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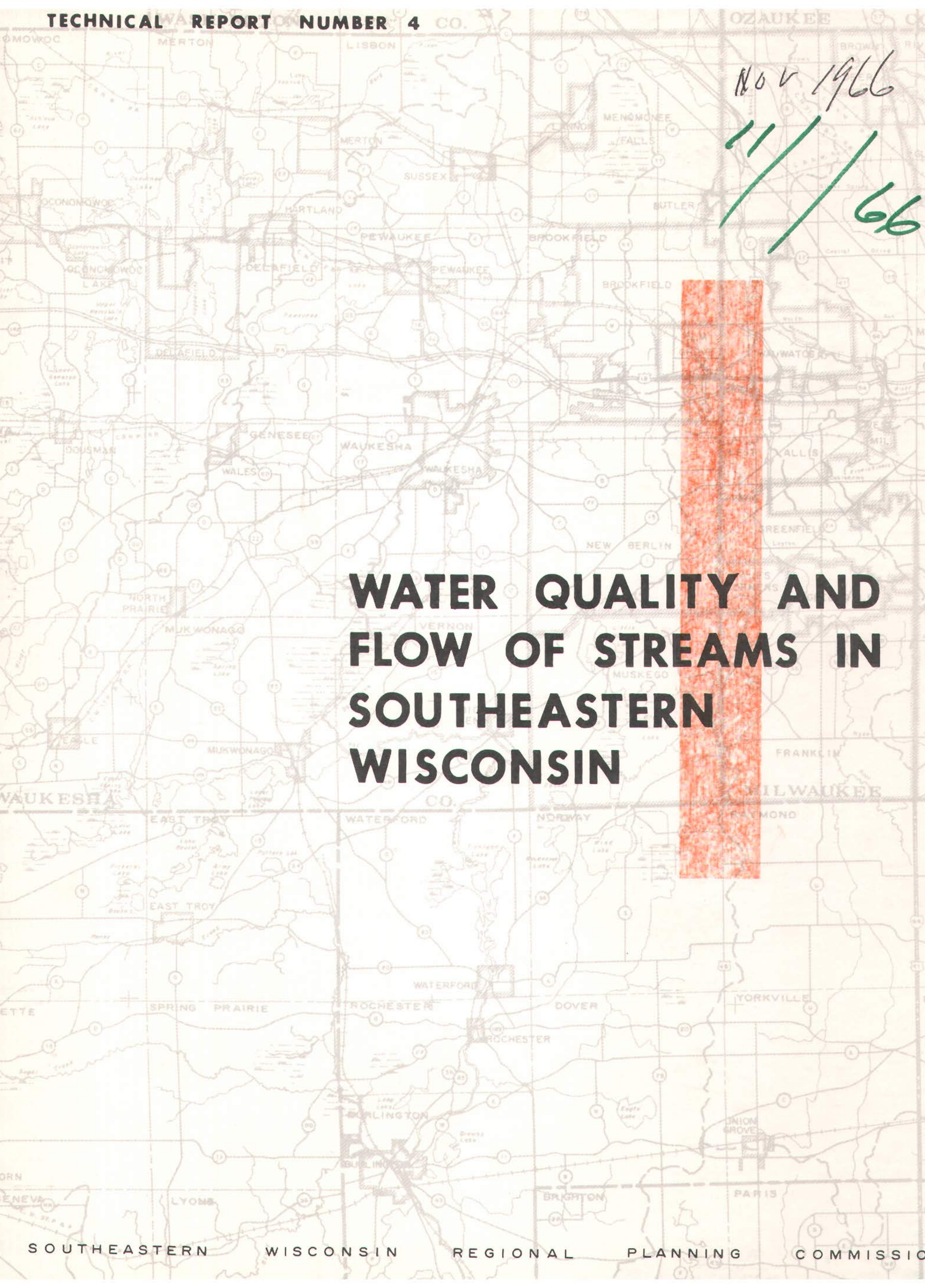

WATER QUALITY AND FLOW OF STREAMS IN SOUTHEASTERN WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgment is due Mr. Roy W. Ryling, SEWRPC Staff Hydrologist, who directed the stream water quality study, participated extensively in the field work, performed the SEWRPC water analyses, and authored this report.

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WATER QUALITY AND FLOW OF STREAMS IN SOUTHEASTERN WISCONSIN

Prepared by the
Southeastern Wisconsin Regional Planning Commission

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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December 2, 1966

STATEMENT OF THE EXECUTIVE DIRECTOR

This report presents the results of a study of stream water quality in the Southeastern Wisconsin Region. The study was made as part of an intensive effort to adjust regional land use and transportation system development plans to the underlying and sustaining natural resource base. As such, it represents a highly unusual, if not unique, attempt to relate stream water quality to land use development and to forecast such water quality under alternative land use development patterns.

More specifically, this report documents stream water quality data collected in the study, relates the present condition of stream water quality within the Region to existing major sources of pollution, assesses the effect of stream water quality on various water uses, and explores the interrelationships between stream water quality and land use patterns. Numerous tables and water quality graphs present the factual and interpretive data produced in the study, and these alone should serve to make this report of lasting historic value. Forecasts of future stream water quality within the major watersheds of the Region are presented for alternative land use development plans. The assumptions and rationale underlying these forecasts should prove of assistance in anticipating future stream water quality conditions within the Region.

Stream water quality conditions within the Region reflect the deleterious effect of human activity, and certain water uses have been seriously impaired or entirely prohibited by such activity. Major waste sources are municipal sewage treatment plants and industries. The anticipated increase of over one million people in the population of the Region over the next 25 years, with the attendant massive conversion of land from extensive rural to intensive urban uses, will place even more severe pollution loadings on many streams. The assumption that technological advances will not only provide the means by which liquid waste loadings can be adjusted to the waste assimilative capacities of the streams and watercourses, regardless of the land use pattern which may generate these loadings, but that the application of these advances will become economically as well as technologically feasible in the near future is a dangerous one. A more sound and conservative approach requires an effort to carefully adjust land use development to the waste assimilative capacities of the streams and watercourses and to other important interrelated elements of the natural resource base. Failure to accomplish such an adjustment can only lead to a continued decline in the quality of the environment for life within the Region.

Respectfully submitted,

Kurt W. Bauer

K. W. Bauer
Executive Director

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Chapter I

INTRODUCTION

The natural resources of an area are vital elements to its economic development and to its ability to provide a pleasant and habitable environment for human life. Moreover, natural resources not only condition but are conditioned by regional growth and urbanization. Any meaningful comprehensive regional planning effort must, therefore, recognize the existence of a limited natural resource base to which urban and rural development must be properly adjusted if serious environmental problems are to be avoided.

It is significant, then, that an extensive effort to relate regional land use and transportation plans to the underlying and supporting natural resource base has been made an integral part of the SEWRPC Regional Land Use-Transportation Study. Land and water resources within the Region are limited and subject to grave misuse through improper land use and transportation facility development. Such misuse may lead to severe environmental problems, which are very expensive to correct, and to the deterioration and destruction of the resource base itself. An intelligent selection of the most desirable regional development patterns from among alternatives must, therefore, be based in part upon a careful assessment of the effects of each development proposal on the supporting natural resource base. Such assessment requires the collection of a great deal of information concerning the natural resource base and its ability to sustain urban development, including definitive data on water resources.

The uses of land and water within the Region are closely interrelated. Urban development is dependent upon surface water resources for the dilution of treated sewage wastes, for the recharge of ground water aquifers, for recreational purposes, and in some cases for water supply. The importance of stream water quality to regional development stems from the limitations that are imposed on water use by the natural mineral content of the water and by the organic and inorganic pollutants that are introduced into the water by man from domestic, municipal, agricultural, and industrial sources. These limitations decrease the number of uses to which the streams can be put, depending upon the mineral concentration and the type and quantity of pollutants present. The economic, aesthetic, and recreational potential of any area is, as a consequence, closely dependent upon water quality; and any meaningful assessment of the possible effects of urban development on the surface water resources of the Region requires information about the quantity and quality of the water in the major streams of the Region.

The quantity of water present in the streams is no less important than the quality of that water in evaluating the multi-purpose use of streams and the use of the adjacent land. In southeastern Wisconsin streams are subject to significant change in seasonal flow. Large differences in flow also occur between the upper and lower reaches of the streams within the Region. Water uses that separately or collectively require the withdrawal of large quantities of stream water can induce low-flow conditions. Low-flow conditions, either natural or induced, can adversely affect water uses, such as waste assimilation and recreation. These and other uses can also be adversely affected by high-flow conditions. Consequently, the quantitative as well as qualitative aspects of streamflow within the Region must be considered in the preparation of regional development plans and in the consideration of proposed multi-purpose use of the streams and of the adjacent land.

PURPOSE OF THE STUDY

For planning application the necessary stream quality and quantity studies must be designed to permit:

1. Assessment of the present condition of stream quality in relation to existing major sources of pollution.

2. Assessment of the effect of stream quality on various water uses and concomitant effects on land use patterns.

3. Forecast of future stream quality in the major watersheds under alternative long-range regional development plans.

SCOPE OF THE STUDY

In order to fulfill the stream quality data requirements of the regional planning program, a cooperative agreement was negotiated with the State Board of Health and the State Committee on Water Pollution for the cooperative completion of a water quality investigation of the major streams within the Region, together with provision of interpretations for planning purposes. In addition, the Public Health Service, of the U. S. Department of Health, Education and Welfare, agreed to provide equipment and consultive services as might be required.

The major work elements necessary to fulfill the purpose and objectives of the study include:

1. The establishment of 87 stream sampling stations on 43 streams and watercourses distributed over the 12 major watersheds within the Region, as follows:

Watershed	Number of Sampling Stations
Des Plaines River	3
Fox River	28
Kinnickinnic River	1
Menomonee River	12
Milwaukee River	12
Minor streams draining into Lake Michigan	3
Oak Creek	2
Pike River	4
Rock River	13
Root River	6
Sauk Creek	2
Sheboygan River	1

2. The compilation of a photographic record of each sampling station to provide detailed information on its situation and landmarks.

3. A transit and tape field survey of each sampling station to record bridge or culvert dimensions (all stations are at locations where streams are crossed by bridges or flow through culverts), stream cross section, and the angle of bridge traverse across the stream. This information provides a plan and cross section record of the sampling station.

4. The establishment of a bench mark for stream stage measurement at each sampling station. From this information it is possible to evaluate the general conditions of streamflow at the time of each monthly sampling.

5. The collection of stream samples on a monthly basis at the 87 sampling stations. Data derived from the analyses of these samples provide the basic information regarding the chemical and bacteriological quality of the stream.

6. Streamflow records of nine U. S. Geological Survey stream-gaging stations, together with SEWRPC flow measurements at 48 of the 87 sampling stations, during seasonal periods of relatively high- and low-flow, provide the basic information on the quantity of water that flows through the main streams and their major tributaries.

7. The collection of existing stream quality and streamflow data from federal, state, county, and municipal sources. Data derived from these sources form a necessary and valuable supplement to the data collected by the SEWRPC.

8. The selection and application of water quality standards for 10 major water uses to permit mapping and appraisal of stream quality.

9. Correlation of present stream quality and flow with present sources of pollution and population distribution. This information is necessary for forecasting future conditions of stream quality in relation to the alternative land use-transportation plans.

DURATION OF THE STUDY

The regional stream quality study commenced on December 2, 1963, when the staffing of the project was completed. The stream sampling program was started on January 20, 1964, at which time all of the necessary equipment for the study had been gathered and the study design completed. The sampling program lasted 14 months and was completed on February 26, 1965.

ACKNOWLEDGMENTS

The stream quality study would not have been possible without the cooperation of the Wisconsin State Board of Health, the State Committee on Water Pollution, and the Public Health Service of the U. S. Department of Health, Education and Welfare. These agencies have made their extensive knowledge of, and experience in, water quality and stream pollution problems within the Region freely available to the Commission and have made significant recommendations regarding the technical aspects of the water quality study. The State Committee on Water Pollution provided the Commission with the invaluable laboratory services of the State Laboratory of Hygiene in running the determinations of fluoride, chromium, hexavalent chromium, phosphorus, oil, cyanide, biochemical oxygen demand (BOD), and coliform count. The U. S. Department of Health, Education and Welfare provided the Commission on a loan basis with analytical instruments; chemical reagents; analytical glassware; and streamflow measuring equipment, including such items as current meters, a bridge crane, and miscellaneous supporting equipment. The Commission is grateful also to the many other agencies that contributed data on water quality of streams and aquifers in southeastern Wisconsin, particularly to the Metropolitan Sewerage Commission of the County of Milwaukee, who not only provided a wealth of historic data and recent analyses of Lake Michigan water sampled near Milwaukee, but adjusted its own ongoing sampling program to the needs of the study and furnished valuable consultive services as well.

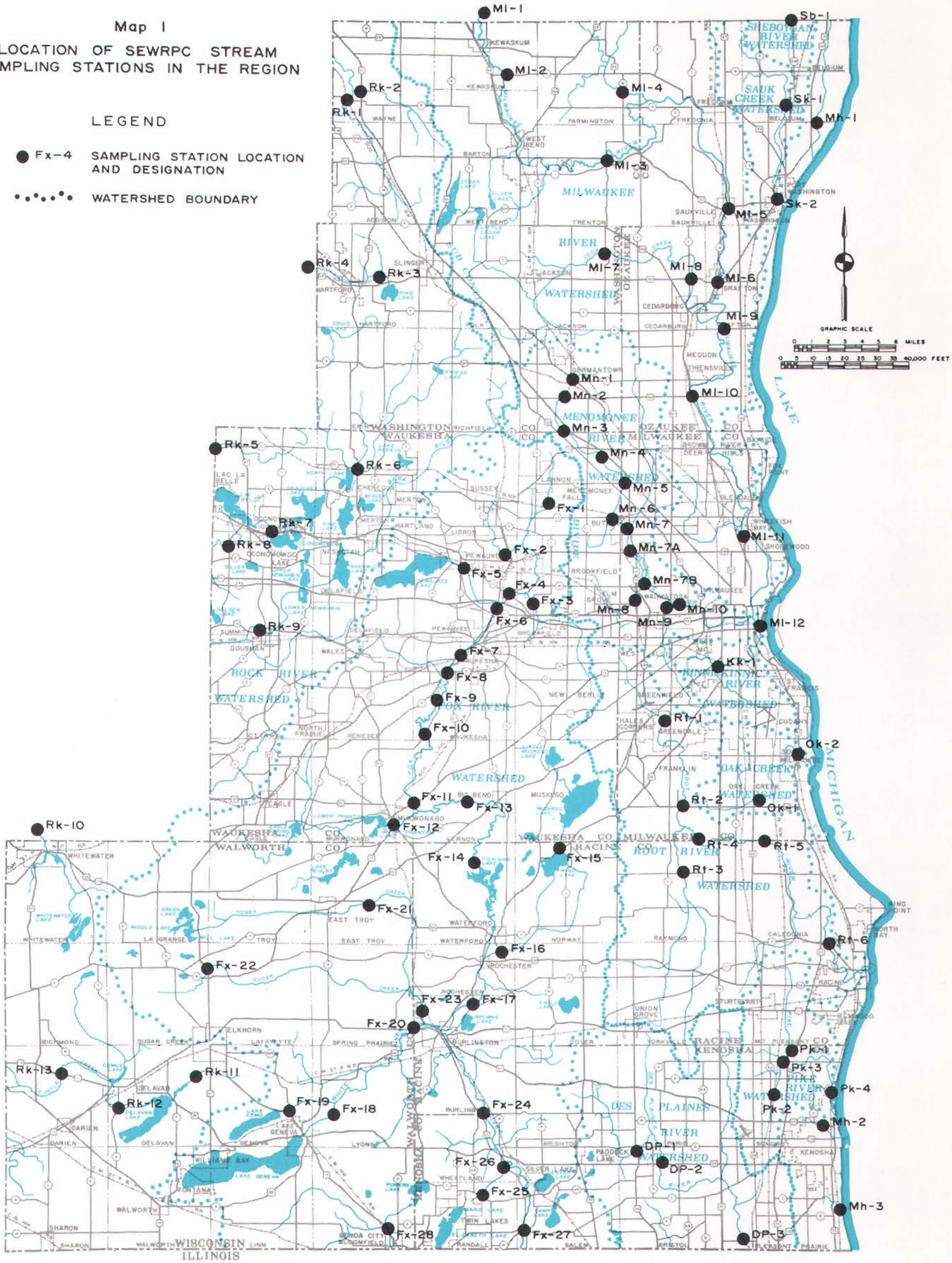
Map 1

LOCATION OF SEWRPC STREAM SAMPLING STATIONS IN THE REGION

LEGEND

● Fx-4 SAMPLING STATION LOCATION AND DESIGNATION

•.•.•.• WATERSHED BOUNDARY



Stream quality data were obtained from chemical, physical, biochemical, or bacteriological analyses of 3,933 water samples collected at 87 sampling stations established by the SEWRPC on 43 streams.

Chapter II

STUDY BACKGROUND

WATER QUALITY SAMPLING STATIONS

Selection of Sites

Prior to beginning actual field work on the stream quality study, an integrated network of potential sampling station sites was selected from inspection of 15-minute and 7 1/2-minute U. S. Geological Survey topographic quadrangle maps. In the selection consideration was given to attaining an adequate dispersal of sampling sites on major streams and tributaries in keeping with the regional approach to the water quality study. Sufficient density was needed, however, in reaches of the streams which were known or anticipated to be heavily polluted. These potential sites were then field inspected to determine their suitability as stream sampling and streamflow measurement stations. In the interest of efficiency, the sampling station sites had to be easily accessible the year around. To meet this requirement, all sites were located at points where the streams were crossed by public streets or highways.

Favorable conditions for the measurement of streamflow were also a requisite of potential stream sampling sites. In this respect, it was of prime importance to avoid selecting a site at which relatively high stream turbulence could be anticipated that would decrease the accuracy of flow measurement. Once a potential sampling site was field inspected and approved, the sampling site was given an identifying designation and was referred to as a sampling station. Map 1 shows the location of SEWRPC stream sampling stations.

Sampling Station Designations

A permanent identifying designation was assigned to each sampling station in the 12 drainage basins of southeastern Wisconsin. The designations consist of a two-letter prefix, representing the watershed in which the sampling station is located, and a number, representing the particular sampling station within the watershed. The numbering sequence is arranged in downstream order in accordance with standard usage.

The sampling station numbers were then painted in black on the respective bridge abutments and culverts in an inconspicuous location. For bridges traversing a stream in a general east-west direction, the sampling station designation was painted on the west abutment under the bridge deck on the downstream side of the bridge. For bridges traversing a stream in a general north-south direction, the station designation was painted on the north abutment under the bridge deck on the downstream side of the bridge. For culverts traversed by roads having a general east-west direction, the station designation was painted on the inner culvert surface on the west downstream side. For culverts traversed by roads having a general north-south direction, the station designation was painted on the inner culvert surface on the north downstream side.

