2,388
Monongahela	Point Marion, Pa.	90.8	2,720
Monongahela	Greensboro, Pa.	85.0	4,407
Monongahela	Charleroi, Pa.	41.5	5,213
Monongahela	Braddock, Pa.	11.2	7,337

The list includes all gaging stations on the Monongahela and West Fork rivers with the exception of gages at Brownsville, W. Va. and Clarksburg, W. Va. Data for the Brownsville gage were not used in the flow-probability studies because of the relatively short term record available; this gage was not placed in operation until August 1946. The Clarksburg record was not used because it does not include total river flow. This record, since October 1, 1931, shows only the amount of water flowing over the dam at Clarksburg and does not include water diverted for the Clarksburg water supply.

For each gaging station the monthly-average flows were tabulated for the period 1939-55 (1955 is the latest year for which a complete record is available). Tygart River Reservior was placed in operation in 1938; therefore, by using only flow records since 1938 it was unnecessary to adjust gage readings for low-flow augmentation resulting from the operation of this reservoir.

Adjustments for the effect of the Youghiogheny River Reservoir on the Braddock gage were necessary, however, since this reservoir did not go into operation until 1948. The Braddock record was adjusted by adding 500 cfs (cubic feet per second) to flows occurring in the months of June through October during the years 1939-1947. This adjustment was made in accordance with information supplied by the U.S. Corps of Engineers regarding the effective period of low-flow augmentation and magnitude of increased flows. Thus, adjusted flows indicate what runoff values would have been if low-flow regulation had been in effect at the time gagings were taken and which can be expected to prevail in the future.

Flow-duration curves

From tabulations of the monthly-average flows duration curves were constructed for each gaging station. These curves, presented in Fig. 2, show the magnitude of flow that may be expected for any selected frequency of occurrence. Use of the curves may be illustrated by pointing out that at Point Marion, for example, flows equal to or less than 860 cfs may be expected 10 percent of the time; or to state this another way, flows equal to or greater than 860 cfs may be expected 90 percent of the time.

Estimates of time-of-flow used in the investigation of oxygen and bacterial conditions were developed from information supplied by the U.S. Corps of Engineers. For the Monongahela main-stem (Fairmont to mouth) it was possible to develop velocity curves on the basis of volumetric-displacement computations together with field measurements in some stretches. These curves are shown in Fig. 3.

Velocity information developed for the Monongahela River at Fairmont was used in investigating quality conditions in the West Fork River above Fairmont, with one modification. A minimum velocity of 0.14 miles per hour (0.2 ft. per second) was used instead of a value of 0.055 miles per hour (0.081 ft. per second), which is encountered during low flows in the Monongahela at Fairmont. This adjustment recognizes that the West Fork is steeper in slope than the Monongahela.

The proportionate amount of total flow in the Ohio River that is contributed from the Monongahela River basin was determined. Results of this determination, which are presented in Table III, show that yield from the Monongahela basin accounts for about 38 percent of the flow in the Ohio immediately below Pittsburgh.

ACID CONDITIONS

An appraisal was made of acid conditions -- as reflected by pH measurements -- in the Monongahela River. Available information included: Data from a 1940 survey by the U.S. Public Health Service (House Document 266, 78th Congress, 1st Session); analyses from Commission-sponsored monitor stations at South Pittsburgh Water Company and Point Marion, Pa.; analyses from a third monitor station at Charleroi, Pa. (operated jointly by Pennsylvania and U.S. Geological Survey); and information from records of the Morgantown, W. Va. and McKeesport, Pa. water plants.

To aid in the interpretation of this data Table IV and Fig. 4 were prepared. In Table IV are shown maximum and minimum pH values at each sampling station; median pH values are also given for some stations. Data from the 1940 survey, which extended over the entire Monongahela basin, reflects conditions during the months of May through December.

Samples were obtained at intermittent intervals during the 1940 survey and not all stations were sampled with the same frequency. At mile points 90.0 (Point Marion) and 84.8 (Greensboro) a total of 20 samples were taken during the eight months; this is the largest number of samples taken at any station. At some stations only three samples were taken during the survey period (median pH values for these stations are not shown in Table IV).

Records from Commission monitor stations and those available from water plants are based on the following sampling-and-analysis schedule:

Morgantown -- Daily analyses for a two-year period August 1, 1956 through July 31, 1958, except for the months of March and April, 1958 (when no analyses were made) and a few scattered days in other months.

Point Marion -- Daily samples, analyses on 10-day composites continuously for two years, 1956-57.

Charleroi -- Daily samples, analyses on 10-day composites continuously for one year, 1957.

McKeesport -- Daily analyses for two years, 1952-53.

South Pittsburgh -- Daily analyses for two years, 1956-57.

There is a long span of years between the 1940 survey and the results obtained during the 1956-57 sampling period. Also, there were differences in frequency and number of samples collected. It is of interest to observe, however, that the data show the pH values were within the same range at Point Marion, Charleroi and South Pittsburgh during both periods (see Table IV).

pH values and their frequency of occurrence

The data from the monitor stations and water plants was sufficient to permit construction of frequency-of-occurrence curves. These are shown in Fig. 4. To illustrate use of these curves it may be pointed out that at South Pittsburgh a pH of 6.0 or less may be expected 80 percent of the time; or to state this another way, a pH of 6.0 or higher may be expected only 20 percent of the time.

Findings of the Commission's Aquatic Life Advisory Committee indicate that stream biota are adversely affected when the pH is depressed below a value of 5.0 ("Aquatic Life Water Quality Criteria," Sewage and Industrial Wastes, March 1955, p. 321). On this basis, then, the Monongahela River throughout most of its length must be considered an unsatisfactory habitat for aquatic life.

At the time of the 1940 survey, acid conditions (pH less than 5.0) were found to exist in the lower 145 miles of the river (see Table IV). On occasion values near neutrality (pH 7.0) were observed at most stations in this stretch, but median values were in the range of 3.4 to 5.3.

It is revealed in Fig. 4 that acid conditions are worse at Point Marion -- just below the West Virginia-Pennsylvania state line -- than at any other station for which data are available. In 1956-57 one of 72 samples taken at Point Marion had a pH of 5.0; the pH of all other samples was lower. Conditions at Charleroi and McKeesport are only slightly better; for about 90 percent of the time the pH values at both of these places were less than 5.0.

It is established that the primary source of acid reaching the Monongahela River is drainage from coal mines. In the 1940-survey report the amount of acid reaching the river from this source was estimated to be 646,000 tons per year.

While there are hopeful signs that measures for the control of mine-drainage will be more aggressively pursued with resultant amelioration of acid condtiions in the stream, it seemed prudent to evaluate sewage-treatment requirements on the basis of prevailing conditions. When acid conditions are ameliorated the requirements for sewage treatment may claim re-evaluation.

OXYGEN CONDITIONS

Estimated BOD (biochemical-oxygen-demand) loads now being discharged into the Monongahela River are shown in Table II. The data has been grouped to indicate specific river stretches, each beginning and ending with a significant source of pollution. The data in the table for each area or locality represents total known and estimated loads, including those from municipal sources as well as those from industrial sources that are discharged either through community sewers or directly to the river.

The data in Table II has been approved by the pollution-control agencies of West Virginia and Pennsylvania as representing their best estimates -- both in terms of contributing population and population equivalent -- of current pollution loads. Each state agency supplied information on the basis of which the detailed 1940 load figures, as reported by the Ohio River Pollution Survey of that year (House Document 266, 78th Congress), were brought up to date.

Effect of acid pollution

In this evaluation of oxygen depletion, it was recognized that certain critical conditions are now masked to considerable extent by the presence of acid pollution. Findings of the 1940 survey (House Document 266) with regard to the effect of acid on biological life in the river are summarized as follows: "The acid condition of the main stream of the Monongahela renders it nearly devoid of plankton or fish life, except where clean tributaries join the main stream. The tributaries, Ten Mile Creek and Pigeon Creek, support a fair plankton and fish population." Additional findings on the effects of acid -- particularly with regard to reduced bacteriological content of the river -- are discussed in a subsequent section of this report.