Sampling Station Locations

The sampling stations were not only designated by watershed and number but were also named with respect to the stream and to the traversing highway or road. Table 1 lists the designations and locations of the SEWRPC stream sampling stations established for the study.

In addition to this method of naming and locating the sampling stations, the stations were also located by the U. S. Public Land Survey system as shown in Table 2. The locations of the stream sampling stations were recorded by township (North), range (East), section, quarter section and quarter-quarter section. Within each section, the quarter sections were numbered from 1 through 4 in counter-clockwise sequence starting with the northeast quarter section as quarter section number 1. The quarter-quarter sections were designated by capital letters A through D in the same counter-clockwise sequence within the quarter section, starting at the northeast quarter-quarter section as quarter-quarter section A.

Table I

DESIGNATIONS AND LOCATIONS OF SEWRPC STREAM SAMPLING STATIONS

Sampling Station Designation	Sampling Station Location	Sampling Station Designation	Sample Station Location
DP- 1	Brighton Creek at USH 45	Mh- 1	Sucker Creek at CTH P
DP- 2	Des Plaines River at STH 50	Mh- 2	Pike Creek at 43rd Street
DP- 3	Des Plaines River at CTH ML	Mh- 3	Barnes Creek at Lake Shore Drive
Fx- 1	Fox River at Mill Road	Ml- 1	Milwaukee River North of Kewaskum
Fx- 2	Sussex Creek at STH 164	Ml- 2	Milwaukee River at CTH H
Fx- 3	Poplar Creek at Barker Road	Ml- 3	Milwaukee River at STH 33 Near West Bend
Fx- 4	Fox River at CTH SS	Ml- 4	North Branch Milwaukee River at CTH M
Fx- 5	Pewaukee River at CTH SS	Ml- 5	Milwaukee River at STH 33 at Saukville
Fx- 6	Pewaukee River at STH 164	Ml- 6	Milwaukee River at STH 57 at Grafton
Fx- 7	Fox River at State Street	Ml- 7	Cedar Creek at CTH M
Fx- 8	Fox River at Sunset Drive	Ml- 8	Cedar Creek at STH 60
Fx- 9	Fox River at CTH HI	Ml- 9	Milwaukee River at CTH C
Fx-10	Fox River at CTH I	Ml-10	Milwaukee River at Mequon Road
Fx-11	Fox River at STH 15	Ml-11	Milwaukee River at Hampton Avenue
Fx-12	Mukwonago River at STH 83	Ml-12	Milwaukee River at STH 32
Fx-13	Fox River at Center Drive	Ok- 1	Oak Creek at Shepard Avenue
Fx-14	Fox River at Tichigan Drive	Ok- 2	Oak Creek at STH 32
Fx-15	Muskego Canal at STH 36	Pk- 1	Pike River at STH 31
Fx-16	Wind Lake Drainage Canal at STH 20	Pk- 2	Pike Creek at 18th Street
Fx-17	Fox River at CTH W	Pk- 3	Pike Creek at STH 31
Fx-18	White River at Sheridan Springs Road	Pk- 4	Pike River at STH 32
Fx-19	Como Creek at CTH NN	Rk- 1	East Branch Rock River at CTH D
Fx-20	White River at STH 11	Rk- 2	Kohlsville River at USH 41
Fx-21	Honey Creek at Carver Road	Rk- 3	Rubicon River at Slinger Road
Fx-22	Sugar Creek at USH 12	Rk- 4	Rubicon River at Goodland Road
Fx-23	Honey Creek at Spring Prairie Road	Rk- 5	Ashippun River at CTH CW
Fx-24	Fox River at CTH J	Rk- 6	Oconomowoc River at STH 83
Fx-25	Bassett Creek at CTH F	Rk- 7	Oconomowoc River at USH 16
Fx-26	Bassett Creek at CTH W	Rk- 8	Oconomowoc River at CTH BB
Fx-27	Fox River at CTH C	Rk- 9	Bark River at USH 18
Fx-28	Nippersink Creek at Darling Road	Rk-10	Whitewater Creek at N. Fremont Street
Kk- 1	Kinnickinnic River at 29th Street	Rk-11	Jackson Creek at Mound Road
Mn- 1	Menomonee River at STH 145	Rk-12	Delavan Lake Outlet at CTH O
Mn- 2	Menomonee River at CTH F	Rk-13	Turtle Creek at STH 11
Mn- 3	Menomonee River at CTH Q	Rt- 1	Root River at Grange Avenue
Mn- 4	Menomonee River at Lilly Road	Rt- 2	Root River at Ryan Road
Mn- 5	Menomonee River at Good Hope Road	Rt- 3	Root River Canal at Six Mile Road
Mn- 6	Menomonee River at Silver Spring Road	Rt- 4	Root River at County Line Road
Mn- 7	Little Menomonee River at STH 100	Rt- 5	Root River at Nicholson Road
Mn- 7A	Menomonee River at Capitol Drive	Rt- 6	Root River at STH 38
Mn- 7B	Menomonee River at North Avenue	Sk- 1	Sauk Creek at CTH A
Mn- 8	Underwood Creek Near N. 106th Street	Sk- 2	Sauk Creek at STH 33
Mn- 9	Honey Creek at Honey Creek Parkway	Sb- 1	Tributary of Sheboygan River at CTH BH
Mn-10	Menomonee River at N. 70th Street		

Source: SEWRPC.

WATER QUALITY PARAMETERS

Water Quality

Pure water in the strict chemical sense is not known to exist in nature. Even rainfall contains dissolved gases. If all water were chemically pure, there would be no water quality problems, no need for water quality studies, and no life on earth as it is known. All hypothetical water analyses would be identical wherever and whenever sampled. In reality, water, regardless of source, always contains foreign matter; and under most conditions this foreign matter is vital to the support of plant and animal life. Consisting of inorganic and organic substances in solution or suspension, these "impurities" can either enhance or detract from the usefulness of water as a vital substance in the biologic and economic existence and welfare of man. The kinds and amounts of foreign matter contained determine the suitability of a particular source of water for particular uses—hence, the concept of "water quality," a term relating to the chemical, physical, biochemical, and bacteriological aspects of water, as determined by water analyses, that affect its usefulness to man.

The inorganic and organic matter that occurs in streams comes from two sources—nature and man. The natural quality of stream water depends upon the flow of the stream, its physical environment of soil and

Table 2

LOCATIONS OF STREAM SAMPLING STATIONS BY THE U.S. PUBLIC LAND SURVEY SYSTEM

Sampling Station	Township	Range	Section	Quarter Section	Quarter-Quarter Section
DP- 1	01	21	05	2	C
DP- 2	01	21	09	1	B
DP- 3	01	22	32	3	A
Fx- 1	08	20	29	1	A
Fx- 2	07	19	12	1	B
Fx- 3	07	20	30	1	A
Fx- 4	07	19	24	4	B
Fx- 5	07	19	15	2	B
Fx- 6	07	19	26	1	D
Fx- 7	06	19	03	3	C
Fx- 8	06	19	16	2	B
Fx- 9	06	19	20	3	A
Fx-10	06	19	31	4	C
Fx-11	05	18	24	4	A
Fx-12	05	18	35	1	A
Fx-13	05	19	22	3	B
Fx-14	04	19	10	1	C
Fx-15	04	20	04	1	C
Fx-16	03	19	01	3	B
Fx-17	03	19	22	3	A
Fx-18	02	18	20	3	D
Fx-19	02	17	23	4	D
Fx-20	03	18	25	4	D
Fx-21	04	18	22	3	C
Fx-22	03	16	12	4	A
Fx-23	03	19	30	1	B
Fx-24	02	19	26	2	B
Fx-25	01	19	15	4	D
Fx-26	01	19	12	2	A
Fx-27	01	20	30	3	D
Fx-28	01	18	26	4	C
Kk- 1	06	21	12	4	D
Mn- 1	09	20	15	3	D
Mn- 2	09	20	28	2	A
Mn- 3	08	20	04	1	B
Mn- 4	08	20	12	3	B
Mn- 5	08	21	19	2	B
Mn- 6	08	20	36	1	B
Mn- 7	08	21	31	4	C
Mn- 7A	07	21	07	1	B
Mn- 7B	07	21	20	1	B
Mn- 8	07	21	20	2	B
Mn- 9	07	21	27	2	B
Mn-10	07	21	27	2	A
Ml- 1	13	19	33	2	B
Ml- 2	12	19	23	2	A
Ml- 3	11	20	14	2	B
Ml- 4	12	20	25	2	B
Ml- 5	11	21	36	2	B

Table 2 (continued)

Sampling Station	Township	Range	Section	Quarter Section	Quarter-Quarter Section
Ml- 6	10	21	24	1	D
Ml- 7	10	20	12	2	D
Ml- 8	10	21	23	2	A
Ml- 9	09	22	06	2	B
Ml-10	09	21	26	2	B
Ml-11	07	22	05	2	B
Ml-12	07	22	33	2	B
Mh- 1	11	22	02	2	A
Mh- 2	02	23	30	3	D
Mh- 3	01	23	20	2	C
Ok- 1	05	22	21	4	C
Ok- 2	05	22	02	4	C
Pk- 1	02	22	02	3	B
Pk- 2	02	22	15	3	C
Pk- 3	02	22	02	3	C
Pk- 4	02	23	18	4	C
Rk- 1	12	18	30	4	A
Rk- 2	12	18	29	1	A
Rk- 3	10	18	15	4	C
Rk- 4	10	17	13	3	A
Rk- 5	08	17	07	2	B
Rk- 6	08	18	16	2	D
Rk- 7	08	17	34	4	C
Rk- 8	07	17	06	4	D
Rk- 9	07	17	33	4	A
Rk-10	05	15	32	1	D
Rk-11	02	16	14	1	A
Rk-12	02	16	19	4	C
Rk-13	02	15	10	3	A
Rt- 1	06	21	33	1	B
Rt- 2	05	21	27	1	A
Rt- 3	04	21	10	4	D
Rt- 4	04	21	02	1	A
Rt- 5	05	22	34	3	C
Rt- 6	03	23	06	1	C
Sk- 1	12	22	33	1	B
Sk- 2	11	22	28	3	A
Sb- 1	13	22	34	3	C

Source: SEWRPC.

rock, and the natural assemblage of plants and animals that live in its watershed. The natural flow of a stream is supported by direct precipitation, surface runoff during and following rainfall, snowmelt, and ground water seepage into the stream channel. Although rainfall is the result of atmospheric condensation of water vapor derived from the natural distillation process of evapotranspiration, it is not free from dissolved gases, such as nitrogen, oxygen, and carbon dioxide. Once rainfall, or melt water, is in contact with the earth and runs into the natural drainage system, this surface runoff dissolves and suspends rock particles and organic matter derived from living or decaying plants and animals. These substances affect the water quality of the main stream and of the tributaries that drain into it. The natural water quality of a stream is determined further by the seepage of ground water into the stream channels. The ultimate source of ground water is precipitation. The prolonged contact of ground water with its subterranean rock environment, however, increases the mineralization of ground water and contributes much to the chemical quality of streams. This natural geologic and biological environment imparts to a stream a more or less characteristic water quality—the natural stream quality.

Natural stream quality is not constant but varies geographically along the course of the stream, with time, and in response to a number of interrelated factors. These factors include the geographic or spatial distribution and intensity of rainfall, surface runoff, streamflow, ground water conditions, daily and seasonal temperature changes, seasonal growth and decay of plants, and diurnal and seasonal changes in photosynthetic processes of plant life in the stream proper.

Human activities comprise the second major source of inorganic and organic matter that affects the water quality of streams. Municipal, industrial, domestic, agricultural, and commercial waste-water discharges can profoundly affect the water quality of streams. These discharges can transform a brook, creek, or river into an open sewage trough that is disgusting to the senses and useless except as a sewer. Between such an extreme condition of waste loading and the natural condition of a stream that is not used for waste disposal, there is a complete spectrum of quality conditions determined by the impact of human activities within a watershed. The deleterious effects on water uses of wastes discharged into a watercourse constitute pollution. It is important to note, however, that whether or not such effects are considered deleterious ultimately depends upon what use is to be made of the stream water.

Water quality is determined by chemical, physical, biochemical, and bacteriological tests of representative water samples. These tests, or analyses, are developed for the specific purpose of determining the quantity or magnitude of a given substance, physical property, or organism in a given quantity of sampled water. These substances, physical properties, and organisms are commonly referred to as "parameters"[1] and the quantity or magnitude of the parameters is expressed on a numerical scale. In this report, the physical parameters are listed with the chemical parameters.

There are hundreds of possible water quality parameters available for study; and this number can be expected to increase as new processes, products, and materials are developed by a highly industrialized and technological society. Water quality analyses are generally expensive to perform and often time consuming. A water quality surveillance must, therefore, of necessity select for determination from the hundreds of possible parameters those specific parameters which best meet the objectives of the study.

Chemical and Physical Water Quality Parameters

To describe the present chemical and physical quality of the streams in southeastern Wisconsin, it was determined that 32 parameters should be used. Of this total the SEWRPC performed the analyses for 25 parameters directly by chemical or physical determinations or indirectly by calculation from the results of the chemical tests for other parameters. In addition to analyses of water samples for the 25 parameters, stream temperature was measured in degrees centigrade and Fahrenheit.

The Wisconsin State Laboratory of Hygiene, in cooperation with the State Committee on Water Pollution, performed the analyses for 6 of the 32 parameters: fluoride, chromium, hexavalent chromium, phosphorus, oil, and cyanide.

The 32 parameters selected to describe the present chemical and physical stream water quality were:

1. Silica
2. Iron
3. Manganese
4. Chromium
5. Hexavalent chromium
6. Calcium
7. Magnesium
8. Sodium (and potassium)
9. Bicarbonate
10. Carbonate
11. Sulfate
12. Chloride
13. Fluoride
14. Nitrite
15. Nitrate
16. Phosphorus
17. Cyanide
18. Oil
19. Detergents (synthetic)
20. Dissolved solids
21. Hardness
22. Noncarbonate hardness

[1] *The term "parameter," as applied in this report, is defined as a chemical substance, a physical property, or an organism analytically determined in a water sample as an indicator of water quality.*

23. Calcium hardness
24. Magnesium hardness
25. Alkalinity P
26. Alkalinity M
27. Specific conductance at 25°C
28. Hydrogen ion (pH)
29. Color
30. Turbidity
31. Dissolved oxygen
32. Temperature

Biochemical and Bacteriological Water Quality Parameters

In addition to the chemical and physical analyses of stream samples, the State Laboratory of Hygiene performed biochemical and bacteriological analyses on stream samples collected in the study. The two parameters determined were: biochemical oxygen demand and membrane filter coliform count.

The analytical methods used by the SEWRPC in performing the analyses for the 25 parameters previously noted are discussed in Appendix A. Complete tabulation of the SEWRPC determinations and of the biochemical and bacteriological analyses performed by the State Laboratory of Hygiene is presented in Appendix B.

Table 3 lists the number of samples collected and the number of analytical determinations performed by the State Laboratory of Hygiene and by the SEWRPC.

Table 3

NUMBER OF STREAM SAMPLES COLLECTED AND ANALYTICAL DETERMINATIONS PERFORMED BY THE STATE LABORATORY OF HYGIENE AND THE SEWRPC

Type of Water Analysis	Number of Samples Collected	Number of Determinations	Analysis by
Complete Chemical Analysis.	539	12,348[a]	SEWRPC[b]
Special Chemical Analysis			WSLH[c]
Fluoride, chromium, hexavalent chromium, phosphorus, and oil	48	240	
Cyanide	30	30	
Subtotal	*78*	*270*	
Supplemental Chemical Analysis.	136		SEWRPC
Nitrate	--	101	
Detergents (synthetic).	--	12	
Specific Conductance.	--	16	
Hydrogen Ion (pH)	--	9	
Color	--	18	
Turbidity	--	20	
Subtotal	*136*	*176*	
Determination of Biochemical Oxygen Demand.	1,064	1,064	WSLH
Analysis for Dissolved Oxygen	1,066	1,066	SEWRPC
Determination of Membrane Filter Coliform Count	1,050	1,050	WSLH
Temperature Measurement (exclusive of that made as part of the complete chemical analysis).	--	520	SEWRPC
Subtotal - Determinations by SEWRPC		*14,110*	
Subtotal - Determinations by WSLH		*2,384*	
Total	3,933	16,494	

[a] *Includes 22 determinations made toward an additional complete chemical analysis.*
[b] *Southeastern Wisconsin Regional Planning Commission.*
[c] *Wisconsin State Laboratory of Hygiene.*

Source: Wisconsin State Laboratory of Hygiene; SEWRPC.

STREAM SAMPLING METHODS

The methods used to collect stream samples for analysis depend upon the purpose of the water quality study and upon the characteristics of the stream being sampled. Methodology involves instrumentation, procedure, and sampling location. The study purpose may be one of many. It may be a research project to determine physical principles and cause-and-effect relationships and involve a staff of technicians, numerous sampling stations, and frequent stream sampling and flow measurement at specified intervals of time. The purpose may also be to study a local pollution problem and involve one man tracing a pollutant to its source. The stream itself, the object of study, has variable characteristics, such as width, depth, flow, velocities, turbulence, and cross-sectional and longitudinal channel configuration. These characteristics affect the choice of sampling methods to be used. The variety of purposes of water quality studies of streams and the variety of stream characteristics require that the sampling methods be carefully selected and evaluated as to suitability, particularly during the early period of study.

In considering sampling methods, one of the first questions which must be answered is whether water samples, to be representative of conditions in the stream, must be taken at several locations and depths across the stream at each station and blended to form a composite sample or whether a single "grab" sample can be used to represent conditions at each station. A primary factor in reaching a decision is the streamflow characteristics encountered.

The mixing of waters of different composition and volume is a function of the turbulence of the receiving stream. If a single water sample taken at a point location is to represent properly the water quality of the entire cross-sectional area of the stream through the point, then water entering the receiving stream at one bank must be well dispersed laterally from bank to bank and vertically from surface to bottom; and the diluting flow of the receiving stream must disperse high local concentrations of pollutants throughout the cross-sectional area of the stream. If any pollutants move downstream for many miles in concentrated sub-streams within the channel, composite samples, rather than the so-called "grab" samples, would be required.

A map study of the streams in southeastern Wisconsin, together with a field inspection of all potential sampling sites, indicated that stream turbulence should adequately mix converging waters if the sampling station were at least one mile downstream from the point of convergence as measured along the course of the stream. Exceptions to this generalization were found, for example, in the entire Root River Canal and the Milwaukee River downstream from sampling station Ml-11 at Lincoln Park. Inadequate mixing for "grab" sampling purposes is assumed to prevail over a much greater distance because of the predominantly linear rather than sinuous configuration of both these streams at the locations noted.

Sampling For Chemical Analysis

Four methods were used in collecting stream samples for chemical analysis. The particular method used depended upon the type of water analysis to be run on the sample. The four types of analysis were:

1. Complete chemical analysis: the determination of as many as 25 parameters; Nos. 1, 2, 3, 6 through 12, 14, 15, 19 through 30, and 32, as listed on page 9.

2. Supplemental chemical analysis: the determination of one parameter; Nos. 15, 19, 27, 28, 29, or 30.

3. Special chemical analysis: the determination of five or six parameters; Nos. 4, 5, 13, 16, 17, and 18.

4. Analysis for dissolved oxygen.

Sampling For Complete Chemical Analysis: Samples for complete chemical analysis were collected in plastic bottles of 2-quart capacity. The sample bottles were premarked with grease pencil on the textured bottle surface, indicating sampling station and month of collection. As standard procedure the bottles were rinsed twice with the stream water at the point of collection at each sampling station. This was done to remove probable moisture of distilled water remaining in the bottle as the last step of the bottle-cleaning process. The sample bottle was held by its handle and immersed, where possible, to approximately six-tenths of stream depth. The bottle was placed into the stream on the upstream side of the person sampling, with the bottle opening tilted upstream and the handle oriented downstream from the opening. Care was taken not to sample water with turbidity resulting from the stream bed being stirred up during sampling.

Samples were collected under many conditions of weather and streamflow, and the basic method described above was used most frequently. However, under low-flow conditions on minor tributaries, the stream depth was too shallow for sampling in the manner described. To permit sampling directly into the 2-quart plastic bottle, a small trench was dug into the channel bottom. After the turbidity caused by the digging was cleared away by the flow of the stream, the bottle was lowered into the trench and tilted into sampling position. Care was taken not to sample the turbidity that may occur near the bottle neck under this condition of sampling.

Sampling For Supplemental Chemical Analysis: Samples for supplemental analysis were collected in plastic bottles of 8-ounce capacity. All procedures were identical to those discussed under sampling for complete chemical analysis.

Sampling for supplemental chemical analysis involved the collection of 136 samples for the determination of nitrate, synthetic detergents, specific conductance, pH, color, or turbidity. The purpose of this sampling was to provide additional water quality data at selected stations not scheduled for chemical sampling during the particular month or months involved. For example, in the Fox River watershed heavy rains in July 1964 resulted in a flushing effect upon the swamps at the headwaters of the Fox River proper and upon the marshland bordering Lake Muskego. The color of the Fox River was noticeably more dense than usual, and 18 samples for supplemental determination of color were collected in addition to the 10 samples scheduled for complete analysis in July.

Sampling For Special Chemical Analysis: Stream samples for special analysis by the State Laboratory of Hygiene were collected in plastic 2-quart bottles and sampled according to the methods discussed above under Sampling For Complete Chemical Analysis. Fluoride, chromium, hexavalent chromium, phosphorus, and oil were analyzed from the 2-quart samples, whereas the analysis for cyanide required the collection of a separate 2-quart sample to which 4 ml of sodium hydroxide solution was added at the time of collection. The samples for cyanide analysis were delivered under refrigerated conditions to the State Laboratory of Hygiene on the day of collection.

All sampling involved the full immersion of the sampling container well below water surface; and this practice was applied to samples collected for oil analysis, as well as all others.

Sampling For Dissolved Oxygen: Samples for dissolved oxygen determination were collected in 250 ml glass-stoppered bottles. Where stream depths were sufficient to permit use of a sampling device (a sewage sampler), the glass bottle was lowered into the stream in the sampler. The intake tube was kept well below the surface of the stream. Upon filling, the sampler was raised from the stream; and the sample bottle was inspected immediately for air bubbles before being stoppered. If no bubbles appeared floating within the sample or adhering to the inside, the bottle was stoppered immediately and again inspected. If no bubbles were observed, reagents were added to the sample as discussed in Methods of Water Analysis, Appendix A.

If air bubbles were observed in the sample upon removal from the sampler, immediate attempts were made to dislodge the bubbles by tapping the bottle. If the bubbles did not rise and escape through the bottle neck, the sample was discarded; and the procedure was repeated until a satisfactory sample was obtained.

Where stream depth was insufficient for use of the sampler, the 250 ml bottle was hand-held well below the water surface. The bottle was tilted upstream; and as it filled, it was reoriented progressively toward the vertical. If bubbles adhered to the inside, the bottle was re-immersed without spillage and tapped on the side opposite the bubbles. Bubbles accumulating on the shoulder of the sample bottle were removed by tapping and tilting to permit high-angle rise of the bubbles to the bottle opening. Unsuccessful attempts at removal of entrapped air necessitated resampling.

When successive attempts failed at bubble removal, a small part of the sample was poured out, permitting a larger bubble to enter the upper part of the bottle. This bubble, by tilting and turning the bottle around its long axis, was made to overrun and engulf the smaller bubbles adhering to the bottle shoulder. The larger bubble would then be dispelled by re-immersion. This technique, although used in a number of cases, was avoided and used only as a last solution to the problem of entrapped air.

To obtain the most reliable results, quickness of procedure was required both in the techniques of sample collection and of sample preparation by the addition of reagents. All sampling techniques discussed were applied when appropriate.

Sampling For Biochemical Oxygen Demand And For Coliform Count: Samples for the determination of biochemical oxygen demand and of coliform count were collected in separate glass bottles furnished by the State Laboratory of Hygiene. The samples were collected in the same manner as described previously, with one exception: the samples for determination of coliform count were collected by holding the coliform bottle at its base and lowering it into the stream in the inverted position. At the desired depth of sampling, the bottle opening was pointed upstream, permitting water to enter the bottle. Care was taken to avoid touching the bottle and lid where the sample could become contaminated by contact with the hands. The samples were stored in ice in boxes specifically designed for storage and shipment of BOD and coliform samples.

The BOD and coliform samples were delivered by the SEWRPC to the State Laboratory of Hygiene the same day of sampling. Sampling began after 8:00 a. m. and usually ended before 1:30 p. m. Samples were received at the State Laboratory about 3:00 p. m. In the few instances when samples were delivered the day after collection, the time span between collection and completed delivery was less than 22 hours.

FREQUENCY OF STREAM SAMPLING AND STREAMFLOW MEASUREMENT

The SEWRPC collected 3,933 stream samples for chemical, biochemical, and bacteriological analyses during the 14-month field investigation. Samples were collected on a monthly basis; and of the total analyses, 539 were complete chemical analyses; 78, special chemical analyses; 136 supplemental chemical analyses; 1,064, BOD determinations; 1,066, D.O. determinations; and 1,050, coliform counts.

The frequency of stream sampling with respect to the principal sample categories is shown in Figure 1. The category designated C includes complete analyses only. Special chemical analyses and supplemental chemical analyses are not included in the frequency chart. Ten to 14 samples for complete chemical analysis were collected at intervals of one month or more at 30 key stations in the Region; 9 stations were sampled for complete chemical analysis during each of the 14 months; 16 stations were sampled 13 times; 4 stations were sampled 12 times; 1 station was sampled 10 times; 1 station was sampled 7 times; 1 station was sampled 5 times; 4 stations were sampled 4 times; 21 stations were sampled 3 times; 26 stations were sampled twice; and 4 stations were sampled once. In April 1964, during a period of relatively high streamflow, samples were collected for complete chemical analysis at 82 of the 85 stations established at that time. In September and October 1964, during a period of low flow, samples for complete chemical analysis were collected at all 87 stations established for the water quality study.

Samples for special chemical analysis were collected once at 53 selected stations during the 14 months of field investigation. These samples were collected between September 11, 1964, and January 28, 1965. Such one-time sampling is not shown on the frequency chart but is listed in Appendix C.

Samples for supplemental analysis were collected at many stations throughout the Region at irregular intervals for spot-check purposes. Also omitted from the sampling frequency chart, these analyses are listed with the SEWRPC analyses in Appendix B.

The sampling for BOD, D.O., and coliform count are combined in one category, which is designated B in the chart. Samples for determinations of BOD, D.O., and coliform count were collected at 27, 53, and

Figure 1

FREQUENCY OF STREAM SAMPLING AND STREAMFLOW MEASUREMENT

C SAMPLING FOR COMPLETE CHEMICAL ANALYSIS

B SAMPLING FOR BOD, D.O., AND COLIFORM COUNT DETERMINATION

S STREAMFLOW MEASURED BY SEWRPC

STREAMFLOW MEASURED BY U.S. GEOLOGICAL SURVEY (NOT TOTALED)

STREAM SAMPLING STATION	1964																																				1965					
	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC			JAN			FEB		
	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S
DP-1										X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
DP-2										X	X			X			X			X			X			X		X	X			X			X			X			X	
DP-3	X	X		X	X		X	X		X	X	X	X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
SUBTOTAL	1	1	0	1	1	0	1	1	0	3	3	2	1	3	1	1	3	0	1	3	0	1	3	0	1	3	0	3	3	2	1	3	0	1	3	0	1	3	0	1	3	0
Fx-1	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Fx-2				X	X			X		X	X	X		X			X			X			X			X		X	X	X		X						X			X	
Fx-3				X	X			X		X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
Fx-4				X	X	X	X	X	X	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Fx-5				X	X			X		X	X			X			X			X			X			X		X	X			X			X			X			X	
Fx-6	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Fx-7	X	X		X	X		X	X		X	X			X		X	X			X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Fx-8	X	X		X	X		X	X	X	X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Fx-9		X			X			X			X			X			X			X			X			X		X	X			X			X			X			X	
Fx-10		X			X			X			X			X			X			X			X			X		X	X			X			X			X			X	
Fx-11	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Fx-12				X	X	X	X	X	X	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Fx-13	X	X		X	X			X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Fx-14		X		X	X			X		X	X			X			X			X			X			X		X	X			X			X			X			X	
Fx-15										X	X			X			X			X			X			X		X	X			X			X			X				
Fx-16								X		X	X			X	X		X			X			X			X		X	X	X		X			X			X				
Fx-17	X	X		X	X	X	X	X		X	X	X	X	X			X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Fx-18										X	X			X	X		X			X			X			X		X	X	X		X			X			X			X	
Fx-19										X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
Fx-20				X	X			X		X	X		X	X	X		X			X			X			X		X	X	X		X			X			X				
Fx-21										X	X			X			X			X			X			X		X	X			X			X			X			X	
Fx-22										X	X			X			X			X			X			X		X	X			X			X						X	
Fx-23				X	X			X		X	X		X	X	X		X			X			X			X		X	X	X		X			X			X				
Fx-24	X	X		X	X		X	X		X	X			X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Fx-25										X	X			X			X			X			X			X		X	X			X			X			X			X	
Fx-26								X		X	X	X		X			X			X			X			X		X		X												
Fx-27	X	X		X	X			X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Fx-28										X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
SUBTOTAL	9	12	2	17	19	5	8	21	5	26	28	10	11	28	5	10	28	0	10	28	0	11	28	0	11	28	0	28	27	15	11	27	0	11	26	0	11	26	0	11	23	0
Kk-1										X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
SUBTOTAL	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
Mn-1	X	X		X	X			X	X	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Mn-2										X	X			X			X			X			X			X		X	X						X			X			X	
Mn-3				X	X					X	X	X		X			X			X			X			X		X	X	X					X			X			X	
Mn-4										X	X			X			X			X			X			X		X	X			X			X			X			X	
Mn-5				X	X					X	X	X		X			X			X			X			X		X	X	X					X			X			X	
Mn-6	X	X					X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Mn-7				X	X					X	X	X	X	X			X			X			X			X		X	X	X		X			X			X			X	
Mn-7A																	X			X			X			X		X	X						X			X				
Mn-7B																	X			X			X			X		X	X			X			X			X				
Mn-8				X	X					X	X	X	X	X			X			X			X			X		X	X	X		X			X			X				
Mn-9				X	X			X		X	X	X	X	X		X	X			X					X	X		X	X	X	X	X		X	X		X	X		X	X	
Mn-10	X	X		X	X			X	X	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
SUBTOTAL	3	3	0	7	7	0	1	4	2	10	10	6	6	10	0	4	12	0	3	12	0	3	11	0	4	12	0	12	12	6	4	8	0	4	12	0	4	12	0	4	9	0

Figure I (continued)

STREAM SAMPLING STATION	1964																																				1965					
	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC			JAN			FEB		
	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S	C	B	S
Mh-1										X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
Mh-2														X		X	X			X			X		X	X		X	X	X	X	X		X	X		X	X		X	X	
Mh-3										X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
SUBTOTAL	0	0	0	0	0	0	0	0	0	2	2	2	0	3	0	1	3	0	0	3	0	0	3	0	1	3	0	3	3	3	1	3	0	1	3	0	1	3	0	1	3	0
Ml-1	X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X			X	X	X	X		X	X		X	X		X	X		X	X	
Ml-2				X	X					X	X			X			X			X			X		X	X			X			X			X			X			X	
Ml-3				X	X			X		X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Ml-4				X	X					X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Ml-5	X	X		X	X			X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Ml-6				X	X			X		X	X			X			X			X			X		X	X			X			X			X			X				
Ml-7										X	X			X			X			X			X		X	X			X			X			X			X			X	
Ml-8	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Ml-9				X	X					X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Ml-10				X	X					X	X			X			X			X			X		X	X			X			X			X			X			X	
Ml-11	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Ml-12										X	X			X			X			X			X		X	X			X			X			X			X			X	
SUBTOTAL	4	4	0	10	10	0	3	6	0	12	12	4	4	12	0	4	12	0	4	12	0	4	12	0	11	12	4	4	12	0	4	12	0	4	12	0	4	12	0	4	11	0
Ok-1										X	X			X			X			X			X		X	X			X			X			X			X			X	
Ok-2	X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
SUBTOTAL	1	1	0	1	1	0	1	1	0	2	2	1	1	2	0	1	2	0	1	2	0	1	2	0	2	2	1	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0
Pk-1				X	X			X		X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Pk-2							X	X		X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Pk-3				X	X			X		X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
Pk-4	X	X		X	X		X	X		X	X	X	X	X	X	X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
SUBTOTAL	1	1	0	3	3	0	2	4	0	4	4	4	2	4	1	2	4	0	2	4	0	2	4	0	4	4	4	2	4	0	2	4	0	2	4	0	2	4	0	2	4	0
Rk-1							X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
Rk-2										X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Rk-3				X	X			X		X	X			X			X			X			X		X	X			X			X			X			X			X	
Rk-4	X	X		X	X			X	X	X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
Rk-5				X	X					X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Rk-6								X		X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Rk-7				X	X			X		X	X			X			X			X			X		X	X			X			X			X			X			X	
Rk-8	X	X		X	X			X	X	X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
Rk-9								X		X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Rk-10										X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Rk-11								X		X	X			X			X			X			X		X	X			X			X			X			X			X	
Rk-12				X	X			X		X	X	X		X			X			X			X		X	X	X		X			X			X			X			X	
Rk-13	X	X		X	X			X		X	X	X	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X	
SUBTOTAL	3	3	0	7	7	0	1	10	2	13	13	10	4	13	0	4	13	0	4	13	0	4	13	0	13	13	10	4	13	0	4	13	0	4	13	0	4	13	0	4	13	0
Rt-1							X	X		X	X			X			X		X	X		X	X		X	X			X			X			X			X			X	
Rt-2				X	X			X		X	X			X			X			X			X		X	X			X			X			X			X			X	
Rt-3				X	X			X		X	X			X			X			X			X		X	X			X			X			X			X			X	
Rt-4							X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
Rt-5				X	X			X		X	X			X			X			X			X		X	X			X			X			X			X			X	
Rt-6	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
SUBTOTAL	1	1	0	4	4	0	3	6	0	6	6	0	2	6	0	2	6	0	3	6	0	3	6	0	6	6	0	2	6	0	2	6	0	2	6	0	2	6	0	2	6	0
Sk-1										X	X			X			X			X			X			X		X	X			X			X			X			X	
Sk-2	X	X		X	X			X		X	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X	
SUBTOTAL	1	1	0	1	1	0	0	1	0	2	2	1	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	2	2	1	1	2	0	1	2	0	1	2	0	1	2	0
Sb-1										X	X	X		X			X			X			X			X		X	X	X		X			X			X			X	
SUBTOTAL	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0
TOTAL	24	27	2	51	53	5	20	54	9	82	84	42	32	85	7	30	87	0	29	87	0	30	86	0	55	87	20	62	86	28	31	82	0	31	85	0	31	85	0	31	78	0

Source: THIS AND ALL SUBSEQUENT FIGURES ARE SEWRPC.

54 stations during January, February, and March 1964, respectively. From April 1964 through February 1965, all stations were scheduled for sampling once a month.

Streamflow measurements were made by the SEWRPC at 48 selected stations and included 113 individual flow measurements. Of this total number of flow measurements, 95 were made during high- and low-flow conditions in April and in September-October 1964, respectively. The remaining 18 flow measurements were made for spot-check purposes at 12 stations. The frequency of SEWRPC flow measurements are shown in Figure 1 in the column designated S for streamflow measurement.

The Surface Water Branch of the U. S. Geological Survey[2] has stream gaging stations at nine locations in the Region, as indicated in Figure 1. Approximately 3,825 daily mean streamflow determinations were made by the Survey from data collected at these nine stations during the SEWRPC 14-month field investigation. The number of streamflow measurements made at these stations during the period of the SEWRPC field investigation are not included in the frequency chart.

STREAMFLOW AND STREAM STAGE MEASUREMENT

Uses of streams are closely dependent upon streamflow and stream depths, as well as upon the stream quality. Changing quantities of water in movement through the watercourses of the Region relative to the varying quality define the limits within which these watercourses can be used. Where stream quality is acceptable for a particular use, the streamflow may be inadequate, thus excluding this use of the stream regardless of water quality. No study of the water quality of streams can be fully useful without supporting data on streamflow.

Streamflow Measurement

Pygmy Current Meter: A pygmy current meter was used by the SEWRPC in making 83 stream discharge measurements in the Region. This meter was used where streams were too shallow for convenient or accurate use of a small Price current meter. Flow measurements were made at six-tenths depth where stream depths were two and one-half feet or less.

The pygmy current meter had a cup-type bucket wheel, no tailpiece, and a single-revolution contact and was used with a five-foot wading rod. Distance along the stream section was measured by tag line or by measuring off the stream traverse with a three-foot gage section. Spin tests were run before and after the flow determinations.

Each station was inspected both downstream and upstream for the most favorable site of measurement. Favorable sites were those where turbid flow was at a minimum, near-bank and channel vegetation were least extensive, rock obstructions were absent or would cause the least problems of flow measurement, and where the channel was constricted and stream velocities correspondingly increased to permit flow measurements on sluggish streams. All measurements were made on the downstream side of station bridges or culverts.

Small Price Current Meter: A small Price current meter was used in making 30 stream discharge measurements in the Region. The meter was used where streams were too deep for wading, where stream widths were about 75 feet or more, or where the current was too swift for accurate use of a pygmy meter.