It is reasonable to assume that the reduction in biological population in the river exerts an inhibiting influence on biochemical-oxidation reactions. This means that in acid stretches less of the oxygen demand is satisfied than would be satisfied under non-acid conditions. The tendency, therefore, would be for dissolved oxygen in the river to remain at levels higher than those that would be maintained if oxidation proceeded at normal rates.

In view of this, it was decided to evaluate conditions first on the basis of normal rates of oxidation. A finding of satisfactory conditions would mean, therefore, that further evaluation regarding rates of oxidation under acid conditions, which could be measured only by field observations, need not be undertaken.

It is recognized that part of the oxygen demand of wastes discharged to acid stretches may be carried downstream to be satisfied in stretches that are not affected by acid. Fundamental research has never been directed toward determining what this delayed-action effect may mean in terms of oxygen levels in the stream. However, this delayed-action effect does not appear to be of any practical significance in the present study, because oxygen resources are abundantly available in the Ohio River below the point where the effects of acid are exhibited and where there is a normal population of biological organisms (see Commission publication: "Ohio River Pollution-Abatement Needs -- Pittsburgh-Huntington Stretch," 1953).

Oxygen conditions are most critical during times of low flow and high temperature. For purposes of this investigation, the one-percent flow, which may be defined as the flow that is exceeded 99 percent of the time, was selected for evaluation of critical conditions. Values of the one-percent flow at the several gaging stations are as follows (see Fig. 2): Butcherville, 1 cfs; Enterprise, 26 cfs; Hoult, 390 cfs; Point Marion, 420 cfs; Greensboro, 500 cfs; Charleroi, 600 cfs; Braddock, 1,350 cfs.

Computation of oxygen profile

A profile showing dissolved-oxygen concentrations in the Monongahela River at the one-percent flow is given in Fig. 5. The profile was computed from pollution loads shown in Table II; it should be noted that these loads include sewage and organic wastes discharged directly to the Monongahela as well as wastes discharged within the first 20 miles of each tributary. For converting load figures in terms of population equivalents to pounds of BOD, a factor of 0.25 lb. per day of first-stage BOD per population equivalent was used.

Computation of the oxygen profile involved the application of relationships developed by Streeter and Phelps ("A Study of the Pollution and Natural Purification of the Ohio River," Public Health Bulletin No. 146, 1925). For computing the amount of BOD remaining at a location downstream from a point of waste discharge, the formula is as follows:

$$\text{Log } L' - \text{Log } L = -k_1 t$$

in which
- L = BOD at upper point
- L' = BOD at lower point
- k_1 = deoxygenation coefficient
- t = time of flow in days

Dissolved-oxygen values were calculated using the Streeter-Phelps "oxygen-sag" equation. The river was divided into sections, each beginning and ending at a known source of pollution. Initial BOD values for each section included BOD remaining from the upstream section, and these values were adjusted for added pollution or dilution. Dissolved-oxygen content remaining at the end of each section was taken as the initial dissolved oxygen for the next section downstream.

Values used for the deoxygenation coefficient, k_1, and the re-oxygenation coefficient, k_2, were as follows: $k_1 = 0.12$; and $k_2 = 0.15$. These values reflect reaction rates under non-acid conditions. They were selected on the basis of previous Ohio River studies as corresponding to summer-flow conditions, when average temperature in the Monongahela is 24 degrees Centigrade and the river is in pool.

Solution of the oxygen-sag equation was facilitated by use of nomographs developed by Colonel Streeter and published in Sewage Works Journal, September 1949, page 884. Computed data from which the oxygen profile was plotted is shown in Table V. The table shows BOD and DO (dissolved oxygen) values at the beginning and end of each river section, as well as the minimum DO value in each section.

In constructing the profile shown in Fig. 5, it was estimated that dissolved-oxygen content of the Tygart River at its point of confluence with the West Fork River would not be less than 6.5 ppm (76 percent saturation at 24 degrees Centigrade). This is a conservative estimate; data from a study made in 1940 show DO values at the mouth of the Tygart ranging from 93 to 101 percent saturation.

A similar value of 6.5 ppm was used as the initial DO content (before the addition of pollution loads) of downstream tributaries as they entered the Monongahela. With regard to the West Fork River, the assumption was made that this river in the stretch between Weston and the confluence with the Tygart should not be permitted to become completely devoid of oxygen. The basis for this assumption is discussed in the following paragraphs.

Oxygen conditions at critical flow and temperature

A study of conditions in the West Fork River revealed that at extremely low flows -- such as the one-percent flow -- dissolved oxygen in the river could be completely depleted if deoxygenation and reoxygenation proceed at normal rates. The pollution loads from Weston and Clarksburg, 52,300 population equivalents, are simply too great for assimilation by a flow of from one to 26 cfs. This leads to the conclusion that a high degree of treatment, in terms of BOD removal, is required for sewage discharged from these two communities.

Since the West Fork River lies entirely within West Virginia, the decision on the degree of treatment for sewage discharged at Weston and Clarksburg is the prerogative of the State of West Virginia. However, it seems reasonable to assume that the state will establish a degree of treatment high enough to prevent complete exhaustion of oxygen resources in the West Fork. And it is on this basis that oxygen conditions in the Monongahela were evaluated.

The profile shown in Fig. 5 indicates that acceptable oxygen levels may be expected, even at low river flow, throughout the Monongahela from its point of origin at the confluence of the West Fork and Tygart rivers to the mouth at Pittsburgh. Dissolved-oxygen content at the state line is near saturation (8.53 ppm at 24 degrees Centigrade). And at the mouth the profile shows a value of 5.5 ppm.

Below the West Virginia-Pennsylvania state line, low point in the profile is a DO content of about 4 ppm. This low value is produced by the pollution loads at Clairton and McKeesport. Although a value of 4 ppm may be less than ideal, it is not considered inadequate.

Conclusions

On the basis of the foregoing analysis, the following conclusions are reached:

(a) Treatment of sewage now being discharged to the Monongahela River in accordance with the minimum degree of treatment specified in the Compact will insure the maintenance of adequate oxygen concentrations at points of interstate concern; and

(b) A degree of treatment greater than primary is required for sewage discharged to the West Fork River -- notably for discharges from Weston and Clarksburg -- so that West Virginia can achieve satisfactory conditions in the river as measured by dissolved-oxygen content.

BACTERIAL CONDITIONS

Because of acid conditions in the Monongahela River the bacterial concentrations are below levels that might otherwise be expected to result from known discharges of sewage and from the normal action of natural purification. Because of these conditions the required degree of sewage treatment to secure bacterial reduction is less than otherwise would be indicated. The effect of acid on bacterial concentrations has been taken into consideration in the following analysis.

For purpose of estimating coliform concentrations under various conditions of pollution loads and river flow, liberal use was made of information developed in previous studies regarding per capita contributions of coliform organisms. The classic reference in this specialty of sanitary science is Public Health Bulletin No. 143 (July 1924), titled: "A Study of the Pollution and Natural Purification of the Ohio River." From exhaustive laboratory and field observations made in 1914-16, Streeter, Hoskins, et al determined that in non-acid stretches of the river the relationship during the summer season between coliform densities in the river and contributing population can be expressed as follows.

$$\text{Coliform density, in terms of MPN per 100 ml} = \frac{14 \times \text{contributing population}}{\text{river flow (in thousands of cfs)}}$$

Another way of expressing the relationship is: With a river-flow unit of 1,000 cfs, the per capita contribution of coliforms, in terms of MPN per 100 ml in the river, is 14.

Effect of acid pollution

In a study made by our Commission in 1953 on sewage-treatment requirements in the upper Ohio River the effects of acid pollution on coliform densities were again evaluated with the collaboration of Colonel Streeter. In those stretches of the Ohio that are subject to acid pollution it was found that coliform densities are only one-tenth the densities that might be expected from populations of equivalent size with discharge to non-acid stretches.

Expressed in terms of per capita contributions, it was determined that coliform densities in the extreme upper portion of the Ohio were about 1.5 per capita, as compared to 14 per capita in non-acid stretches downstream. At times the densities observed in the upper portion of the river ranged up to 3.0 per capita, but these greater densities occurred when river flow was high and acid concentrations were somewhat reduced.

For purposes of the present study, the value selected for the per capita contribution of coliforms was 1.5 MPN per 100 ml in the river at a flow of 1,000 cfs. This is the lower of the two values observed in the upper Ohio River. Use of the lower value is justified because acid conditions prevail in many stretches of the Monongahela for 90 percent of the time or more (see Fig. 4).