The small Price current meter was used with a hand line and a 15-pound Columbus type sounding weight with tail vanes. Measurement of stream depth was made by lowering the current meter assembly to stream bottom at the point of measurement on the bridge railing along the stream traverse. When the sharply decreased pull on the hand line indicated that the sounding weight had reached bottom, all slack was taken from the hand line as it was gently pulled upwards along the outer edge of the bridge railing. Thumb and forefinger were clamped on the hand line at the level of the bridge railing, and the current meter was pulled up until the horizontal weight vane exactly skimmed the surface of the stream. The distance was measured from the edge of the railing to the point on the hand line where thumb and forefinger indicated

[2] *Effective July 1, 1966, the Wisconsin offices of the Surface Water Branch and the Ground Water Branch were consolidated as part of a nationwide reorganization of the Water Resources Division of the U. S. Geological Survey.*

original depth to stream bottom from edge of railing. This measured distance corresponds to the stream depth. Where this depth was less than two and one-half to three feet, the stream current was measured at six-tenths depth. Where stream depth exceeded two and one-half to three feet, the current measurements were made at two-tenths and eight-tenths stream depth.

U. S. Geological Survey Stream Gaging Stations: The Surface Water Branch of the U. S. Geological Survey maintains nine gaging stations in southeastern Wisconsin where continuous records of discharge are obtained. Five of these nine stations are maintained in cooperation with the SEWRPC. The stream discharge records are based on water-stage recorder data or on observer readings of a nonrecording gage. Discharge for any stream stage is computed from stage-discharge relation curves. In addition to the stream-gaging stations, the Surface Water Branch maintains 19 partial-record stations where streamflow data are collected over a period of years for hydrologic analyses.

During the period of SEWRPC field investigation, extending from January 1964 through February 1965, the Surface Water Branch of the U. S. Geological Survey recorded streamflow at the gaging stations listed below:

1. Fox River at Waukesha [3]
2. Fox River at Wilmot
3. Menomonee River at Wauwatosa
4. Cedar Creek near Cedarburg
5. Milwaukee River at Milwaukee
6. Oak Creek at South Milwaukee [3]
7. Root River near Franklin [3]
8. Root River Canal near Franklin [3]
9. Root River at Racine [3]

The location of USGS stream gaging stations are shown on Map 2.

SEWRPC Stream Gaging Stations: The SEWRPC selected 48 sampling stations as sites for streamflow measurements during high- and low-flow conditions and for miscellaneous measurements. These stations are shown on Map 2, together with the U. S. Geological Survey gaging stations.

Stream-Stage Measurements

Stream-stage measurements were made in conjunction with the monthly stream sampling program. These measurements involved the establishment of an arbitrary but "permanent" reference bench mark on bridge railings or bridge decks and on culverts from which the distance to stream level was measured at each station at the time of each monthly sampling. These measurements became part of the regular monthly sampling program in June 1964 and were continued through December 1964.

The purpose of the stream-stage measurements was to obtain information regarding the gross aspect of the flow situation from one month to another, in the absence of monthly flow measurements at each station, and to permit the calculation of stream depth at each station. No attempt was made at rating the stations because the stage measurements, although measured to the nearest one-hundredth of a foot, were considered to be accurate to only one-tenth of a foot and under windy conditions to only one-half of a foot.

[3] *Stations maintained cooperatively with SEWRPC.*

Map 2
LOCATION OF U.S. GEOLOGICAL SURVEY AND SEWRPC STREAM-GAGING STATIONS IN THE REGION

LEGEND

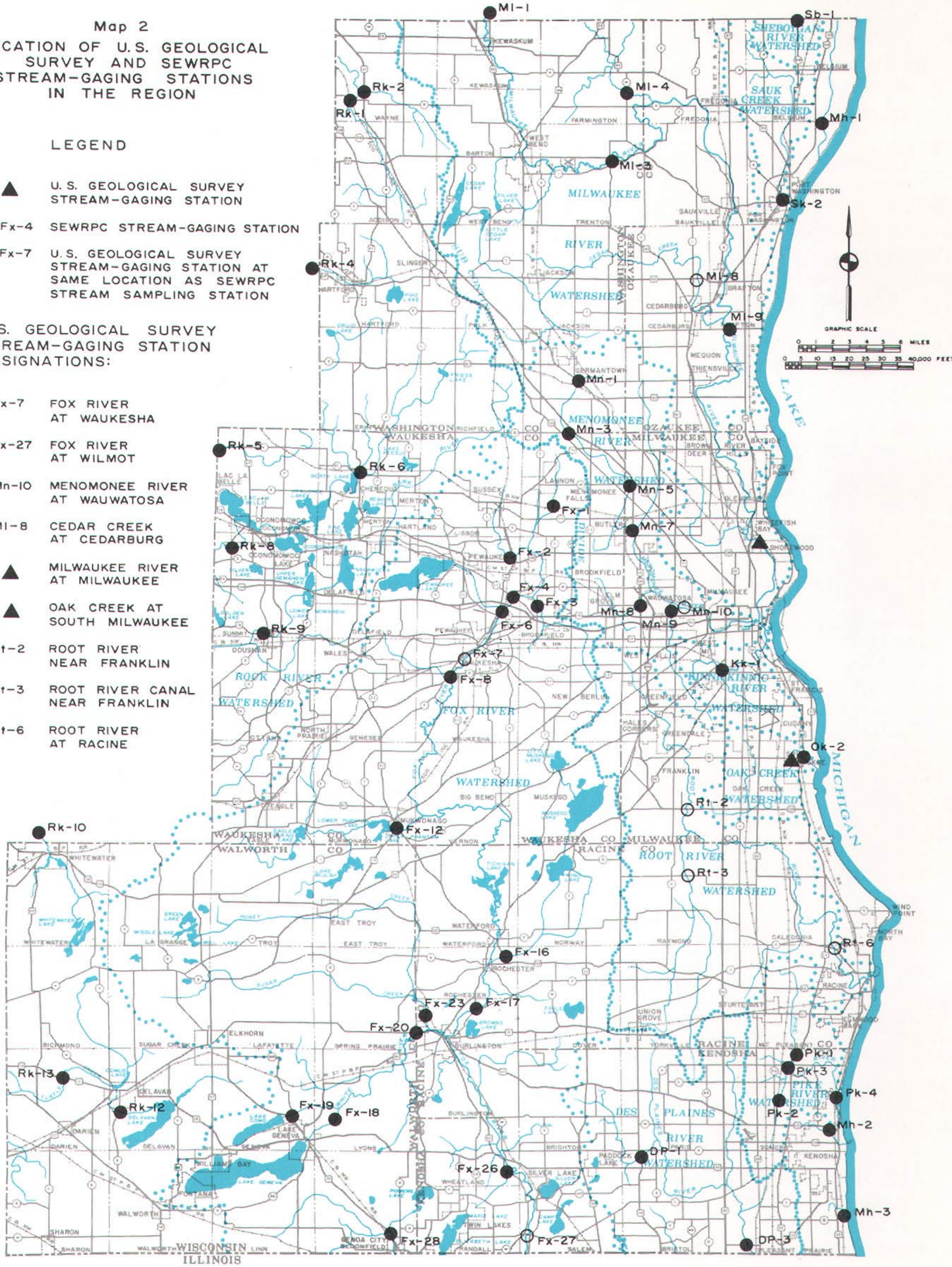
▲ U. S. GEOLOGICAL SURVEY STREAM-GAGING STATION

● Fx-4 SEWRPC STREAM-GAGING STATION

○ Fx-7 U. S. GEOLOGICAL SURVEY STREAM-GAGING STATION AT SAME LOCATION AS SEWRPC STREAM SAMPLING STATION

U. S. GEOLOGICAL SURVEY STREAM-GAGING STATION DESIGNATIONS:

Fx-7	FOX RIVER AT WAUKESHA
Fx-27	FOX RIVER AT WILMOT
Mn-10	MENOMONEE RIVER AT WAUWATOSA
Ml-8	CEDAR CREEK AT CEDARBURG
▲	MILWAUKEE RIVER AT MILWAUKEE
▲	OAK CREEK AT SOUTH MILWAUKEE
Rt-2	ROOT RIVER NEAR FRANKLIN
Rt-3	ROOT RIVER CANAL NEAR FRANKLIN
Rt-6	ROOT RIVER AT RACINE



Streamflow data were obtained from the U. S. Geological Survey, which has nine gaging stations on six streams in the Region, and from 113 SEWRPC discharge measurements at 48 selected sampling stations on 37 streams.

Chapter III

WATER QUALITY STANDARDS AND MAJOR WATER USES

The SEWRPC has no authority to establish, regulate, or enforce water quality standards in the Region. This power rests with the State Committee on Water Pollution, the State Board of Health,[1] the Wisconsin Conservation Commission, the Wisconsin Public Service Commission, and the Metropolitan Sewerage Commission of the County and City of Milwaukee.

The State Committee on Water Pollution regulates industrial waste effluents that are discharged directly into a watercourse, whereas the State Board of Health has jurisdiction over municipal, industrial, and commercial wastes that flow through sewerage systems to sewage treatment plants and are then discharged into a watercourse. The Wisconsin Conservation Commission protects the natural resources of Wisconsin, which include fish and game, lakes, streams, and plant life. The Wisconsin Public Service Commission regulates the level and flow of water in all navigable streams and lakes and is thereby indirectly concerned with water quality standards. The Metropolitan Sewerage Commissions of the County and City of Milwaukee are empowered to maintain reasonable stream quality standards within their geographic jurisdiction and may act jointly or separately to enforce these standards.

The interest of the SEWRPC in water quality standards stems from the fact that water quality and pollution affect and are, in turn, affected by regional development patterns. Land and water use are inextricably interrelated and must be considered together in any meaningful comprehensive planning effort. Numerical expressions of water quality, that is, of the concentrations of dissolved or suspended foreign matter in water, have no significance as such in planning. Only where water quality has been related to potential land and water uses and specific permissible maximum and minimum levels of concentrations of the several parameters established in the form of standards can pollution be defined, land and water use related, future conditions and needs forecast, and plans prepared to meet these needs.

Water standards are of two types, depending on whether the standards apply to the condition of a receiving stream or body of surface or ground water or whether they apply to the composition and strength of the waste discharges from a given source, such as to the effluent from a municipal sewage treatment plant or waste discharges from an industrial plant. These two types of standards are often referred to as "Receiving Water Standards" and as "Effluent Standards," respectively.

In Wisconsin the approach to stream pollution control has been varied with the circumstances, and both effluent and stream quality have received consideration. Pollution abatement has been controlled historically, primarily through effluent quality standards and control measures established and enforced by the Committee on Water Pollution, the State Board of Health, and other authorized agencies. However, mapping and appraisal of regional stream quality require receiving water standards. As of this writing (autumn 1965), few such standards have been established. To meet the requirement, the SEWRPC has adopted, for use in this report, selected water standards that have been established or recommended by responsible state and federal agencies and by industry as related to 10 major water use categories.

The water quality standards adopted by the SEWRPC are intended to serve two principal functions: 1) to provide a basis for mapping stream quality in order to establish the spatial distribution of pollution within the Region and 2) to provide a means of appraising the quality of untreated stream water relative to the following 10 use categories:

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[1] *Effective August 1, 1966, the powers, duties, and functions of the State Committee on Water Pollution and the State Board of Health concerning water quality standards were transferred to the reorganized State Department of Resource Development. The water control functions of the Wisconsin Public Service Commission will also be transferred to the State Department of Resource Development effective July 1, 1967. Before June 30, 1967, the State Department of Resource Development will establish water quality standards applicable to interstate waters within the State and formulate plans for the implementation and enforcement of the standards.*

1. Municipal (public) water supply.
2. Industrial water supply.
3. Cooling.
4. Waste assimilation.
5. Livestock and wildlife watering.
6. Irrigation.
7. Preservation and enhancement of aquatic life.
8. Recreation.
9. Navigation (commercial).
10. Aesthetics.

The water quality standards adopted by the SEWRPC are listed in Table 4. The water quality standards adopted were derived largely from information provided by five authoritative sources: 1) Water Quality Criteria by the California State Water Quality Control Board; 2) Drinking Water Standards - 1962 by the Public Health Service, U. S. Department of Health, Education and Welfare; 3) Wisconsin State Board of Health and the State Committee on Water Pollution; 4) unpublished data from the Technical Advisory Committees of the Great Lakes-Illinois River Basin Study; and 5) Water and Its Impurities by Thomas R. Camp. References to the source of each water quality standard are not included in this report.

Table 4 lists the water quality standards adopted by the SEWRPC for water classification and mapping purposes. Standards are presented for 10 selected major water uses. The standards are expressed in terms of 29 parameters measured in the regional stream water quality study. All numbers are maximum permissible or recommended limiting concentrations except where otherwise indicated. Blank spaces indicate that no maximum permissible or recommended limiting concentrations have been established relative to parameter and water use.

MUNICIPAL (PUBLIC) WATER SUPPLY

The most important use of water is to sustain animal and plant life. Living organisms are largely composed of water which they require for vital biological processes and for maintaining sufficient moisture in their internal environment. Any marked reduction in the intake of water to meet the normal water requirements of an animal or plant can result in severe symptoms of water starvation or in death. This biologic requirement for water, obvious and essential as it may be, is often not in the forefront of human consciousness. Nevertheless, the prime function of a municipal water supply is to provide potable and palatable drinking water to meet this essential biologic water need in human beings.

Water quality standards that apply to treated water for municipal use involve 14 parameters: iron, manganese, hexavalent chromium, sulfate, chloride, fluoride, nitrate, cyanide, oil, detergents, dissolved solids, color, turbidity, and coliform count. Iron or manganese in concentrations larger than the established standard for this parameter may impart brownish color to laundry or adversely affect the taste of drinking water or beverages. The amounts of iron and manganese established as standards for treated drinking water are of minor quantity as compared to the amounts normally ingested and are not likely to have toxic effects. Hexavalent chromium is not considered to be toxic to man at levels at and below 0.05 ppm. Water containing larger sulfate or chloride concentrations than the recommended maxima may have a temporary laxative effect upon persons not accustomed to this higher concentration. Fluoride in excess of the maximum permissible concentration at the prevailing annual average maximum daily air temperature may cause discoloration of teeth. Nitrate concentrations exceeding 45 ppm may cause fatal methemoglobinemia in infants.

Table 4

WATER QUALITY STANDARDS[a] FOR MAJOR WATER USES ADOPTED BY THE SEWRPC FOR STREAM QUALITY MAPPING AND APPRAISAL

Parameter[b]	Municipal (Public) Water Supply		Industrial Water Supply														Cooling
			Baking	Boiler Feed (pressure in psi)				Brewing	Carbonated Beverages	Dairy Industry	Food Canning and Freezing	Food Equipment Washing	Industrial Process Water (general)	Laundering	Tanning	
	Raw	Treated		0-150	150-250	250-400	>400									
Silica	---	---	---	40	20	5	1	50	---	---	---	---	---	---	---	---
Iron	---	0.3	0.2	---	---	---	---	0.1	0.2	0.3	0.2	0.2	0.2	0.2-1.0	2.0	0.5
Manganese.	---	0.05	0.2	---	---	---	---	0.1	0.2	0.1	0.2		0.1	0.2	0.2	0.5
Chromium (hex.).	---	0.05	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Calcium.	---	---	---	---	---	---	---	100-500	---	---	---	---	---	---	---	---
Magnesium.	---	---	---	---	---	---	---	30	---	---	---	---	---	---	---	---
Sodium	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Bicarbonate.	---	---	---	50[c]	30[c]	5[c]	0[c]	---	---	---	---	---	---	---	---	---
Carbonate.	---	---	---	200	100	40	20	50- 68	---	---	---	---	---	---	---	---
Sulfate.	---	250	---	---	---	---	---	---	250	60	---	---	---	---	---	---
Chloride	50-250	250	---	---	---	---	---	60-100	250	30	---	250	250	---	---	---
Fluoride	1.7	1.7	---	---	---	---	---	1.0	1.0	---	1.0	1.0	---	---	---	---
Nitrite.	---	---	---	---	---	---	---	0	---	0	---	---	---	---	---	---
Nitrate.	---	45	---	---	---	---	---	10[d]	---	30	15	---	---	---	---	---
Phosphorus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cyanide.	---	0.01	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Oil.	---	---	---	---	---	---	---	0	---	---	---	---	---	---	---	---
Detergents	---	0.5	---	---	---	---	---	---	---	---	---	---	1.0	---	---	---
Dissolved Solids	---	500	---	---	---	---	---	500-1500	850	---	850	850	750	---	---	---
Hardness	---	---	---	80	40	10	2	---	250	180	75-400	10	---	50	513	1,000
Alkalinity (total)	---	---	---	---	---	---	---	75-150	128	---	---	---	---	60	135	---
pH	6.0-9.0	---	---	8.0M	8.4M	9.0M	9.6M	6.5-7.0	---	---	7.5M	---	5.0-9.0	6.0-6.8	6.0-8.0	5.0-9.0
Specific Conductance . . .	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Color.	20-150	15	10	80	40	5	2	10	10	0	---	20	50	---	100	---
Turbidity.	10-250	5	10	20	10	5	1	10	2	---	10	1.0	250	---	20	50
Biochemical Oxygen Demand.	3.0-4.0	---	---	---	---	---	---	---	---	---	---	---	10	---	---	---
Dissolved Oxygen	4.6-6.5	---	---	2.0[c]	0.2[c]	0.0[c]	0.0[c]	---	---	---	---	---	1.0M	---	---	---
Coliform Count	5,000	1	---	---	---	---	---	---	---	100	1	1	5,000	---	---	---
Temperature (°F)	---	65	---	---	---	---	---	---	---	---	---	---	80	---	---	<90

Table 4 (continued)

Parameter[b]	Waste Assimilation	Livestock and Wildlife Watering	Irrigation	Preservation and Enhancement of Aquatic Life: Tolerant	Preservation and Enhancement of Aquatic Life: Fish Facultative	Preservation and Enhancement of Aquatic Life: Intolerant	Recreation: Whole Body Contact	Recreation: Partial Body Contact	Navigation (commercial)	Aesthetics
Silica	The amount of nondegradable and degradable wastes that can be carried in solution or suspension without exceeding the limits of concentration established for those beneficial uses deemed necessary to preserve.	---	---	---	---	---	---	---	---	Quality standards for the aesthetic use of streams are descriptive and qualitative rather than quantitative. Refuse heaps of old tires, tin cans, glass bottles, metallic and wood scrap, paper and waste material, floating garbage, oil, algae slime, foam, and offensive odors adversely affect the aesthetic use of a stream.
Iron		---	---	---	---	---	---	---	---	
Manganese		---	---	---	---	---	---	---	---	
Chromium (hex.)		---	---	0.5	0.5	0.5	---	---	---	
Calcium		---	---	---	---	---	---	---	---	
Magnesium		---	---	---	---	---	---	---	---	
Sodium		---	---	---	---	---	---	---	---	
Bicarbonate		---	---	---	---	---	---	---	---	
Carbonate		---	---	---	---	---	---	---	---	
Sulfate		---	---	---	---	---	---	---	---	
Chloride		1,500	---	500	500	500	---	---	---	
Fluoride		---	---	---	---	---	---	---	---	
Nitrite		---	---	---	---	---	---	---	---	
Nitrate		---	---	---	---	---	---	---	---	
Phosphorus		---	---	---	---	---	---	---	---	
Cyanide		---	---	0.025	0.025	0.025	---	---	---	
Oil		---	---	---	---	---	---	---	---	
Detergents		---	---	3.5	3.5	2.0	---	---	1.0	
Dissolved Solids		7,000	2,000	---	---	---	---	---	---	
Hardness		---	---	---	---	---	---	---	---	
Alkalinity (total)		---	---	---	---	---	---	---	---	
pH		5.0-9.0	---	6.0-9.0	6.0-9.0	6.0-9.0	---	5.0-9.0	5.0-9.0	
Specific Conductance		---	3,000	---	---	---	---	---	---	
Color		---	---	---	---	---	--50	---	---	
Turbidity		250	---	250	250	250	50	250	---	
Biochemical Oxygen Demand		---	---	---	---	---	---	---	---	
Dissolved Oxygen		---	---	3.0M[e]	4.0M[e]	5.0M	3.0M	3.0M	1.0M	
Coliform Count		---	---	---	---	---	2,400	5,000	---	
Temperature (°F)	< 110	---	---	90	85	80	< 90	< 90	---	

[a] *Water quality standards adopted from data obtained from five authoritative sources, as discussed on page . Limits are recommended maximum or maximum permissible values, except minimum limits which have the suffix M. Several standards are presented as a range of limiting values.*

[b] *The limiting values of the chemical, physical, biochemical, and bacteriological parameters are expressed in ppm (mg/l) except pH, specific conductance, color, turbidity, coliform count, and temperature.*

[c] *Limits applicable only to feed water entering boiler, not to original water supply.*

[d] *Nitrate as NO_3-N.*

[e] *Sixteen hours maximum exposure at indicated concentration.*

Source: Table based in part upon data compiled by SEWRPC.