Findings from the upper Ohio River studies indicate that although acid conditions reduce the initial concentration of coliforms produced by sewage discharges, the rate of coliform die-away below points of maximum concentration is about the same in acid stretches as in non-acid stretches. On the basis of this finding die-away curves previously developed for non-acid stretches of the Ohio have been used in evaluating Monongahela River conditions.

The die-away curves used in the Monongahela study are reproduced in Fig. 6. They are based on the fundamental work of Streeter and his colleagues reported in Public Health Bulletin 143.

Coliform levels in the Monongahela were developed for varying flow conditions on the basis of the following information: Per capita contribution of coliforms, rates of die-away and pollution loads in terms of present contributing population as shown in Table II. There are no field observations available against which these estimates may be checked. However, the validity of this method of estimating is substantiated by the correlation of calculated and observed data that was shown to exist in the upper Ohio River under acid conditions and using the same values for per capita contribution and rates of die-away (see Commission publication: "Ohio River Pollution-Abatement Needs -- Pittsburgh-Huntington Stretch," 1953).

Coliform densities at low flow

Estimated coliform densities under low-flow conditions, in the form of a coliform profile, are shown in Fig. 7. For construction of the profile the one-percent flow value at each gaging station was used (see duration curves, Fig. 2). Die-away values were taken from the "summer" curve in Fig. 6, because low flows ordinarily occur during the warm months. Data from which the profile was plotted are given in Table VI.

The one-percent flow is the smallest flow selected for the analysis of coliform conditions in the present study; analyses could be made, of course, at any desired frequency of flow. The one-percent flow corresponds approximately to the minimum monthly-average flow that may be expected to occur once in ten years.

Coliform densities at high flow

Coliform conditions were also evaluated at high river flows. Studies on the Ohio River have shown that coliform densities some distance below a point of discharge may actually be greater at high flows than at low flows. The reason is this: Although the dilution is increased the time-of-flow is reduced and there is less opportunity for die-away.

High flows of varying magnitude were selected for study. Coliform profiles were constructed for flow values having the following frequency of occurrence at each gaging station (see Fig. 2): 99, 95, 90, 80, 70, 60, 50 percent. Since high flows occur normally during the winter-spring season, the profiles were based on rates of die-away shown by the "winter" curve in Fig. 6.

Examination of the several high-flow profiles reveals that coliform densities are greatest throughout most of the river at the 95-percent flow. The profile showing conditions at this flow is presented in Fig. 8.

The patterns of coliform variation under extreme high flow (Fig. 8) and extreme low flow (Fig.7) are quite different. The low-flow (summer) coliform profile is characterized by sharp rises and drops; under high-flow conditions, however, coliform densities remain at a fairly uniform level throughout the river.

Bacterial-quality objectives

As a guide for evaluating quality of water used for potable supplies, the Commission on April 4, 1951 adopted the following objective: The MPN (Most Probable Number) of coliform organisms should not exceed 5,000 per 100 ml. Judged by this criterion the bacterial quality conditions in the Monongahela are more critical at low flows than at high flows.

In some areas water-supply intakes are relatively close to points of sewage discharge. Consequently there is little opportunity for the forces of natural purification to exert their effect in reducing coliform densities. Areas that appear to be most critical in this respect are: The 50-mile stretch of the West Fork River from Weston to Spelter; and the lower 43 miles of the Monongahela, from Charleroi to the mouth (see Fig.7).

With regard to points of interstate concern -- namely, the state line at mile 91.2 and the mouth -- the profiles show that conditions are satisfactory at both high and low flows. Under high-flow conditions the coliform concentrations at both points are only slightly in excess of the 5,000-per-100-ml criterion. If primary treatment of sewage above these points is provided this would reduce concentrations below the 5,000 level.

Under summer low-flow conditions bacterial quality at both places of interstate concern is not unfavorable. Concentrations are well below 5,000; in fact, they are near or below 1,000 coliforms per 100 ml.

It might be pointed out that an MPN of 1,000 is considered suitable for recreational bathing, on the basis of quality objectives previously adopted by the Commission. But it must also be recognized that although bacterial quality may be suitable, there are other types of pollution -- notably acid discharges -- that hinder exploitation of the recreational use of the river.

Conclusions

On the basis of this investigation, the following conclusions are reached:

(a) Treatment of all sewage in accordance with the minimum degree of treatment specified in the Compact should insure maintenance of adequate bacterial quality at points of interstate concern;

(b) The State of West Virginia and the Commonwealth of Pennsylvania may wish to establish sewage-treatment requirements higher than the Compact minimum in order to achieve satisfactory conditions in so far as intrastate interests are concerned.

CONCLUSIONS AND RECOMMENDATIONS

This investigation was made for purposes of evaluating pollution conditions resulting from sewage discharged to the Monongahela and West Fork rivers and for determination of remedial measures in terms of sewage-treatment requirements.

Recommendations resulting from the investigation reflect the following considerations: First, sewage discharges originating within one signatory state shall not injuriously affect water uses in another state; second, waters of the Ohio Valley Compact district shall be placed and maintained in a satisfactory sanitary condition, in accordance with the provisions of Article I of the Compact.

Quality conditions were evaluated in terms of estimated dissolved-oxygen levels and coliform-bacterial concentrations at river flows of varying magnitude. From this analysis the following conclusions are reached:

1. Treatment of existing sewage discharges to the Monongahela River (which is formed by the confluence of the West Fork and Tygart rivers) in accordance with the minimum degree of treatment specified in the Compact should insure the maintenance of adequate sanitary quality at points of interstate concern. One point of interstate concern is the West Virginia-Pennsylvania state line at Mile 91.2. Also of interstate concern is the quality of water at the mouth of the Monongahela and its consequent effect on conditions in the Ohio River.

2. Sewage discharged in West Virginia to the West Fork River -- notably from Weston and Clarksburg -- requires something more than primary treatment to achieve satisfactory conditions in the West Fork River as measured by dissolved-oxygen content and coliform bacteria concentrations.

3. To meet local needs with regard to water supplies taken from the Monongahela River at points below certain sewage discharges in Pennsylvania, the sewage-treatment requirements at these places should be somewhat more stringent than those which are necessary to satisfy interstate necessities alone.

Recommendations

It is recommended that:

1. The Commission take such action as will express approval from an interstate point of view, of a program in which all sewage discharged into the Monongahela River is treated so as to provide for substantially complete removal of settleable solids and the removal of not less than 45 percent of the total suspended solids.

2. The State of West Virginia and the Commonwealth of Pennsylvania be invited to utilize such findings in this report as they may find useful in establishing sewage-treatment requirements at certain communities where local conditions claim separate consideration.

3. Quality conditions in the Monongahela River be re-evaluated at periodic intervals, notably with regard to water-quality changes resulting from the operation of sewage-treatment plants and the anticipated mitigation of mine-drainage pollution. Data being collected at Commission-sponsored monitor stations will be most useful toward this end. Equally important, however, will be such additional data as can be developed by West Virginia and Pennsylvania with regard to: (a) sewage and industrial-waste loads; and, (b) river-water analyses made by them and by water-treatment plants under their respective jurisdiction.

TABLE I - Public water supplies taken from the Monongahela and West Fork rivers.

Community	Miles from Mouth of Monongahela River	Estimated Population Served
WEST VIRGINIA		
Weston State Hosp.	194.0	2,000
Weston	194.0	8,200
Jackson Mills	190.0	500
Clarksburg	160.0	35,000
Spelter	150.0	1,000
Jordan	115.0	400
Everettville	111.0	500
National	107.0	400
Booth	106.0	500
Morgantown	101.0	29,300
	Total	77,800
PENNSYLVANIA		
Greensboro	84.0	1,600
Martin	83.2	700
Alicia	81.5	500
Masontown	79.3	5,000
Trotter Plant C	76.7	10,000
Carmichaels	75.1	5,000
Isabella	71.2	8,000
Fredericktown	63.9	8,000
Brownsville	56.7	12,000
California	51.9	5,000
Fayette City	47.0	3,000
Belle Vernon	44.2	8,000
Charleroi	42.6	60,000
Monongahela	33.5	13,500
Elizabeth	23.2	37,000
McKeesport	16.4	70,000
N. Versailles Twp	12.2	3,000
Braddock	11.0	16,500
South Pittsburgh	4.5	300,000
	Total	566,800
	BASIN TOTAL	644,600

TABLE II - Sources of sewage discharged to the Monongahela and West Fork rivers and estimated BOD (Biochemical-oxygen-demand) loads.