Several state and interstate agencies have promulgated raw water standards; and natural waters may be classified as excellent, good, or poor sources for municipal supply depending upon the degree of pretreatment required. The standards adopted by the SEWRPC for stream water meet the requirements for a good source of municipal supply requiring only chlorination and filtration. Significant parameters are chloride, fluoride, pH, color, turbidity, biochemical oxygen demand, dissolved oxygen, and coliform count. Chlorides are not physiologically harmful except at high concentrations or to people with health problems requiring low chloride ingestion. Taste is the principal consideration in establishing the standard. Fluorides may cause discoloration of teeth at concentrations exceeding 1.7 ppm. The pH of raw water to be used for municipal supply affects the taste and corrosiveness of the water and the treatment processes of chlorination and coagulation. Color and turbidity are aesthetically undesirable and must be reduced by pretreatment. Biochemical oxygen demand is not a pollutant but measures the effect of a combination of substances and conditions. Pretreatment reduces the biochemical oxygen demand, which in a good source of supply ranges as a maximum from 3.0 to 4.0 ppm. Dissolved oxygen in municipal water supplies improves the palatability of water and is not considered to be physiologically harmful. Coliform count in a good source of municipal supply must be less than 20 percent over 5000/100 ml. Prechlorination reduces the coliform count to the acceptable sanitary level, which must not exceed 1/100 ml in the treated supply.

The use of water for drinking purposes requires that the municipal supply be afforded sanitary protection to ensure the health and well-being of individuals and the community. The U. S. Public Health Service promulgates quality standards for drinking water on interstate common carriers subject to the Federal Quarantine Regulations. These quality standards apply to the water after treatment and have been accepted by the American Water Works Association and by most state public health agencies as minimum standards for all public water supplies.

Quality standards that apply to the source of water for drinking purposes, that is, to the raw water quality standards, are not promulgated by the U. S. Public Health Service in the 1962 revision of Drinking Water Standards. The reason for this may lie in the present effectiveness and anticipated advances in water treatment methods. Raw water standards for municipal supply could needlessly eliminate the use of some water sources that may become important under changing economic conditions and technological advances. Quality standards applicable to municipal water supply are, therefore, separated into two categories. The first category involves quality standards for raw water at the source of supply. The second category of municipal water supply standards involves quality standards for treated water at the point of use. Although the quality standards for drinking water listed in Table 4 must be met by interstate carriers and although these standards have been accepted by most state regulatory agencies for municipal water supply, many municipal supplies in the United States are using more highly mineralized water without any apparent adverse effects or severe complaints. Where such use occurs, water of lower mineralization is not available. For example, a dissolved solids concentration four times larger than the 500 ppm established as a standard is used in over 100 public supplies in the United States.

Water utilities are charged with the responsibility of collecting water for municipal supply at the source, treating the water as conditions may require, and distributing it to the users. In southeastern Wisconsin the populated areas served by municipal water supply systems provide water, not only for drinking and culinary purposes, but also for a variety of other uses, including waste disposal, bathing, washing, laundering, heating, air conditioning, lawn sprinkling, gardening, industries, business establishments, and fire protection. The temporary curtailment of water use due to water shortages during seasonal periods of high water demand is often the result of an inadequate municipal system of water treatment or distribution capacity rather than of a physical shortage of water at the source.

The municipal water supplies of the Region are presently obtained both from surface water and ground water sources. The cities of Milwaukee, Wauwatosa, West Allis, Greenfield, Cudahy, South Milwaukee, Racine, Kenosha, and Port Washington and the villages of Whitefish Bay, Fox Point, Shorewood, Glendale, and Sturtevant use Lake Michigan water for municipal supply. No other lakes are used for this purpose in the Region. All other cities and villages within the Region use ground water obtained from wells tapping the deep-lying sandstone aquifer, the Niagara aquifer, or the surficial glacial drift.

None of the many streams of the Region are used presently as sources of municipal water supply, nor is it likely that they will be used for this purpose within the foreseeable future. The ready availability of water from Lake Michigan and the thick and extensive subterranean ground water reservoirs that underlie the Region can be expected, with proper planning and management, to meet the water needs of the Region for many decades, both with respect to water quantity and water quality.

The consideration of stream quality standards for municipal water supply is more academic than practical in southeastern Wisconsin. The consistently low mineralization of Lake Michigan water and the relatively uniform chemical and physical characteristics of ground water, coupled with the greater reliability and predictability of these sources of supply as compared to the variable chemical, physical, and bacteriological qualities and available quantities of stream water, exclude streams from serious consideration as a potential source in the foreseeable future.

Although the streams of the Region are not used as a source of municipal water supply, it is common practice for municipalities and industries to use these streams and stream channels for the discharge of treated sewage and occasionally untreated sewage consisting largely of the municipal water supply after it has been fouled by use. During low-flow conditions in the Root River watershed, for example, the flow of the Root River Canal apparently is sustained exclusively by liquid wastes of municipal and industrial origin.

INDUSTRIAL WATER SUPPLY

The industrial water supply category includes a large variety of uses and a corresponding wide range of quality requirements. Quality is not, for example, a consideration in water supply for use as sprays to scrub stack gases to decrease air pollution, whereas distilled or demineralized water is required in several processes applied in the manufacturing of television tubes. Not only do water quality requirements vary with the type of industry; but they vary also within a single industrial plant where water may be used for multiple purposes, each having different quality requirements.

For SEWRPC purposes industrial water supply, exclusive of cooling water, was classified into three major use categories:

1. Boiler feed water: used to produce steam for heating and power production.

2. Process water: used as an ingredient in the preparation of a finished product.

3. General purpose water: used for cleansing and for disposal of industrial wastes.

The wide variety of industrial water uses and the numerous quality standards established by industry preclude simplification to meet the needs of the SEWRPC for water quality mapping and water use appraisal. Table 4 presents water quality standards pertaining to these three major industrial use categories and certain selected subcategories, including baking, boiler feed at four ranges of pressure, brewing, carbonate beverages, dairy industry, food canning and freezing, food equipment washing, laundering, processing (general), and tanning. Water for cooling, that is, water used for engine, compressor, and condenser cooling and air conditioning, is not listed in Table 4 under industrial water use, although a large part of industrial water is used for cooling purposes. Cooling water standards are listed separately in Table 4 and discussed under the following separate heading in order to facilitate a more detailed consideration of this important water use.

COOLING

Engine jacket systems, condensers, air conditioning, refrigeration systems, and a large number of industrial operations require water in the cooling process. The water is circulated through the machinery or equipment to reduce temperatures by absorbing heat and carrying it away. There are three principal types of cooling systems in use: 1) the once-through system, 2) the open recirculating system, and 3) the closed recirculating system. The chemical and physical suitability of water for cooling purposes depends on the type of cooling system involved.

In the once-through cooling system, water moves through the heat-exchange units and goes to waste. The cooling water must be consistently of suitably low temperature and be dependably available in large quantities. No evaporation takes place; and the total mineralization of the cooling water, consequently, is not increased. Scale formation and corrosion adversely affect the cooling system. Principal constituents or properties of water that contribute to deposition of dissolved salts from the cooling water or to the formation of deposits by corrosion are silica, calcium, magnesium, bicarbonate and carbonate, dissolved solids, and pH. Calcium carbonate frequently comprises most of the scale deposit.

In the open recirculating system, the cooling water is passed through the heat-exchange units and is discharged to the atmosphere over structures that facilitate heat dissipation by partial evaporation of the used cooling water. Upon completion of this process, the reconditioned cooling water is recirculated to the heat-exchange system; and the cycle is repeated. This method of cooling causes progressive increase in the mineralization of the cooling water and water loss through evaporation requiring the addition of makeup water. Scale formation becomes more troublesome. Where calcium carbonate usually is the principal precipitate in the once-through system, calcium and magnesium silicate and sulfate salts are also formed in addition to the calcium carbonate in the open recirculating system.

In the closed recirculating system, the cooling water is passed through the heat-exchange units and is reconditioned in an enclosed cooling tower that dissipates absorbed heat by convection. Makeup water is added, and the cooling water is recirculated through the heat-exchange equipment. This method of cooling involves little evaporation loss, and makeup water is used normally in small quantities to replace loss from leakage. Corrosion can be a serious problem in this type of cooling system. Because of the low makeup water requirements, however, corrosion and scale formation can be effectively controlled by adding inhibitors to the cooling water.

Quality standards for cooling water are indicated in Table 4. Water meeting these standards is ideally suited for cooling purposes, with respect to the parameters listed. Industry, however, has contended for many decades with sources of cooling water supply of inferior chemical quality; and a multitude of treatment methods have been developed over the years that may be used to chemically condition the water. Thus, it becomes possible to use sources of water for cooling that are of inferior chemical quality but meet the requirements for temperature and quantity dependability.

WASTE ASSIMILATION

The capacity of a stream to assimilate wastes may be measured in terms of the amount of nondegradable and degradable wastes that can be carried in solution or suspension by the stream without exceeding the limits of concentration established for those uses of the stream water that are deemed necessary or desirable. This capacity depends, in part, directly upon the extent of dilution of nondegradable wastes that occurs in the stream. Nondegradable wastes are wastes, such as chloride, that are not subject to decomposition, chemical change, or physical removal. Primarily, however, the capacity of a stream to assimilate wastes is a dynamic variable that is a function of a multitude of interacting physical, chemical, biochemical, and biological processes that occur naturally in streams. These processes disassociate, decompose, or even remove the degradable wastes from solution or suspension, thus making the streams capable of self-purification.

The self-purification processes of a stream are always operative, but the processes may become ineffective from a practical standpoint if waste loading creates a condition of pollution over extensive and important reaches of the stream that far exceeds the natural waste assimilation capacity. The major interrelated factors that determine whether extensive gross pollution will occur are the amount and quality of water available in the stream to dilute the wastes relative to the quantity and concentration of these wastes.

No one water quality parameter can be used to determine the extent to which a stream has assimilated wastes. Although the biochemical oxygen demand is a commonly applied measure of this capacity and of the pollutional load (because oxygen-demanding wastes are common), other wastes are also important. The extent to which a stream has assimilated wastes is, of course, related to the undesirable condition known as pollution. Pollution is defined in Drinking Water Standards, 1962, as "... the presence of any foreign substance (organic, inorganic, radiological, or biological) in water which tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water." The Federal Security Agency of the U. S. Public Health Service in Suggested State Water Pollution Control Act and Explanatory Statement defines pollution as "... such contamination, or other alteration of the physical, chemical, or biochemical properties of any waters of the state, or such discharge of any liquid, gaseous or solid substance into any waters of the state, as will or is likely to create a nuisance or render such waters harmful or detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life."

Definitions of pollution usually make no reference to the sources of the foreign substances, contamination, or discharges causing the undesirable condition; yet the sources may significantly affect the meaning and use of the term. The SEWRPC regards water pollution as being exclusively related to human activity. Such activity may be the direct cause of pollution, as for example, through the discharge of domestic sewage or industrial wastes into a stream. Such activity may also be the indirect causes of pollution, as for example, through the introduction into a stream of body wastes from a herd of cattle or poor agricultural practices that increase erosion and thereby augment the sediment load of a stream. A broader concept associated with the term pollution is one which not only describes human activities as the sources of pollution but also includes natural processes. Thus, a stream having a natural minimum chloride concentration of about 2,000 ppm, and consequently being unsuited for many purposes, is "naturally polluted" in the broad inclusive sense of the word. According to the usage adopted by the SEWRPC, this stream would not be polluted with respect to its chloride content but would be referred to as having a natural chloride concentration making the stream unsuited for specified uses.

Pollution occurs only when the waste assimilation capacity of a stream has been exceeded with respect to those parameters for which standards have been established for the existing or potential water uses involved. An industry discharging wastes into a stream is polluting it only in that reach of the stream where the undiluted, partially diluted, or completely diluted wastes adversely affect the water quality with respect to specified uses. The distance along the stream channel affected by the waste discharge may also be a factor in defining pollution. Where, for example, an industry is contributing pollutants that are diluted by the stream to acceptable levels of concentration within a relatively short distance downstream from the point of effluent outfall, the effect of this pollution may be so localized, and from a regional standpoint so insignificant, that the industry may be considered to be contributing only to a potential condition of regional pollution.

LIVESTOCK AND WILDLIFE WATERING

Water used for agricultural purposes is commonly separated into two categories: irrigation water that is applied to the cultivated soil by various methods of spreading to sustain the growth of plants and non-irrigation water that is used for watering livestock and poultry and for cleansing and general purposes relating to farm activities.

Quality standards for water used by livestock, poultry, and wildlife should be set to assure the same basic objective as standards for drinking water for human consumption; namely, preservation of the health and well-being of the animals. The limits of water quality tolerance, however, are apparently greater for animals than for human beings. A careful review of selected authoritative publications on water quality standards indicates that few quality standards have been established for water used by livestock, poultry, and wildlife. The general sparsity of quality standards for water used by animals may indicate that the water sources that have been used to date to sustain livestock and poultry offer few serious health problems in terms of severity of disorder and number of animals involved.

Theoretical factors that should have a bearing on the suitability of a water source for livestock, poultry, and wildlife are the animal species, age, sex, physiology, and inherent adaptability to water quality conditions. Factors that pertain to the water source are its chemical composition in terms of the many possible types and concentrations of organic and inorganic substances in solution or suspension, the toxic nature of these substances, pH, synergic and antagonistic effects, water temperature, and the pathogenic microorganisms that may be present. An external factor of importance may be the season of the year.

The vast number of possible combinations of theoretical factors makes the establishment of water quality standards immensely complex. Any generalization or oversimplification of the possible multitude of standards could result in erroneous evaluations, and no standards are presently established that have gained national stature and application. In Wisconsin, no water quality standards have been established for livestock, poultry, or wildlife.

Water of high mineralization may have sufficiently severe physiologic effects to cause death. Lactation and egg production are known to decrease and possibly terminate due to continuous ingestion of highly mineralized water. Concentrations of 7,000 ppm dissolved solids may be safe for temporary and short-term use. Although animals can adjust to the use of highly mineralized water, the change in concentration should be gradual because sudden large increases in mineralization may cause acute poisoning and death.

Bacteriologically polluted water may be expected to transmit disease to livestock, poultry, and wildlife. Independent studies have shown that cattle and swine which had been fed water highly polluted with both treated sewage and untreated sewage for periods ranging from six months to two years remained without symptoms of bacterial infection although virulent disease organisms were known to occur in the polluted water. This is, however, not to be considered final in the matter; and water known to contain bacteria pathogenic to livestock and wildlife generally should not be used for watering or animal care. Beef tape-worms may be transmitted through sewage, and waste waters from dairies and slaughterhouses are suspect but not proven sources of animal disease. Toxic algae and protozoa are known to be fatal to livestock and poultry; oils and oily substances could be detrimental to livestock and adhering to the feathers of water fowl may reduce their buoyancy.

As already noted, widely accepted quality standards have not as yet been developed with respect to the parameters listed in Table 4 as related to livestock and wildlife use. However, the water quality classification published by the Agriculture Experiment Station of the South Dakota State College has been adopted. The following classifications represent the suitability of water for cattle, swine, and poultry as related to concentrations of dissolved solids.

Water Quality	Dissolved Solids (ppm)
Excellent	0 - 1000
Good	1000 - 4000
Satisfactory	4000 - 7000
Unsatisfactory	Over 7000

IRRIGATION

The suitability of water for irrigation depends on soil characteristics, on the types of plants to be irrigated, and on the quality of the irrigation water. As with human beings and with farm animals, the water quality should be such as to contribute to the health of the plants. Successful irrigation is not possible, even with water of excellent quality, if the soil is poorly drained.

The complex interrelationships between soil, plant, and water make it extremely difficult to establish quality standards for irrigation water. Quite aside from the multitude of variables inherent in each of the three aspects bearing directly on the problem generally, there are also the climatic conditions of rainfall, temperature, and humidity which bear indirectly on the problem in a given area. Moreover, the effects of the numerous chemical constituents and physical properties of irrigation water are not well known. It may, therefore, be assumed that when quality standards are established they will have provincial rather than general applicability. The presence of coliform bacteria in water spread for irrigation is generally considered to be objectionable, not because of the effect upon the plants, but because of possible effect on human and animal health. Insufficient data is available, however, to permit a standard to be established.

The Technical Committee of the U. S. Public Health Service Great Lakes-Illinois River Basins Project, together with the Project Staff, concluded in a recent work group study that while "... chemical quality is important to irrigators in the western part of the United States, it is not considered to be of sufficient importance in the Lake Michigan Basin to merit setting limits."[2] Strictly interpreted, this statement applies to the nine watersheds in the Region tributary to Lake Michigan and excludes the watersheds of the Des Plaines River, the Fox River, and the Rock River, which are outside the area of study of the Great Lakes-Illinois River Basins Project in that they drain into the Mississippi River. Considering climatic conditions, soils, and stream quality, there is no reason to believe, however, that this statement should not apply equally well to all of the watersheds of the Region.