Status of treatment facilities indicated thus: A - adequate treatment
C - facilities under construction
I - inadequate treatment

Miles from Mouth of Monongahela River	Communities discharging directly to Monongahela and West Fork rivers	Communities discharging to tributaries (within 20 miles of confluence with Monongahela or West Fork rivers)	Census Population 1950	Estimated BOD Load in Population Equivalent
	WEST VIRGINIA			
193	Weston (C)		10,900	10,900
159	Clarksburg (C)	Elk Cr: Nutter Fort	41,400	41,400
146	Bridgeport, Shinnstown	Ten Mile Cr: Lumberport	6,400	6,400
135	Worthington, Monongah		2,100	2,100
129		Tygart River: Grafton, Pruntytown	7,700	7,700
125	Fairmont (C)		29,300	35,000
122		Buffalo & Paw Paw Crs: Mannington, Rivesville, Farmington, Grant Town, Fairview	7,400	7,400
100	Morgantown (C), Westover, Star City	Deckers Cr: Masontown, Reedsville (I)	32,200	32,200
	PENNSYLVANIA			
89	Point Marion	Dunkard Cr: Bobtown (C)	3,800	3,800
76	Masontown, Nemacolin, Cumberland Twp (I), Carmichaels, Greensboro		15,200	15,200

Continued on next page

TABLE II - Continued

Miles from Mouth of Monongahela River	Communities discharging directly to Monongahela and West Fork rivers	Communities discharging to tributaries (within 20 miles of confluence with Monongahela or West Fork rivers)	Census Population 1950	Estimated BOD Load in Population Equivalent
65		Ten Mile Cr: Marianna, Clarksville, Morgan Twp (A), Clyde (I)	6,500	6,500
55	Brownsville, W.Brownsville,Luzerne	Red Stone Cr: Uniontown (A), N.Union Twp.	50,500	50,500
51	California, Calif. State College, Centerville (A)		9,100	9,100
47	Elco, Roscoe, Stockdale		2,900	2,900
45	Fayette City, Allenport, Bentleyville, Dunlevy		6,000	6,000
43	Speers, Belle Vernon, N. Belle Vernon, Rostraver Twp.		15,700	28,700
41	Charleroi, N.Charleroi, Monessen		30,400	30,400
36	Donora		12,200	12,200
31	Monongahela, New Eagle		11,200	11,200
22	Elizabeth (A), W. Elizabeth	Peters Cr: Library, Finleyville, Cokesburg, Ellsworth	9,400	9,400
20	Clairton, Dravosburg, Pleasant Hills (I), Glassport		36,000	208,000
15.5		Youghiogheny R: W. Newton, Versailles, Liberty, Port Vue	12,800	12,800
15	McKeesport, N. Versailles Twp., White Oak		67,500	73,800
12	Duquesne		17,600	17,600
10		Turtle Cr: Jeanette (I), Penn (I), Manor, Irwin	22,600	22,600

TABLE III - Yearly-average flows in the Monongahela and Ohio rivers, 1939-1955.

Year	Yearly-average flow in Monongahela River at Braddock gage (11.2 mi. from mouth) cfs	Yearly-average flow in Ohio River at Sewickley gage (11.8 mi. from Pittsburgh) cfs	Proportionate amount of Ohio River flow contributed from Monongahela Basin percent
1939	11,550	27,610	41.8
1940	13,720	34,260	40.0
1941	9,708	22,760	42.7
1942	14,220	37,480	37.9
1943	11,810	34,230	34.5
1944	13,250	30,110	44.0
1945	16,680	44,590	37.4
1946	9,352	26,960	34.7
1947	9,520	31,700	30.0
1948	15,880	36,800	43.2
1949	11,990	29,160	41.1
1950	16,430	45,300	36.3
1951	14,960	39,320	38.0
1952	11,720	34,450	34.0
1953	9,199	26,580	34.6
1954	10,730	29,770	36.0
1955	10,780	30,150	35.8
		Average	37.8

TABLE IV - pH values in the Monongahela and West Fork rivers.

Miles from Mouth	Location	Source of Data	Dates of Sampling	pH		
				Maximum	Minimum	Median
195.0		1940 USPHS Survey	Jun-Jul 1940	7.2	7.0	
193.5	Weston	1940 USPHS Survey	Jun-Jul 1940	7.0	6.9	
193.2	Weston	1940 USPHS Survey	Jun-Jul 1940	7.0	6.9	
192.0		1940 USPHS Survey	Jun-Jul 1940	7.1	6.8	
189.0	Jackson Mills	1940 USPHS Survey	Jun-Jul 1940	7.0	6.9	
180.3		1940 USPHS Survey	Jun-Jul 1940	7.2	7.0	
174.0		1940 USPHS Survey	Jun-Jul 1940	7.2	7.0	
167.0	Nutter Fort	1940 USPHS Survey	Jun-Jul 1940	7.2	7.1	
161.0	Clarksburg	1940 USPHS Survey	May-Jul 1940	6.8	6.0	6.6
158.0	Clarksburg	1940 USPHS Survey	May-Jul 1940	6.7	6.0	6.6
155.0		1940 USPHS Survey	May-Jul 1940	6.8	6.1	6.3
149.8		1940 USPHS Survey	May-Jul 1940	6.6	4.1	6.2-6.3
145.5		1940 USPHS Survey	Jun-Jul 1940	4.7	3.2	3.4
143.5		1940 USPHS Survey	May-Jul 1940	4.8	3.2	3.4-3.5
138.0		1940 USPHS Survey	May-Jun 1940	5.7	3.5	
132.5		1940 USPHS Survey	May-Jun 1940	6.0	3.3	3.6
129.0	Fairmont	1940 USPHS Survey	May-Jun 1940	5.4	3.6	4.3
126.7	Fairmont	1940 USPHS Survey	May-Jun 1940	5.4	3.9	4.5
124.2		1940 USPHS Survey	May-Jun 1940	6.6	3.9	
104.1		1940 USPHS Survey	May-Jun 1940	5.2	3.5	4.5-4.9
101.0	Morgantown	Water-plant Record	Aug 56-Jul 58	7.9	2.5	4.8
100.9	Morgantown	1940 USPHS Survey	May-Jun 1940	5.4	3.5	4.4-4.8
97.7		1940 USPHS Survey	May-Jun 1940	5.2	3.5	4.3-4.4
90.8	Pt. Marion	Monitor Record	Jan 56-Dec 57	5.0	3.2	3.9
90.0	Pt. Marion	1940 USPHS Survey	May-Dec 1940	5.1	3.2	3.8-3.9
84.8	Greensboro	1940 USPHS Survey	May-Dec 1940	6.5	3.2	3.8-3.9
68.3		1940 USPHS Survey	Aug-Dec 1940	6.5	3.2	3.6
56.5	Brownsville	1940 USPHS Survey	Aug-Dec 1940	6.8	3.5	4.1
41.5	Charleroi	1940 USPHS Survey	Aug-Dec 1940	6.3	3.3	3.8
40.5	Charleroi	Monitor Record	Jan-Dec 1957	6.2	3.3	3.8
23.8		1940 USPHS Survey	Sep-Dec 1940	6.2	3.4	3.7
16.7	McKeesport	Water-plant Record	Jan 52-Dec 53	7.2	3.2	4.3
16.4	McKeesport	1940 USPHS Survey	Aug-Sep 1940	4.5	3.7	
11.2		1940 USPHS Survey	Aug-Dec 1940	6.7	3.4	3.9
4.5	S.Pittsburgh	Monitor Record	Jan 56-Dec 57	6.9	3.8	5.3
0.05	Mouth	1940 USPHS Survey	Sep-Dec 1940	6.6	3.5	4.3-4.4

TABLE V - Dissolved-oxygen levels computed for the Monongahela River at the one-percent flow and at summer temperature.

Station	Miles from Mouth	Estimated BOD Load in Population Equivalent	Flow 1,000 cfs	Days from Sta. Above	BOD - ppm			Dissolved Oxygen ppm
					Remain-ing	Added	Total	
WEST VIRGINIA								
Tygart River	129						11.3	4.4
Fairmont	125	35,000	.390	3.0	4.9	4.2	9.1	3.4
Buffalo Creek	122	7,400	.390	2.5	4.6	8.8	13.4	3.5
Morgantown	100	32,200	.390	22.9	0.0	3.8	3.8	8.4
PENNSYLVANIA								
Point Marion	89	3,800	.420	11.5	0.2	0.4	0.6	8.0
Masontown	76	15,200	.500	13.5	0.0	1.4	1.4	8.1
Ten Mile Creek	65	6,500	.500	13.1	0.0	0.6	0.6	8.4
Brownsville	55	50,500	.600	10.4	0.0	3.9	3.9	8.1
California	51	9,100	.600	4.2	1.2	0.7	1.9	7.3
Elco, Roscoe	47	2,900	.600	4.2	0.6	0.2	0.8	7.6
Fayette City	45	6,000	.600	2.1	0.4	0.5	0.9	7.7
Speers	43	28,700	.600	2.1	0.5	2.2	2.7	7.7
Charleroi	41	30,400	.600	1.7	1.7	2.3	4.0	7.6
Donora	36	12,200	.600	4.2	1.3	0.9	2.2	7.0
Monongahela	31	11,200	.600	4.2	0.7	0.9	1.6	7.5
Elizabeth	22	9,400	.600	9.4	0.1	0.7	0.8	8.3
Clairton	20	208,000	.600	2.1	0.5	16.0	16.5	8.2
Youghiogheny R.	15.5	12,800	1.350	2.7	7.6	0.4	8.0	5.0
McKeesport	15	73,800	1.350	0.3	7.4	2.5	9.9	5.1
Duquesne	12	17,600	1.350	1.8	6.1	0.6	6.7	3.8
Turtle Creek	10	22,600	1.350	1.0	5.1	0.8	5.9	3.8
Mouth	0		1.350	4.9	1.5			5.9

TABLE VI - Coliform densities computed for the Monongahela and West Fork rivers at the one-percent flow and at summer temperatures.

Station	Miles from Mouth	Sewered Population	Flow 1,000 cfs	Hours from Sta. Above	Coliforms - MPN/100 ml		
					Remaining	Added	Total
WEST VIRGINIA							
Weston	193	10,900	.001			16,350,000	16,350,000
Clarksburg	159	41,400	.001	242	14,700	62,100,000	62,114,700
Lumberport	146	6,400	.026	93	38,200	370,000	408,200
Worthington	135	2,100	.026	79	11,000	121,000	132,000
Tygart River	129	7,700	.390	43	1,050	29,600	30,650
Fairmont	125	29,300	.390	73	1,070	112,500	113,570
Buffalo Creek	122	7,400	.390	60	8,150	28,400	36,550
Morgantown	100	32,200	.390	550	12	123,000	123,000
PENNSYLVANIA							
Point Marion	89	3,800	.420	275	114	13,600	13,700
Masontown	76	15,200	.500	325	9	45,500	45,500
Ten Mile Creek	65	6,500	.500	314	39	19,500	19,550
Brownsville	55	50,500	.600	250	19	126,000	126,000
California	51	9,100	.600	100	1,890	22,700	24,600
Elco, Roscoe	47	2,900	.600	100	370	7,250	7,600
Fayette City	45	6,000	.600	50	680	15,000	15,700
Speers	43	15,700	.600	50	1,400	39,200	40,600
Charleroi	41	30,400	.600	40	5,700	76,000	81,700
Donora	36	12,200	.600	100	1,230	30,500	31,700
Monongahela	31	11,200	.600	100	4,750	28,000	32,750
Elizabeth	22	9,400	.600	225	49	23,400	23,450
Clairton	20	36,000	.600	50	2,100	90,000	92,100
Youghiogheny R.	15.5	12,800	1.350	64	230	14,200	14,450
McKeesport	15	67,500	1.350	7	11,800	74,700	86,500
Duquesne	12	17,600	1.350	42	11,250	19,500	30,750
Turtle Creek	10	22,600	1.350	24	9,200	25,000	34,200
Mouth	0		1.350	118	275		

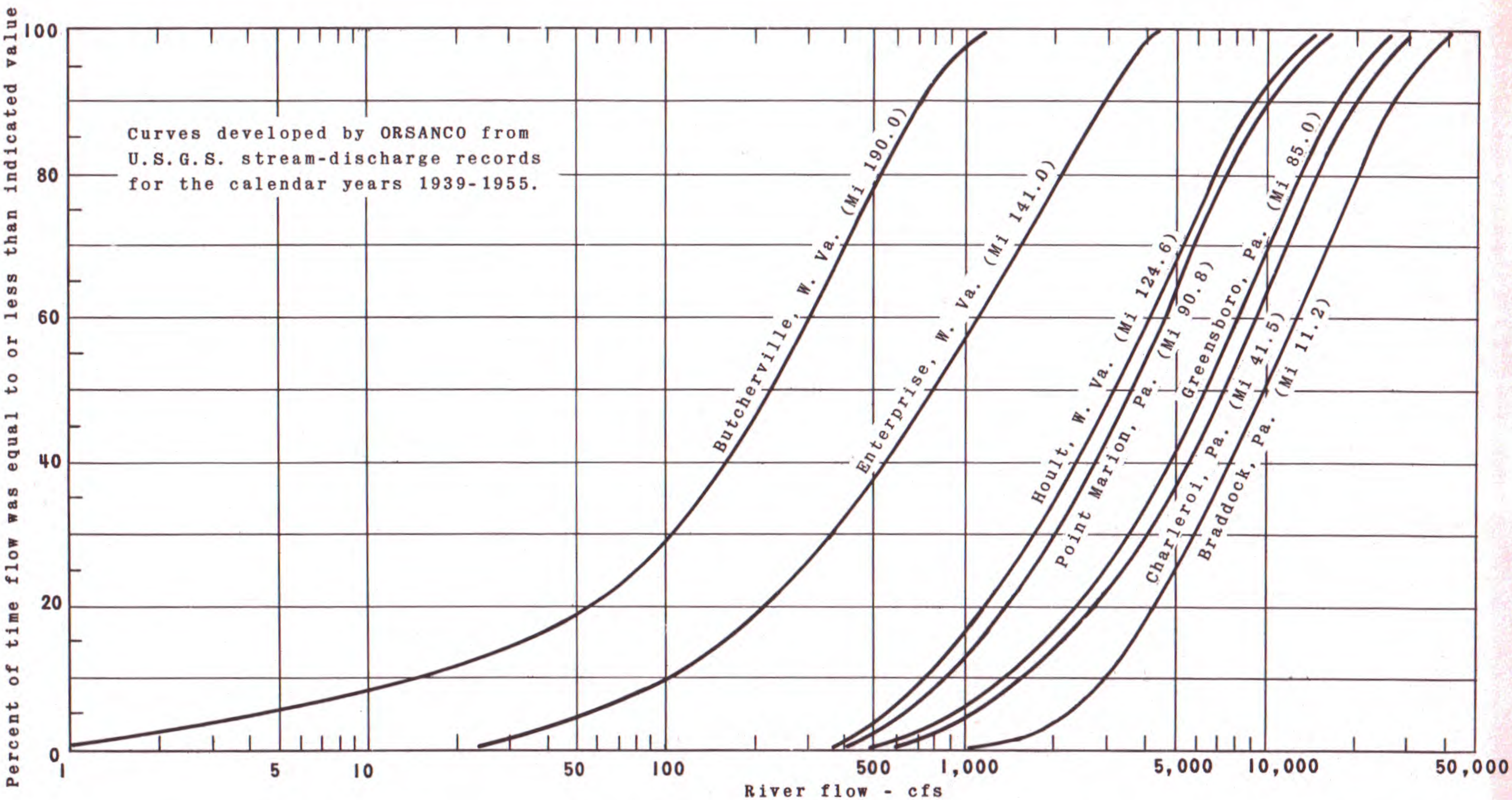

FIG. 2 - MONTHLY-FLOW DURATION CURVES FOR THE MONONGAHELA AND WEST FORK RIVERS. These show the frequency of occurrence for flows of various magnitudes at each of seven gaging stations.