In order to provide a scale by which the water quality of the streams of the Region can be measured in terms of suitability for irrigation use, however, it was decided to adapt two of the criteria of the California State Water Control Board; namely, dissolved solids and specific conductance. Because of the limited experience available within the Region, the resulting standards should not be construed as rigid or immutable. Rather, the numerical values indicated should be thought of as guides to the evaluation of the water quality data for irrigation use. The numerical values selected may change in light of the findings of possible future studies aimed at establishing standards for irrigation water specifically for the Region. The parameters are maxima and are listed below:

Parameter	Standard
Dissolved solids	2000 ppm
Specific conductance	3000 micromhos/cm at 25°C

PRESERVATION AND ENHANCEMENT OF AQUATIC LIFE

The primary significance of the fish and related aquatic life in southeastern Wisconsin lies in the aesthetic and recreational values that they offer to the sport fisherman, the vacationer, and to the adult and child who enjoy nature in the course of their daily experiences. The fish of stream and lake (and the wildlife of field and forest) have intrinsic value to man which is intangible, difficult to define, and incalculable in terms of money. Although the value of fish to man can be approximated in terms of what sportsmen spend annually on equipment, licenses, and sports-related travel, such approximation in no way measures the human values derived. Sportsmen, vacationers, and people engaged in the everyday routine of living appear to be more consciously seeking the natural beauty of their environment and attempting, through governmental action, to decrease the apparent unfavorable impact urbanized and industrial life is having on fish of stream and lake.

A program of water quality control that implements stream quality standards for the preservation and enhancement of aquatic life attempts to maintain or restore the aquatic environment that is essential to the survival, growth, and propagation of fish that live in the streams and, consequently, also of the wildlife that seek the streams for water and food. The establishment of such water quality standards can also serve to assist in defining the goals of pollution control and facilitates enforcement of pollution control regulations.

There are a large number of complexly interacting factors that must be considered in establishing water quality standards to maintain or restore stream conditions favorable to fish life. To maintain or restore a favorable aquatic environment for fish, the level of a wide variety of possible pollutants should be held at all times to a concentration or magnitude that is less than the threshold value at which the pollutants produce harmless but slight detectable effects. Although many cause-and-effect relationships have been determined regarding various pollutants and their effects upon fish, it would appear that much additional research is required in this field.

There are numerous factors that must be considered in establishing water quality standards with respect to fish life. These factors may be separated into four categories relating to: 1) the physiologic characteristics of fish, 2) the food chain that sustains the fish, 3) the aquatic environment, and 4) the technical and interpretive problems involved in the research experiments performed to establish quality standards. Only the first three categories are of direct interest in the regional stream quality study.

[2] *For example, the California State Water Quality Control Board publication Water Quality Criteria presents a detailed quality classification of irrigation waters in tabular form, considering interrelationships of sodium content, specific conductance, and dissolved solids content of the water and plant tolerances to boron, chloride concentration, and sulfate concentration.*

The physiologic characteristics of fish ultimately determine what effect various pollutants will have upon their health and survival. Important variables within this category are the species, stage of growth (egg, fry, adult, old age), sex, activity phase (vegetative versus propagative), adaptability to adverse conditions of aquatic environment, and the condition of health prior to exposure to pollution. Water that is of favorable quality to one species of fish may not be adequate for another. Eggs and fry have high oxygen requirements, because of high metabolic rates, making them vulnerable to low dissolved oxygen levels in a stream. Fish may build up a tolerance to toxic substances if they are continuously exposed to gradually increasing concentrations, further complicating the task of establishing quality standards.

The food chain that sustains fish may be adversely affected by concentrations of substances that do not directly affect the fish, and only one link in the food chain need be eliminated to produce highly unfavorable conditions for fish sustenance. Fish may survive by migration to unaffected reaches of a stream or may perish if conditions do not improve. The tolerance levels are imperfectly known for pollutants that may affect the many forms of aquatic life that range from phytoplankton and zooplankton to hellgrammites and crayfish that comprise a small part of the chain of organisms providing food for fish life. The food chain, therefore, must also be considered in establishing water quality standards.

Changes in the aquatic environment through human activities may have effects upon the fish life of a stream that range from undetectability through mild effects to severe effects and death. Of particular concern in this respect are pesticides, insecticides, and herbicides, which may enter a stream by wind or by surface runoff in such concentrations as to cause local or regional fish kills.

Of the parameters measured in the regional stream quality study, the oxygen content of the water is of greatest importance to the preservation of fish life. The dissolved oxygen in the aquatic environment of fish is equally vital to fish for the same reason that oxygen in the atmosphere is vital to human beings. Whereas air at sea level contains about 20 percent oxygen by weight, or about 200,000 ppm, the maximum dissolved oxygen content of water is 14.6 ppm, under conditions of saturation at 32°F. Although this maximum dissolved oxygen content of water is extremely small as compared to the oxygen content of the air, this relatively small concentration is more than enough to meet the physiologic oxygen requirements of fish and of the organisms which make up the food chain.

There are two principal sources of dissolved oxygen that occurs in streams: the atmosphere and the photosynthetic plants. Atmospheric oxygen is taken up by the stream through the process of absorption at the water-air interface. Wave action in the main channel, along the stream embankments, and at and near obstructions, together with the agitation and dispersal in stream rapids, waterfalls, and at dam spillways, results in atmospheric aeration of the stream. This process of stream aeration is further augmented by wind action.

The second important source of oxygen in streams is derived from the photosynthetic processes of both microscopic and macroscopic plants. The photosynthesis occurring during daylight hours releases oxygen into the stream. The amount of oxygen taken up by the stream from aquatic plants, principally composed of algae, depends on many factors. A condition of supersaturation with respect to dissolved oxygen in the streams of the Region is not uncommon, however, and often results, in part, from photosynthetic action.

According to Professor Champ B. Tanner,[3] the physical principle that accounts for the buildup of dissolved oxygen to levels of supersaturation is the diffusion rate of dissolved gases in water. This diffusion rate is very slow; and as the aquatic plants release oxygen, this low diffusion rate permits the buildup of the dissolved oxygen content to supersaturation at the prevailing equilibrium of temperature and pressure. There is no instantaneous diffusion of the excess dissolved oxygen from the plant source through the water to the stream surface where the excess quantities can be immediately released to the atmosphere.

Streamflow in southeastern Wisconsin is largely maintained by ground water discharge into the stream channels, and ground water could be an important source of the dissolved oxygen that occurs in the rivers

[3] *Personal communication, 1965, Champ B. Tanner, Professor of Soils and Meteorology, University of Wisconsin.*

and creeks. However, there appears to be little information on this subject based on direct investigations. Ground water may be deficient in dissolved oxygen.

There are a number of naturally occurring processes that oppose the aeration or oxygenation of streams. Rather than adding oxygen to the rivers and creeks, these processes remove the oxygen from solution and thus reduce the amount of dissolved oxygen available to the respiratory processes of fish and of the many aerobic forms of life that comprise the food chain. Important among these processes of deoxygenation are biochemical processes that demand oxygen for completion of the process. The organic wastes discharged into streams from municipal, industrial, or domestic sources are decomposed to stable substances by bacteria and other microorganisms. These organisms require oxygen in the processes of decomposition of organic wastes and may cause the marked lowering or complete depletion of the dissolved oxygen content of the stream.

The algae and other plant life in the streams contribute oxygen to the stream by photosynthesis during the daylight hours. During the night and during periods of insufficient light intensities; these same plants will use oxygen in respiratory processes, resulting in small to large decreases in dissolved oxygen depending on the plant population, temperature, and net effect of processes of aeration. The daily changes in the dominance of the photosynthetic over the respiratory processes result in a diurnal change in the dissolved oxygen content of the streams. This diurnal change may vary from a condition of supersaturation to a condition of critically low dissolved oxygen concentration.

Fish life and the organisms comprising their food chain depend upon the actual concentration of dissolved oxygen in their aquatic environment. The opposing processes of oxygenation and deoxygenation have at all times a net effect that controls the absolute amounts of oxygen available to sustain fish life. The minimum oxygen content that must be available to fish at all times is not a matter of general agreement. When the preservation of fish life is involved, however, whatever the concentration that is decided upon as a minimum standard, this minimum must not only be adequate for all species of fish life desired to be preserved but also for all stages of their development and for the maintenance of a healthy food chain. If dissolved oxygen standards are established for the preservation of preferred species of fish, the minimum dissolved oxygen concentration of the stream must at all times be adequate for those species of fish, for those stages of fish development that require the most dissolved oxygen, and for the food chain organisms.

The various species of fish have different dissolved oxygen requirements and are classified as tolerant, facultative, and intolerant to stream pollution. Tolerant fish species include carp, catfish, goldfish, and suckers, all requiring a minimum of 3.0 ppm dissolved oxygen. Facultative species include alewives, shiners, walleyes, crappies, bluegills, northern pike, and perch. A minimum of 4.0 ppm dissolved oxygen is a generally accepted standard for this group of fish. Intolerant fish include trout, chubs, and whitefish, requiring a minimum of 5.0 ppm dissolved oxygen.

The SEWRPC has adopted quality standards with respect to dissolved oxygen required for the preservation of fish life. These standards, together with those for other important parameters, are listed in Table 4. It should be noted that the dissolved oxygen concentrations are minimum values that should apply to all seasons of the year.

The preservation of wildlife, as distinguished from fish life, should meet the quality requirements of streams used for livestock and poultry, as previously noted. Few standards have been established for this non-irrigational use of water for agricultural purposes.

RECREATION

The recreational use of streams and lakes in southeastern Wisconsin involves such activities as swimming, bathing, fishing, boating, water skiing, picnicking in park areas adjacent to water, skating, and ice boating. The predominant recreational use of the streams of the Region is fishing, which is done frequently from bridges and stream banks. Whereas swimming and bathing in the streams is now uncommon within the Region, picnic areas adjacent to streams are becoming increasingly numerous. Because of relatively narrow channels, shallow depths, and frequent meander bends, streams within the Region offer poor competition to lakes for summer boating and water skiing and winter ice boating. Skating on the ice of river and creek is hazardous because of the solid materials that can project through the ice, the frequent unsafe ice conditions near the stream banks, and the tension and heave fractures that readily develop under changing weather conditions.

The recreational uses of streams are commonly divided into two categories relating to whether there is partial-body contact or full-body contact. Water quality standards established for recreational use reflect concern for human health, well-being, and aesthetic enjoyment. The Wisconsin State Board of Health promulgates that for full-body contact activities, such as swimming and bathing, the coliform count should not exceed 2,400 per 100 ml during the recreational season. The Technical Advisory Committee of the U. S. Public Health Service Great Lakes-Illinois River Basin Study recommends as a standard for partial-body contact a monthly average of 5,000 coliforms per 100 ml during the recreation season. Table 4 presents these and other standards for recreational use of streams.

NAVIGATION (COMMERCIAL)

In southeastern Wisconsin there are four port cities that serve users of the upper Great Lakes and the St. Lawrence Seaway: Milwaukee, Racine, Kenosha, and Port Washington. The harbors of these cities are deep enough to accommodate ocean-going vessels of moderate size. The navigation of such vessels as ore boats, coal boats, barges, tugs, and large pleasure craft is possible only in the very lower reaches of those streams that enter the harbors at Milwaukee, Racine, and Kenosha. At Milwaukee the Milwaukee River, the Menomonee River, and the Kinnickinnic River are navigable by large commercial vessels for distances of approximately one to three miles upstream from the Milwaukee River estuary. At Racine the Root River is navigable by large pleasure craft for a distance of about one mile upstream from its mouth. At Kenosha Pike Creek is navigable by large pleasure craft for about one-half mile upstream from its mouth.

The pollutants that are deleterious to the use of streams for navigation are acids or alkalies that corrode metal or cause the deterioration of wood, floating debris, and suspended solids that can be a hazard to ships and floating oil that could ignite and cause fire damage. Approximate standards are provided in Table 4. In the lower reaches of the streams entering Lake Michigan at the port cities, there are complex shifting currents causing the irregular dispersal of Lake Michigan water into the stream estuaries and lower stream channels. Water quality sampling stations were not established where this condition was known to exist, in order to avoid a water quality and flow complex that properly requires separate and extremely detailed study. An exception to this rule was the establishment of station Ml-12 on the Milwaukee River at STH 32. This station was used for comparative purposes only and not for the mapping of stream quality.

AESTHETICS

The aesthetic value of streams relates to man's emotional and intellectual response to Nature. His appreciation of the scenic beauty of a stream is both intangible and indefinable, but nonetheless real. This appreciation of the beauty of a brook, creek, and river is in contrast to his appraisal of the usefulness of water as expressed in physical or economic terms.

Our civilization is developing with an ever-increasing deleterious effect upon the streams of the Nation. In southeastern Wisconsin, where 40 percent of the population live in 5 percent of the land area of the state, this development has caused undesirable changes in both the number and kind of fish that occur in the streams, occasional severe fish kills, accelerated nutrient enrichment giving rise to unsightly algae blooms, and increased pollutional loads that adversely affect extensive reaches of many streams. Moreover, the aesthetic value of the streams of the Region have been decreased markedly or in some cases entirely destroyed.

In contrast to the technical appraisal of streams in terms of their usefulness as sources of water supply or for waste disposal, the aesthetic values of a stream involve parameters for which numerical concentrations are physically meaningless. Aesthetic values involve man's sight, scent, sound, and touch. In contrast to the technical appraisal of streams that involves numerical expression of water quality parameters, the aesthetic use of a stream may immediately be impaired by the mere presence of any one of a wide variety of materials or substances that are offensive to eye and nose or to body contact. At many locations throughout the Region, refuse heaps litter the banks of streams and extend into their channels. Discarded automobile and truck tires, tin cans, glass bottles, metallic and wood scrap, paper, and waste material of all varieties are to be observed locally on all streams and watercourses. Floating or suspended garbage, oils, sewage wastes, algal slime, detergent foam, offensive odors, and a wide array of unpleasant matter can preclude the aesthetic enjoyment of a reach of stream. Maximum permissible concentrations are not meaningful in relationship to the aesthetic use of streams unless one arbitrarily states that the concentration should be zero for all unsightly and odoriferous materials. Quality standards for the aesthetic use of streams are descriptive and qualitative rather than quantitative.

Chapter IV

THE NATURE AND SIGNIFICANCE OF SELECTED STREAM QUALITY PARAMETERS

SELECTED STREAM QUALITY PARAMETERS

The SEWRPC study of the water quality and flow of streams in southeastern Wisconsin was undertaken for regional planning purposes and has as its first objective the assessment of the present stream quality in relation to major sources of pollution. This chapter discusses the nature and significance of the 34 parameters of water quality determined as part of this study and presents in tabular form the numerical values of the parameters obtained in the sampling program, including the maximum, average, and minimum concentrations found of each parameter by watershed. Thirteen regional stream quality maps are also included, which permit ready comparison of maximum, minimum, or average conditions within the Region and its subareas with respect to 11 selected parameters.

Of the 34 stream quality parameters determined in the laboratory analyses, three will be omitted from discussion: calcium hardness, magnesium hardness, and alkalinity P. The analytical determinations of these parameters were performed as necessary steps in the calculation of the ionic concentrations of calcium, magnesium, and carbonate, respectively, which serve as the actual water quality parameters. The tables presenting the maximum, average, and minimum concentrations, or numerical values, of the remaining 31 parameters are based exclusively upon the SEWRPC and the State Laboratory of Hygiene analyses. Where available, comparable stream quality data obtained from state, county, and municipal agencies were reviewed and were found to be of similar orders of magnitude for the period of study at sampling locations relatively near or at those established for the study. The average concentrations, or numerical values, of the parameters discussed in this chapter are presented in several stream quality maps and are tabulated by watershed as unweighted averages. Included in the tables is the number of stream samples upon which the maximum, average, and minimum values are based.

The 13 interpretive stream quality maps show the similarities and differences in the concentrations of each of 11 selected water quality parameters in the main streams and larger tributaries in the 12 watersheds of southeastern Wisconsin. These maps show expected maximum, minimum, or average concentrations for 1965 based on the SEWRPC and State Laboratory of Hygiene water analyses of stream samples. Where sufficient information is available on the occurrence of a particular parameter, the maps show expected stream quality conditions not only for 1965 but also for a period extending five to ten years into the future. Unless otherwise stated in the discussion of each interpretive stream quality map, these maps apply only to 1965.

For the illustration of stream quality conditions, the parameter concentrations, or numerical values, are expressed by map symbols representing ranges of concentrations. The ranges selected were considered to be sufficiently wide to permit reasonable accuracy in mapping without being so wide as to be of little use in regional planning or so narrow as to imply an unreasonably high accuracy of mapping. The limits of each range are related to the standards presented in the preceding chapter for one or several major water uses. For example, the stream quality standards for the preservation and enhancement of fish life indicate that minimum concentrations of dissolved oxygen for tolerant, facultative, and intolerant species of fish are 3.0, 4.0, and 5.0 ppm, respectively. In mapping the dissolved oxygen concentrations in the streams of the Region, the ranges of concentration are related to these standards and are: 0 to 3.0 ppm, 3.1 to 5.0 ppm, 5.1 to 10.0 ppm, and more than 10.0 ppm. The stream quality interval of 3.1 to 4.0 ppm dissolved oxygen was avoided in mapping because the range interval was considered to be too narrow for any reasonable representation of general conditions on regional maps. A relatively broad range of concentration (5.1 to 10.0 ppm) was used where the dissolved oxygen concentrations exceeded the minimum requirement for intolerant species of fish. No standard was established for the maximum dissolved oxygen concentration recommended; and, therefore, the range interval has an undefined upper limit: more than 10.0 ppm.

Mapping of stream quality in the lower reaches of the Milwaukee River, Menomonee River, Kinnickinnic River, Oak Creek, Root River, and Pike River was not possible because of insufficient data or because of the extreme complexity of the streamflow patterns where the varying stream stages are at or near the changing levels of Lake Michigan into which these streams discharge. Stream reaches were not mapped where sufficient data were not available upon which to prepare interpretations of expected stream quality conditions.

Color was used in the interpretive mapping to indicate channel reaches wherein the stream quality, as indicated by the numerical value of the parameter used in mapping, was substandard or marginal with respect to selected water uses. Progressively deeper shades of color signify progressively poorer water quality.

In presenting the occurrence and significance of the 31 stream quality parameters, information has been drawn from many sources. To promote readability, this report has intentionally avoided reference to all but the most important; and these are footnoted in the text or are listed in the Selected Bibliography.

The reader is referred to publications of the Wisconsin Geological and Natural History Survey and of the U. S. Geological Survey for reports pertaining to the geology and hydrology of southeastern Wisconsin. Discussions of the geology and of hydrologic principles presume knowledge of the technical nomenclature.

Silica

Silica is composed of silicon dioxide (SiO_2) and under laboratory conditions is considered to be insoluble in water and in acids (except hydrofluoric). Although more than 60 percent of the earth's crust is composed of silica, the low solubility of this substance under natural conditions of occurrence largely accounts for its relatively low concentration in most bodies of surface water and ground water.