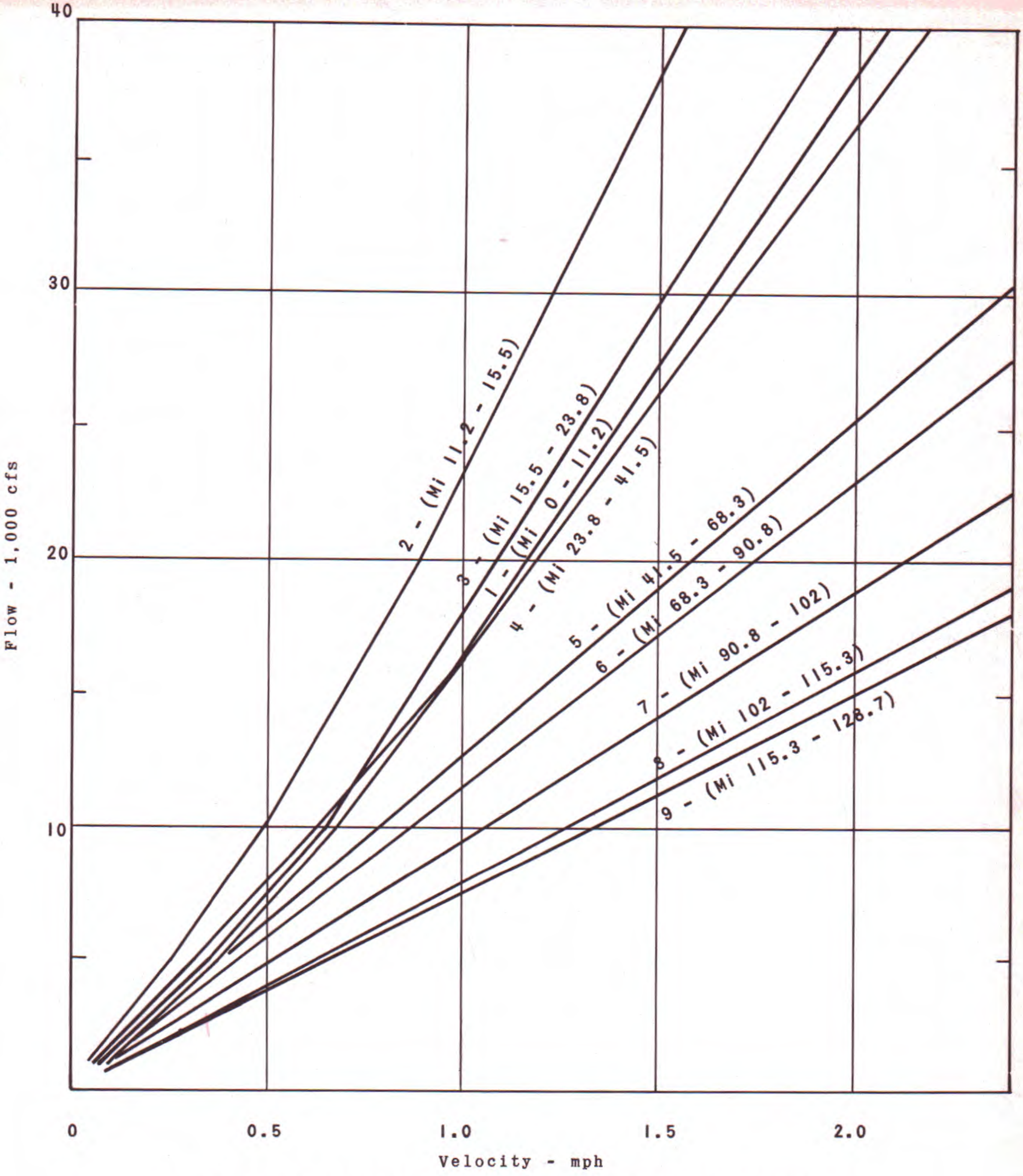

FIG. 3 - VELOCITIES IN THE MONONGAHELA RIVER AT VARIOUS FLOW LEVELS. Developed from information furnished by the U. S. Corps of Engineers

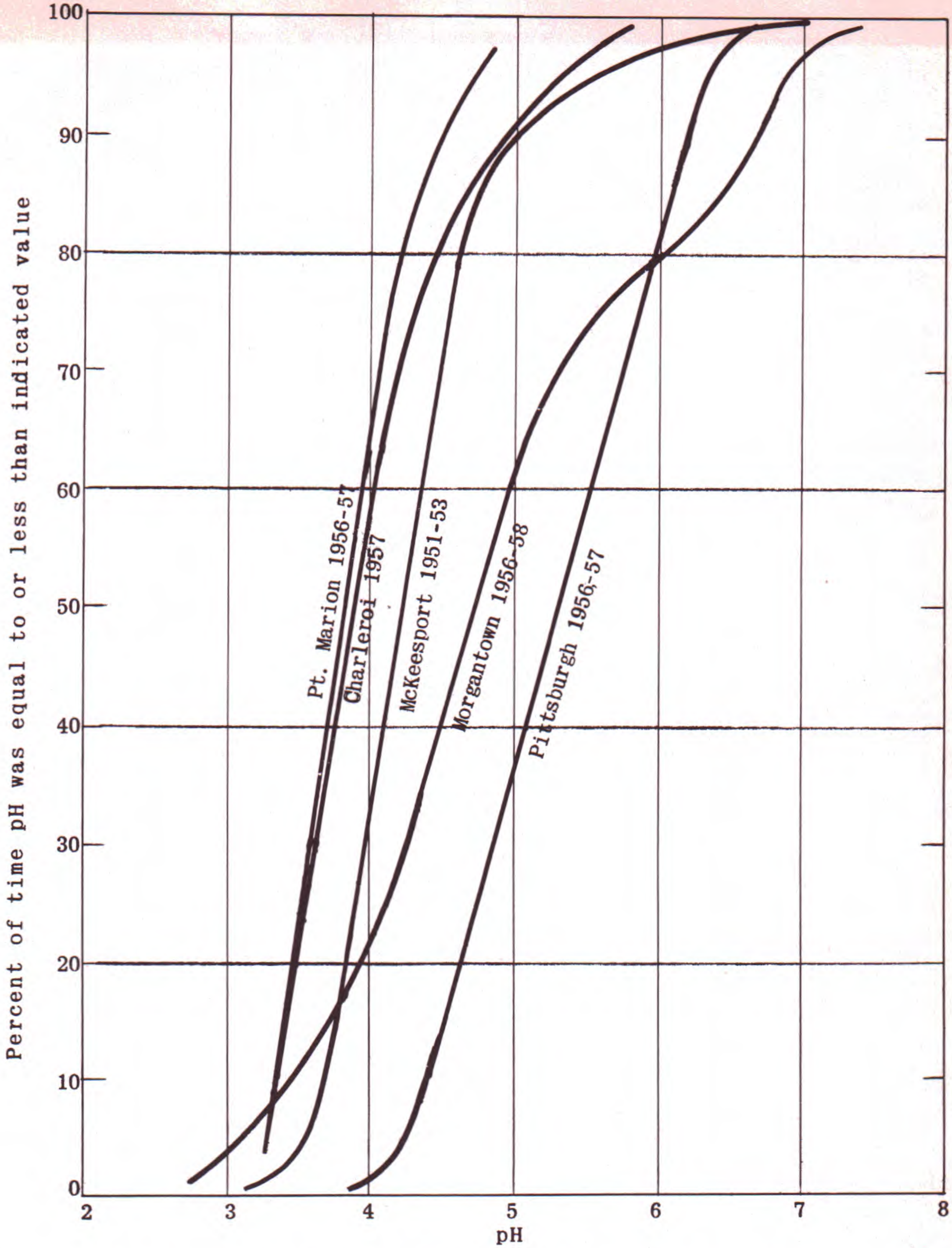

FIG. 4 - pH VALUES AND FREQUENCY OF THEIR OCCURRENCE AT FIVE LOCATIONS IN THE MONONGAHELA RIVER. This shows, for example, that at Pt. Marion, Charleroi and McKeesport pH values of 5.0 or less occurred 90 percent of the time.