Few uses of water are affected by its silica content. The presence of silica in concentrations found in natural waters is not known to have adverse physiologic effects upon human beings, livestock, poultry, fish and wildlife, or upon irrigated plants. Boiler feed water, however, must be practically free of silica to avoid formation of boiler scale. Water used in the brewing industry preferably should contain no more than 50 ppm. All other uses listed in Table 4 are unaffected by the silica content of water.

The natural silica content of the streams of southeastern Wisconsin, as with most other constituents, is determined by the silica concentration of the ground water, surface runoff, and direct precipitation that enter the stream channel and that individually or collectively make up the water of the stream. In addition to these three natural sources of silica—ground water seepage, surface runoff, and direct precipitation—there appears to be a fourth source: swamps and marshes along the course of the stream. Such wetlands form the headwaters of many of the streams of the Region. Water analyses of stream samples collected during the period of study from January 1964 through February 1965 indicate exceptionally high silica concentrations in the upper reaches of these streams during periods of relatively high streamflow resulting from prolonged moderate or sudden heavy rains that tend to flush the wetlands of stagnant water. The physical and chemical properties of swamp water and the physical characteristics of the swamp lands may be conducive to the accumulation because of the normally stagnant conditions that prevail in a swamp or marsh. Such accumulations may then be flushed downstream during periods of heavy rain and high streamflow. The specific reasons for the high silica concentrations are, however, a matter of speculation; and it is beyond the scope of this study to establish the cause and effect relationships of this phenomenon.

Silica may also enter streams artificially with the effluent waste waters from municipal sewage treatment plants, industries, and domestic sources. All development within the Region, other than that served by Lake Michigan water, depends upon ground water as a source of supply. This water is obtained from wells that may tap the shallow water-bearing glacial drift, the Niagara aquifer, or the deeper sandstone aquifer.

Ground water from the glacial drift and the Niagara aquifer discharges naturally by seepage and by springs into the streams of Washington, Ozaukee, Milwaukee, Racine, and Kenosha counties and into the streams traversing approximately the eastern three-quarters of Waukesha County and the eastern one-half of

Walworth County. The Milwaukee Formation, which underlies the glacial drift in eastern Ozaukee County and northeastern Milwaukee County, presumably contributes locally to the flow of the Milwaukee River, Sucker Creek, Sauk Creek, and the Little Menomonee River. In southwestern Washington County, in western Waukesha County, and in the western half of Walworth County, the glacial drift and presumably the underlying Platteville-Galena unit[1] contribute to the flow of the Ashippun River, the Oconomowoc River, the Bark River, Whitewater Creek, Turtle Creek, Jackson Creek, the Delavan Lake Outlet, Honey Creek, Sugar Creek, and the White River by way of Lake Geneva. Water from these rock units may thus sustain the flow of the streams in the Region during periods of dry weather and significantly influence the chemical and physical quality of the streams.

Under natural conditions water from the sandstone aquifer directly supports the flow and affects the quality of streams in southwestern Washington County, in the western part of Waukesha County, and in the western half of Walworth County. Water from this aquifer reaches the streams in the northern and eastern parts of the Region indirectly by discharge from sewage treatment plants which process waste water from municipalities and industries that obtain water from wells tapping the sandstone aquifer. Thus, water from the sandstone aquifer may affect the chemical and physical quality of streams, including the silica concentration, throughout most of the Region.

Other probable artificial sources of silica in waste discharges reaching the streams are the zeolite used in the process of water softening and silicates used in municipal water treatment as coagulants and corrosion inhibitors. Sodium silicofluoride has been used in fluoridating water supplies.

Concentrations of silica in natural waters exceeding 100 ppm are relatively rare. Concentrations ranging from 30 to 100 ppm are fairly common. The most common range is 1 to 30 ppm. Water issuing from a spring on Rio San Antonio in Sandoval County, New Mexico, is recorded as having a silica concentration of 103 ppm. High temperature water (122^{o}F) from an 800-foot deep flowing artesian well in Owyee County, Idaho, has a silica concentration of 99 ppm. Sea water contains very little silica—0.04 ppm. Lake Michigan water sampled near Milwaukee had a concentration of 3 ppm.

In the regional stream quality study, a total of 540 samples collected at 87 sampling stations in all 12 watersheds of the Region were analyzed for silica concentration. The regional maximum, average, and minimum concentrations of this constituent were found to be 24, 7, and 0 ppm, respectively. The corresponding concentrations for each watershed within the Region are listed in Table 5.

Map 3 shows the maximum silica concentrations that may be expected in the streams of the Region as of 1965. There is no reason to believe that the maximum silica concentrations indicated will change markedly within the foreseeable future, so that Map 3 may be regarded as not only representative of present conditions but also indicative of conditions which may prevail for possibly the next 10 years. The silica concentrations are mapped on a scale ranging from 0 to more than 50 ppm. This scale is subdivided into seven intervals of concentration as shown on Map 3. The four lower intervals of concentration that range from 0 to 20 ppm are mapped in black, whereas the three intervals ranging from 21 to more than 50 ppm are shown in color. The seven successive intervals indicate progressively larger concentrations of silica. The color patterns apply to higher concentrations as related to water quality standards for water uses affected by this parameter. The break between black patterns and color patterns at 21 ppm is intended to visually emphasize those reaches of the several streams that are of relatively acceptable quality (black patterns) and those that are relatively unacceptable (color patterns). The concept of relativity is important in this connection because of the wide range in the numerical values of the standards established for silica concentrations in boiler feed water and water for brewing.

<u>Iron</u>

Iron is one of the more abundant metallic elements of the earth's crust. In natural surface waters, it occurs as ferrous (bivalent) or ferric (trivalent) salts. Streams that are well aerated seldom have high

[1] *The Platteville Formation, the Decorah Formation, and the Galena Dolomite area are referred to collectively as the Platteville-Galena unit in this report.*

Table 5

SILICA CONCENTRATIONS IN STREAMS IN THE REGION

(1964 - 1965)

Watershed	Silica Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	16	6	2	18
Fox River	24	7	0	185
Kinnickinnic River	8	6	4	2
Menomonee River	16	7	0	69
Milwaukee River	23	6	0	77
Minor Streams[a]	10	6	2	11
Oak Creek	14	8	2	16
Pike River	16	7	0	32
Rock River	16	7	0	73
Root River	16	6	0	40
Sauk Creek	13	5	1	15
Sheboygan River	8	7	6	2
Total Samples				540

[a] *Composite watershed comprising minor streams that are tributary to Lake Michigan.*

Source: SEWRPC.

concentrations of iron. Ferrous iron is soluble only under anaerobic conditions. In the presence of oxygen, the ferrous ions tend to oxidize to the ferric state forming insoluble hydroxides that precipitate and settle upon or coat the surfaces of rock and other solid materials of the stream channel. When the oxygen content is depleted, as for example, when a stream carries a heavy pollution load with a high biochemical oxygen demand, the ferric state is reduced to the ferrous state; and the ferrous salts go into solution. This may result in the increased concentration of silicate, iron, phosphate, and bicarbonate, depending on the natural chemical quality of the water. Iron-fixing bacteria precipitate iron hydroxides as sheets covering the bacteria, or they excrete strands that adhere to objects in the streams.

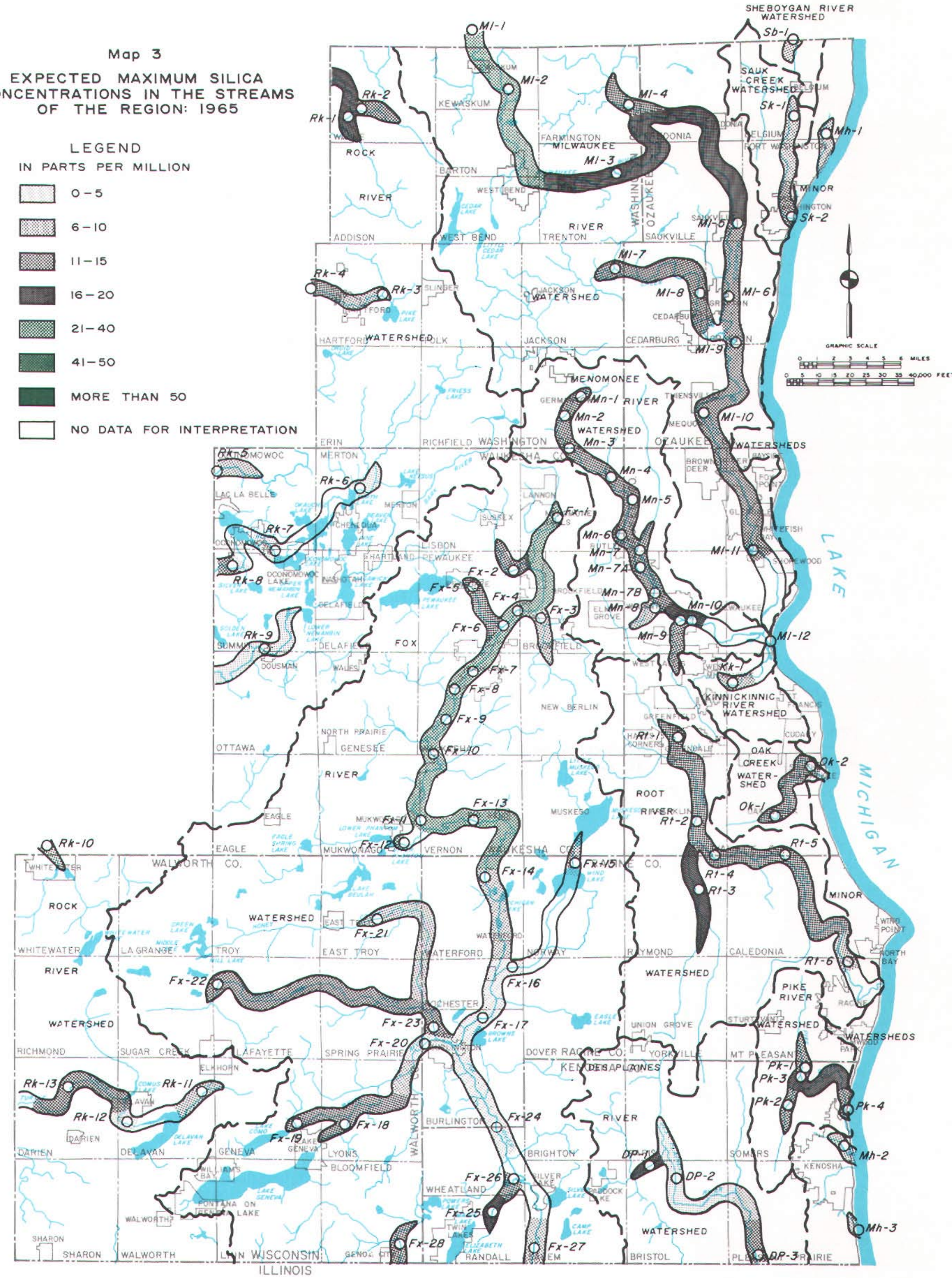
Many uses of water are adversely affected by its iron content. Even the relatively small concentrations of iron that naturally occur in streams make them unsuited for many uses without pretreatment. Drinking water may have an unpleasant bitter taste when the iron concentrations are 1.8 ppm or larger, although taste acuity varies with individuals and the bitter taste may be detected at lower concentrations. Iron concentrations exceeding the 0.3 ppm standard established as a recommended maximum for municipal supplies may deposit a reddish stain on laundry, porcelain, and enamel ware. Coffee, tea, and a variety of foods become discolored when prepared with such water. Iron in concentrations of 1.0 ppm is not known to have an adverse physiological effect. Industrial use of water most frequently requires low iron concentrations, as listed in Table 4, Chapter III. Cooling water must be of low iron content because iron is an incrusting substance and can precipitate and form a scale which reduces the efficiency of the cooling process by decreasing the heat exchange. Water high in iron content (no recommended limiting concentration has been established) can cause dairy cows to drink less water and thus reduce milk production.

The iron content of a stream depends largely upon the dissolved oxygen concentration and pH of the water and upon the natural and artificial sources of iron in the stream environment. In well-aerated water of slightly alkaline pH, iron occurs in concentrations of less than 0.50 ppm and commonly less than 0.10 ppm. In highly acid water where the pH may be less than 3.0 ppm, iron may be present in more than 100 ppm. In Shamokin Creek at Weigh Scale, Pennsylvania, where the stream quality has been affected by acid coal mine drainage, the dissolved iron concentration is recorded as 37 ppm. Pond River at Jewel City, Kentucky, has a maximum iron content of 15 ppm. A recent analysis of Lake Michigan water sampled near Milwaukee contained 0.06 ppm total iron.

Stream samples were analyzed for iron concentration largely during conditions of low flow in the Fall of 1964. The samples were not treated with acid to redissolve the iron fraction that may have precipitated

Map 3

EXPECTED MAXIMUM SILICA CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum silica concentrations for 1965 range from 25 to 5 ppm. Maximum concentrations are not anticipated to increase significantly in the foreseeable future. The general conditions shown on the map may prevail for the next 10 to 15 years.

during sample storage. As a consequence the results of the SEWRPC iron analyses may be regarded as minimum values of concentration and represent the iron in solution at the time of analysis.

The maximum, average, and minimum dissolved iron concentrations of the streams of southeastern Wisconsin were 0.60, 0.07, and 0.00 ppm, respectively. These figures are based upon 174 analyses performed upon samples collected at 87 sampling stations in all 12 watersheds of the Region. Sauk Creek was found to have the highest iron concentrations for the period of record at station Sk-1. The lowest concentrations occurred in the Fox River, Pewaukee River, and Muskego Canal at stations Fx-1, Fx-6, and Fx-15, respectively, and in the Pike River and Pike Creek at stations Pk-1, Pk-2, and Pk-3. The ranges in dissolved iron concentrations by watershed are listed in Table 6.

Table 6

IRON CONCENTRATIONS IN STREAMS IN THE REGION
(1964 - 1965)

Watershed	Iron Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	0.14	0.07	0.01	6
Fox River	0.48	0.07	0.00	56
Kinnickinnic River	0.17	0.11	0.06	2
Menomonee River	0.45	0.08	0.01	22
Milwaukee River	0.14	0.05	0.02	24
Minor Streams	0.07	0.04	0.03	5
Oak Creek	0.29	0.10	0.03	4
Pike River	0.27	0.05	0.00	8
Rock River	0.32	0.05	0.01	29
Root River	0.52	0.12	0.01	12
Sauk Creek	0.60	0.16	0.01	4
Sheboygan River	0.14	0.09	0.05	2
Total Samples				174

Source: SEWRPC.

Manganese

Manganese is similar to iron in its occurrence and chemical properties; however, it is much less abundant in nature and is commonly present in stream water in only trace amounts. The dissolved manganese in streams affects the same major water uses as iron. Whereas iron is not known to have toxic effects in excessive concentrations, manganese dust and fumes are reported to have adverse physiologic effects. The minimum levels of manganese concentration in drinking water that would produce harmful effects are not known. The U. S. Public Health Service states that domestic "... complaints arise when the level of manganese exceeds 0.15 mg/1 regardless of iron content." Previous standards have indicated that the combined concentrations of iron and manganese should not exceed 0.3 ppm. The U. S. Public Health Service Drinking Water Standards 1962 considers these constituents separately and recommends that manganese have a limiting concentration of 0.05 ppm.

Stream samples were analyzed for manganese content during the period of low streamflow in the autumn of 1963. As with iron, manganese also tends to precipitate upon sample storage; and the SEWRPC analyses determined dissolved manganese rather than total manganese. However, the difference between dissolved and total manganese may be unimportant as compared to iron.

The manganese content of stream water depends upon the presence of this constituent in ground water, surface runoff, and wastes entering the streams. Reducing conditions and bacterial activity would appear to be important processes in bringing manganese into solution. Natural waters most commonly contain less than 0.20 ppm manganese. Surface water does not often have a manganese concentration larger than 1.0 ppm except when mining or industrial wastes contain manganese. In Shamokin Creek at Weigh Scale, Pennsylvania, the manganese concentration was recorded to be 10 ppm. Lake Michigan water sampled near Milwaukee contained 0.0 ppm manganese.

The maximum, average, and minimum concentrations of manganese in the streams of southeastern Wisconsin were 0.07, 0.01, and 0.00 ppm, respectively. These figures are based on 88 analyses performed upon samples collected at 87 stations in all 12 watersheds of the Region. Poplar Creek in the Fox River watershed had the maximum concentration of 0.07 ppm at station Fx-3. Minimum concentrations of 0.00 ppm occurred in all watersheds except in those of the Kinnickinnic River, Milwaukee River, and Sauk Creek. The ranges in manganese concentrations by watershed are listed in Table 7.

Table 7

MANGANESE CONCENTRATIONS IN STREAMS IN THE REGION

(1964 - 1965)

Watershed	Manganese Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	0.03	0.01	0.00	3
Fox River	0.07	0.01	0.00	27
Kinnickinnic River	---	---	0.04[a]	1
Menomonee River	0.02	0.00	0.00	12
Milwaukee River	0.03	0.02	0.01	12
Minor Streams	0.01	0.00	0.00	3
Oak Creek	0.03	0.01	0.00	2
Pike River	0.01	0.00	0.00	4
Rock River	0.01	0.00	0.00	15
Root River	0.04	0.01	0.00	6
Sauk Creek	0.03	0.02	0.01	2
Sheboygan River	---	---	0.00[a]	1
Total Samples				88

[a] *Only one sample collected and analyzed.*

Source: SEWRPC.

Chromium

Chromium normally occurs in natural waters in minute trace amounts. Under strongly oxidizing conditions, chromium may occur as chromate; but natural occurrences of chromate are rare. Industrial waste waters are likely sources of chromium where streams contain unusual concentrations of this substance.

Chromium is known to cause cancer when inhaled by man. However, it is not known whether chromium will cause cancer when ingested. According to the U. S. Public Health Service Drinking Water Standards 1962, chromium "... is not known to be a common or significant element in food sources. That which may be found in small quantities in foods is in trivalent form, is usually adventitious, and arises chiefly from cooking in stainless steel ware. Neither the amounts nor the assimilability are known to be of any hygienic significance."

None of the 10 major water-use categories listed in Table 4 have recommended limiting or maximum permissible concentrations for chromium. This element is not significant to these uses, except that chromium salts may be toxic to aquatic life depending upon the species of plant or animal, the temperature, pH, chromium valence, and the effects of synergism or antagonism. The conditions of toxicity are complex, and the SEWRPC lists no standards for chromium salts other than for hexavalent chromium discussed subsequently.

The maximum, average, and minimum concentrations of chromium determined on 48 samples collected at 48 sampling stations in the 12 watersheds of southeastern Wisconsin were 0.04, less than 0.012, and less than 0.005 ppm, respectively. The maximum concentration of 0.04 ppm was determined on a stream sample collected at station Fx-8 on the Fox River. Minimum values of less than 0.005 occurred in 8 of the 12 watersheds. The ranges in chromium concentrations by watershed are listed in Table 8. Appendix C presents the chromium analyses by sampling station.