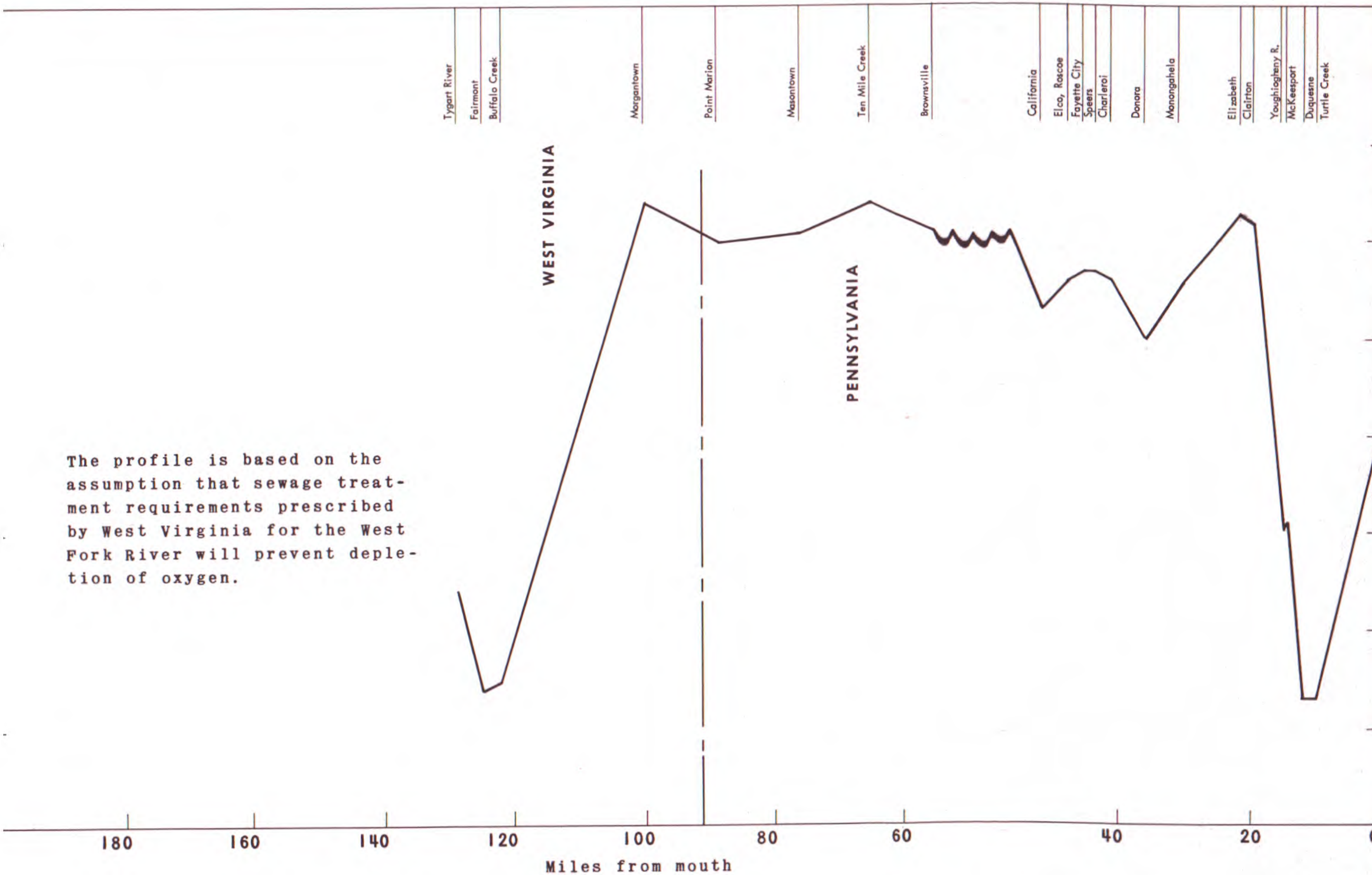

FIG. 5 - DISSOLVED-OXYGEN PROFILE FOR THE MONONGAHELA RIVER AT THE ONE-PERCENT FLOW AND AT SUMMER TEMPERATURES.

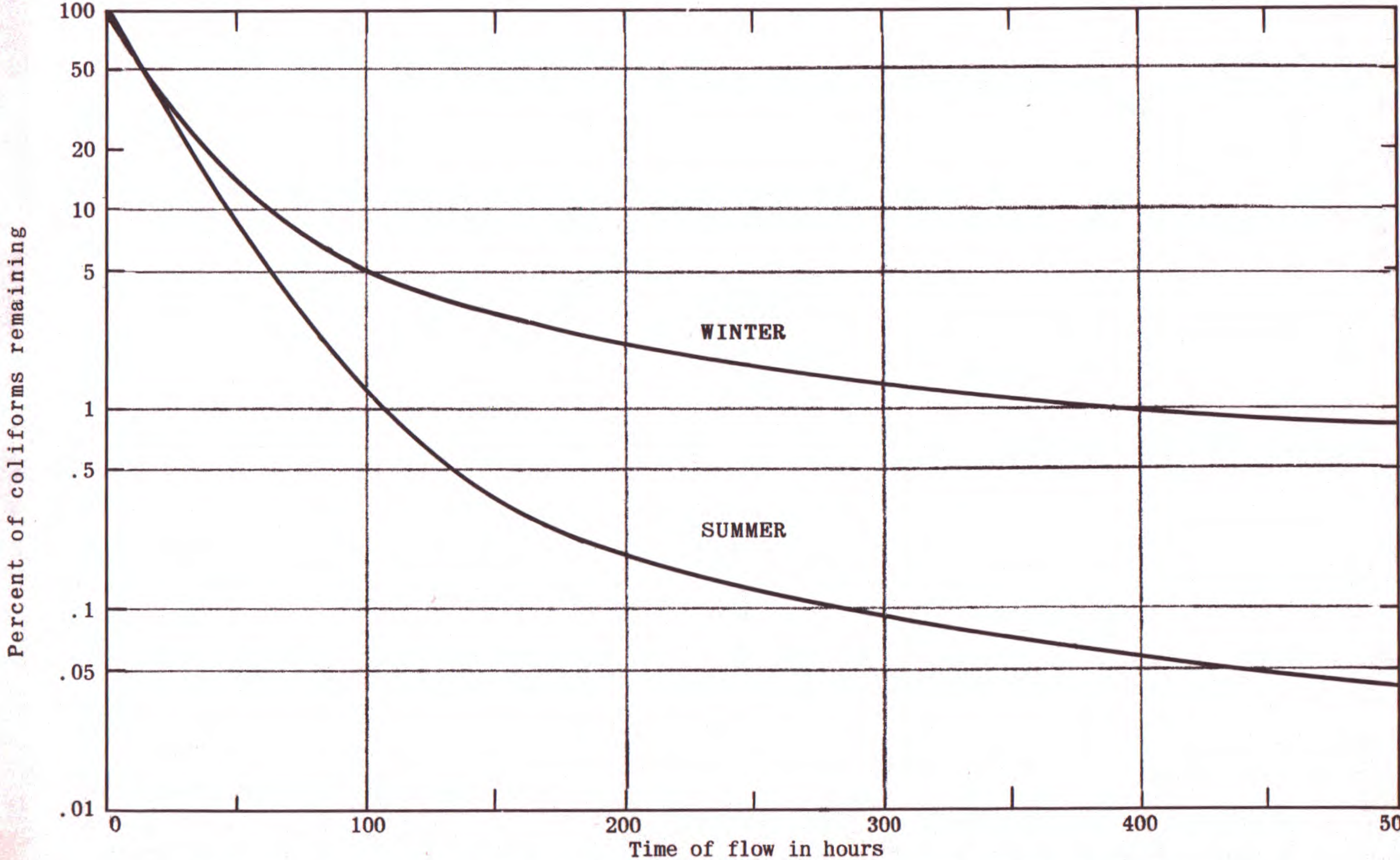

FIG. 6 - RATES OF COLIFORM DIE-AWAY DURING WINTER AND SUMMER PERIODS. Curves are based on Ohio River surveys below Cincinnati 1914-16 (P. H. Bull. 143).

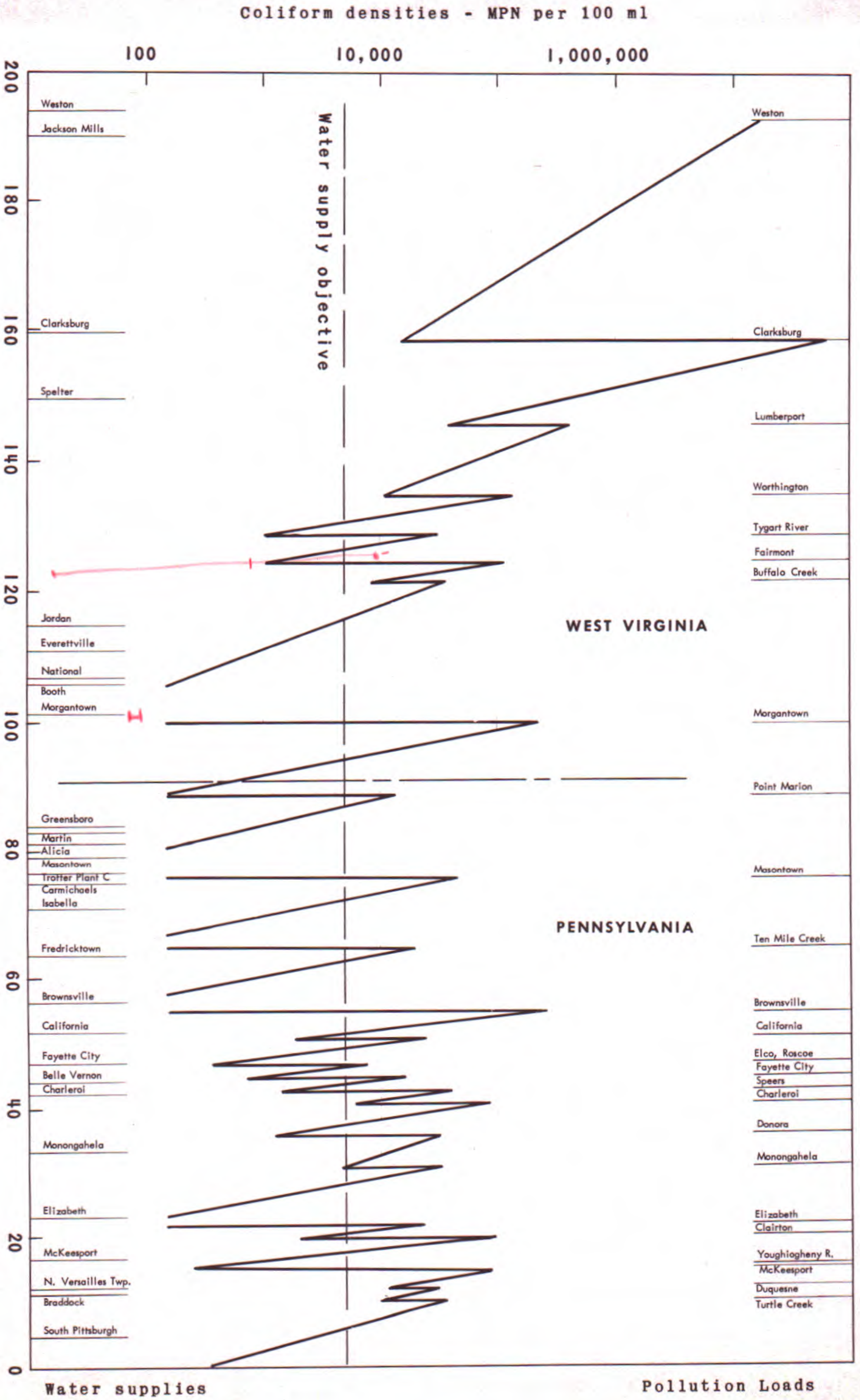

FIG. 7 - COLIFORM DENSITIES CALCULATED FOR THE MONONGAHELA AND WEST FORK RIVERS AT THE ONE-PERCENT FLOW AND AT SUMMER TEMPERATURES.

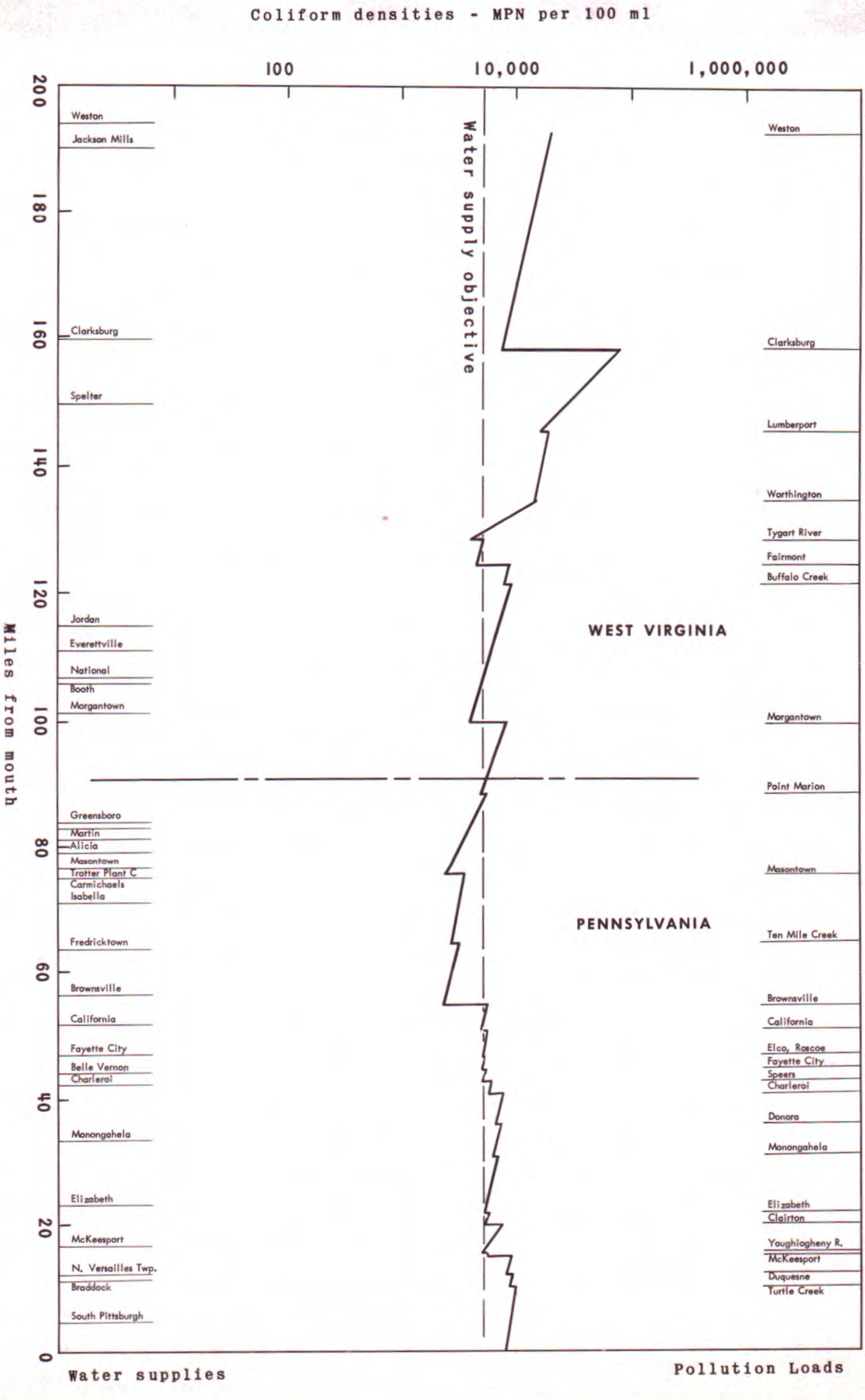

FIG. 8 - COLIFORM DENSITIES CALCULATED FOR THE MONONGAHELA AND WEST FORK RIVERS AT THE NINETY-FIVE PERCENT FLOW AND AT WINTER TEMPERATURES.

January 1959

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