Table 8

CHROMIUM CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Chromium Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	---	---	0.005[a]	1
Fox River	0.04	< 0.01	0.005	18
Kinnickinnic River	---	---	< 0.06[a]	1
Menomonee River	0.01	< 0.01	0.004	8
Milwaukee River	< 0.02	< 0.02	< 0.005	6
Minor Streams	0.005	0.005	0.005	2
Oak Creek	---	---	< 0.01[a]	1
Pike River	---	---	< 0.01[a]	1
Rock River	< 0.02	< 0.011	< 0.005	6
Root River	---	---	< 0.02[a]	1
Sauk Creek	< 0.005	< 0.005	< 0.005	2
Sheboygan River	---	---	< 0.005[a]	1
Total Samples				48

[a] *Only one sample collected and analyzed.*

Source: State Laboratory of Hygiene and SEWRPC.

Hexavalent Chromium

Hexavalent chromium is commonly considered a relatively toxic form of chromium. The U. S. Public Health Service Drinking Water Standards 1962 establishes a maximum permissible concentration of 0.05 ppm. Water Quality Criteria states that "... it appears that the following concentrations of chromium, trivalent or hexavalent, will not interfere with the specified beneficial uses:

a. Domestic water supply 0.05 mg/1

b. Stock and wildlife watering 5.0 mg/1

c. Fish life 1.0 mg/1
   Other aquatic life . . . . 0.05 mg/1"

Maximum, average, and minimum concentrations of hexavalent chromium encountered in the streams of southeastern Wisconsin were less than 0.02, 0.00, and 0.00 ppm as based on 48 analyses performed upon samples collected at 48 stations in all of the 12 watersheds of the Region. The trace determination of less than 0.02 ppm occurred in the sample collected at station Fx-8 on the Fox River. A trace concentration of less than 0.01 ppm occurred at station Mn-10 on the Menomonee River. All other analyses were 0.00 ppm. The ranges in concentrations of hexavalent chromium by watershed are listed in Table 9. Appendix C presents the hexavalent chromium analyses by sampling station.

Calcium

Calcium occurs abundantly in the soil, glacial drift, and bedrock of southeastern Wisconsin. Because it oxidizes readily in air and reacts with water, elemental calcium does not exist in nature but occurs as carbonates, oxides, and other salts. Calcium salts and ions are the most common substances in the streams of the Region.

There is no significance in the calcium concentration of water in relation to many uses of water. The U. S. Public Health Service Drinking Water Standards 1962, makes no reference to recommended limiting concentrations or maximum permissible concentrations of calcium. Cause and effect relationships between high and low calcium concentrations in drinking water and the formation of kidney stones and a severe form of rickets have not been proven. Water Quality Criteria states that concentrations of cal-

Table 9

HEXAVALENT CHROMIUM CONCENTRATIONS IN STREAMS IN THE REGION

(1964 - 1965)

Watershed	Hexavalent Chromium Concentration in ppm			Number
	Maximum	Average	Minimum	of Samples
Des Plaines River	---	---	0.00[a]	1
Fox River	0.02	0.00	0.00	18
Kinnickinnic River.	---	---	0.00[a]	1
Menomonee River	0.01	0.00	0.00	8
Milwaukee River	0.00	0.00	0.00	6
Minor Streams	0.00	0.00	0.00	2
Oak Creek	---	---	0.00[a]	1
Pike River.	---	---	0.00[a]	1
Rock River.	0.00	0.00	0.00	6
Root River.	---	---	0.00[a]	1
Sauk Creek.	0.00	0.00	0.00	2
Sheboygan River	---	---	0.00[a]	1
Total Samples				48

[a] *Only one sample collected and analyzed.*

Source: State Laboratory of Hygiene and SEWRPC.

cium up to 1,800 ppm in drinking water are reported to be harmless. Household use of water high in calcium concentration is undesirable because its reaction with soap forms insoluble curds that interfere with washing, bathing, and laundering. Calcium also tends to form deposits on cooking ware and in humidifiers and water heaters. The brewing industry prefers to use water containing no more than 500 ppm calcium. Minimum concentrations of 50 ppm calcium are recommended to inhibit corrosion of cast iron and steel. The toxic effects of many substances upon fish and other forms of aquatic animal life are inhibited by the presence of moderate quantities of calcium (50 ppm) in the water.

Calcium and magnesium are the principal ions that cause water hardness. Both ions can be readily removed by water softening processes that involve ion exchange with sodium. For this reason the calcium (and magnesium) content of a water source can be frequently disregarded when considering the usability of the water source. Hardness is discussed in a separate section of this chapter.

Principal sources of calcium in the streams of the Region are the calcium and magnesium carbonate minerals that are abundant in the soil and geologic terrane that forms the rock environment of the streams. The shallow bedrock units of the eastern part of the Region (the Niagara aquifer and the Milwaukee Formation) are composed largely of these minerals. The shallow bedrock unit underlying the southeastern part of the Region (the Platteville-Galena unit) is also composed largely of calcium and magnesium carbonate minerals. The glacial drift overlying these units includes considerable rock debris in the form of calcareous silt, sand, gravel, and boulders of bedrock origin. The soils are residual except in the flood plains and are also largely calcareous. This rock and soil environment of the streams imposes its broad chemical characteristics upon the water that flows over and through this terrane on its way to the streams.

The calcium content of water depends not only upon the availability of a source but also largely upon the carbon dioxide content of the water. Streams are in contact with the air and usually have a condition of equilibrium between carbon dioxide and calcium carbonate. The buildup of carbon dioxide in the streams as the result of the nightly cessation of the photosynthetic processes of aquatic plants may have a marked influence upon the overall calcium content of the streams. The ability of water to take calcium carbonate into solution increases with increased carbon dioxide content of the water. The loss of carbon dioxide from a solution at equilibrium will result in the precipitation of calcium carbonate.

Calcium concentrations in natural surface waters have a wide range of variation. An example of high concentration is the Pecos River near Roswell, New Mexico, where the calcium content has been as high as 842 ppm. Lake Michigan water near Milwaukee contained 35 ppm calcium.

The maximum, average, and minimum calcium concentrations in the streams of southeastern Wisconsin were 213, 82, and 24 ppm, respectively. These figures are based upon analyses of 540 samples collected at 87 sampling stations in all 12 watersheds of the Region. The maximum and minimum concentrations occurred in the Muskego Canal at station Fx-15 and in the East Branch Rock River at station Rk-1, respectively. The ranges in calcium concentrations by watershed are listed in Table 10.

Table 10

CALCIUM CONCENTRATIONS IN STREAMS IN THE REGION
(1964 - 1965)

Watershed	Calcium Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	131	99	56	18
Fox River	213	78	25	185
Kinnickinnic River	93	72	51	2
Menomonee River	197	103	55	69
Milwaukee River	101	71	43	77
Minor Streams	140	81	34	11
Oak Creek	104	77	46	16
Pike River	132	94	48	32
Rock River	111	66	24	73
Root River	136	98	43	40
Sauk Creek	124	85	26	15
Sheboygan River	108	106	104	2
Total Samples				540

Source: SEWRPC.

Map 4 shows the expected maximum calcium concentrations in the streams of the Region as of 1965. The calcium concentrations in streams may increase with nutrient enrichment by nitrogenous and phosphatic substances. These nutrients can be expected to increase growths of algae and other aquatic plants which, in turn, will increase the carbon dioxide content of the stream and thus facilitate the solution of calcium carbonate. Although this process of further nutrient enrichment may be expected to take place over the years to come, the rate of calcium increase should be relatively low. Map 4, therefore, may be regarded as not only representative of present conditions but also indicative of the calcium concentrations that may prevail for possibly the next 10 years or more.

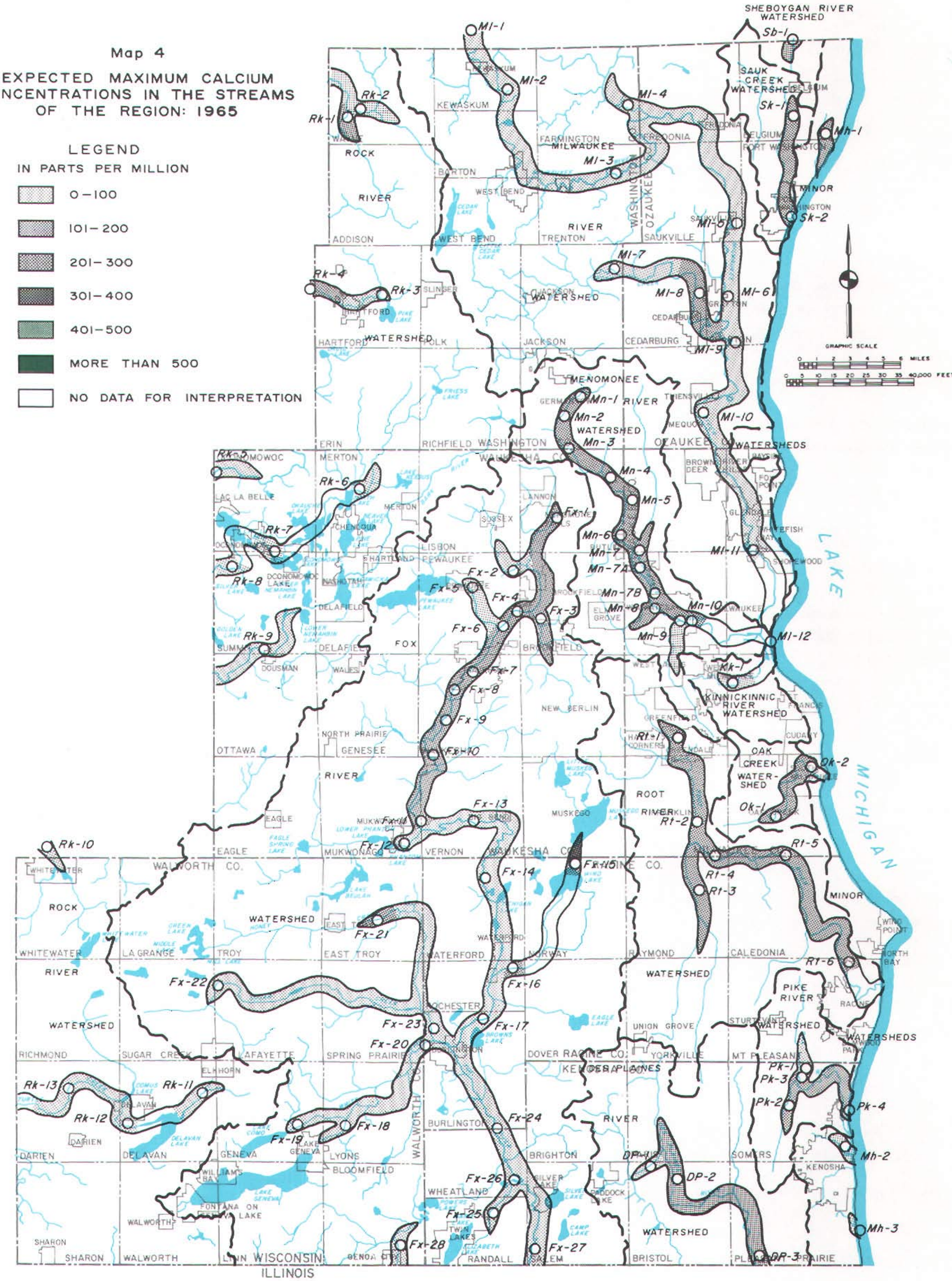
There appears to be no simple solution to the problem of flourishing algae growth. If the artificial sources of nitrogenous and phosphatic substances were adequately controlled to avoid nutrification, the problem of algae growth might still persist, inasmuch as "calcium and magnesium are also of importance in their influence upon the total number of algae present, because the bicarbonates of these metals furnish a supplemental supply of carbon dioxide for photosynthesis. The greater abundance of algae in hard-water lakes, as compared with their abundance in soft-water lakes, is traceable directly to a utilization of dissolved bicarbonates in photosynthesis."[2] The streams of southeastern Wisconsin are naturally high in calcium and magnesium bicarbonates.

The calcium concentrations are mapped on a scale ranging from 0 to more than 500 ppm. This scale is subdivided into six intervals of concentration. The four lower intervals of concentration, ranging from 0 to 400 ppm, are mapped in black, whereas the two intervals ranging from 401 to more than 500 ppm are shown in color. The black patterns denote expected maximum calcium concentrations that are well below the 500 ppm established as a maximum standard for brewing water. The color patterns denote concentrations that are marginal or exceed this water quality standard.

[2] *Birge and Juday, 1911.*

Map 4

EXPECTED MAXIMUM CALCIUM CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum calcium concentrations for 1965 range from 225 to 50 ppm. Maximum concentrations are anticipated to increase at a low rate. The conditions shown on the map may prevail for the next 10 years.

Magnesium

Magnesium, like calcium, occurs abundantly in the soil, glacial drift, and bedrock of southeastern Wisconsin. Because this metallic substance is chemically active, it is not found in its elemental form under natural conditions. In solution magnesium is normally present in ionic form and tends to remain in solution with greater constancy than calcium. The salts of magnesium are very soluble except hydroxides at high pH levels. In the presence of carbon dioxide, the solubility of magnesium carbonate is increased. Magnesium does not precipitate from solution to form carbonate salts as readily as calcium. Magnesium carbonate is more soluble in water containing sodium salts (including sodium chloride) than in pure water.

A recommended limiting concentration of magnesium is not established in the U. S. Public Health Service Drinking Water Standards 1962. At high concentrations magnesium salts have a laxative or diuretic effect on man and beast. However, this condition is normally temporary because physiologic tolerance can be established to originally unaccustomed concentrations. Water high in magnesium and low in calcium content used by stock and wildlife may cause rickets. In the brewing industry, the limiting concentration of magnesium is 30 ppm.

Magnesium and calcium are the principal ions that contribute to the forming of hard water. Water hardness can be fully removed by water softening processes that involve the precipitation or retention of these ions. For this reason the magnesium (and calcium) content of a water source can be frequently disregarded when considering the usability of the water source.

The magnesium content of natural waters has a wide range of variation. Sea water contains about 1,270 ppm. Lake Michigan water sampled near Milwaukee had a magnesium concentration of 11 ppm.

The maximum, average, and minimum magnesium concentrations of 540 stream samples collected at 87 sampling stations in southeastern Wisconsin were 97, 43, and 9 ppm, respectively. The maximum concentration of 97 ppm was obtained on a stream sample collected at station Fx-15 on Muskego Canal in the Fox River watershed. The minimum concentration occurred in Pike Creek at station Mh-2. Ranges in magnesium concentrations by watershed are listed in Table 11.

Table 11

MAGNESIUM CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Magnesium Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	69	55	32	18
Fox River	97	43	28	185
Kinnickinnic River	49	36	24	2
Menomonee River	91	47	23	69
Milwaukee River	68	39	17	77
Minor Streams	63	35	9	11
Oak Creek	47	38	23	16
Pike River	92	51	21	32
Rock River	57	38	12	73
Root River	61	47	26	40
Sauk Creek	59	40	10	15
Sheboygan River	51	48	45	2
Total Samples				540

Source: SEWRPC.

Sodium

Sodium is a chemically active metallic element that does not occur in a free state in nature. Most sodium salts are very soluble in water, and the sodium that enters streams from natural and man-related sources will remain in solution. Sodium salts exist as minor constituents in the rock formations that contribute to the flow of streams of southeastern Wisconsin. Major man-related sources of sodium are effluent discharges from sewage treatment plants, wastes entering the streams from industries using soluble sodium compounds, and winter applications of salt on highways to provide safe and convenient movement of traffic.

No quality standards have been established or adopted by the SEWRPC regarding the sodium concentrations in water used for the ten water uses considered important to regional planning. No recommended limiting or maximum permissible concentrations of sodium are established in U. S. Public Health Service Drinking Water Standards 1962. Persons with heart, kidney, or circulatory diseases require drinking and culinary water that contains little or no sodium. Boiler feed water containing more than 50 ppm sodium and potassium may cause foaming. Irrigation water high in sodium content may be toxic to plants and adversely affect soil conditions. A threshold limit of 2,000 ppm for livestock water has been suggested. Although sodium concentrations of 500 to 1,000 ppm reportedly are toxic to fish in aerated distilled or soft water, when the sodium salts of chloride and nitrate were tested, it appeared that in the hard-water streams of southeastern Wisconsin sodium concentrations of 1,000 ppm or less should not be harmful to fish regardless of their species or stage of development.

The sodium concentration of natural waters ranges from 0 to more than 100,000 ppm. Sea water contains about 10,560 ppm. Lake Michigan water sampled near Milwaukee contained 5 ppm sodium (and potassium).

The maximum, average, and minimum sodium concentrations calculated from the analyses of 539 stream samples collected at 87 sampling stations were 800, 65, and 0 ppm, respectively. The maximum concentration of 800 ppm occurred at station Mn-9 on Honey Creek in the Menomonee River watershed. The minimum value of 0 ppm occurred in 7 of the 12 watersheds of the Region. Ranges in sodium concentrations of stream samples by watershed are listed in Table 12.

Table 12

SODIUM CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Sodium Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	110	50	0	18
Fox River	340	45	0	185
Kinnickinnic River	80	50	20	2
Menomonee River	800	115	0	69
Milwaukee River	115	35	0	76
Minor Streams	175	75	20	11
Oak Creek	110	80	50	16
Pike River	140	55	0	32
Rock River	590	80	0	73
Root River	175	95	0	40
Sauk Creek	80	45	30	15
Sheboygan River	50	45	40	2
Total Samples				539

Source: SEWRPC.

Bicarbonate

Bicarbonate (HCO_3^-) ions in natural waters may come from many sources. Important among these are the carbonate rocks and rock debris that make up the geologic environment of the watersheds of the Region. The interaction of water and dissolved carbon dioxide with the calcium and magnesium carbonate minerals results in the formation of bicarbonate, which in solution reaches the streams by ground water seepage and surface runoff. Bicarbonate may also be formed by the interaction of carbon dioxide and water through hydrolysis or by decomposition of organic matter. Industrial wastes commonly contain bicarbonate salts.

Bicarbonates in water generally do not adversely affect most water uses. They contribute to the dissolved solids content of the water and tend to form carbonates and scale at high temperature. In industrial use, as indicated in Table 4, Chapter III, boiler feed water should contain no more than 0 to 50 ppm bicarbonate, depending upon boiler pressure. High bicarbonate concentrations reportedly affect the stability of vitamins in processing of preserves and cause the swelling of skins in tanneries.

The bicarbonate content of natural waters has a wide range of variation, extending from concentrations exceeding 5,000 ppm to 0 ppm. Ocean water contains about 140 ppm bicarbonate. Lake Michigan water sampled near Milwaukee had a bicarbonate content of 107 ppm.

The maximum, average, and minimum bicarbonate concentrations of 540 stream samples collected at 87 stations in the 12 watersheds of southeastern Wisconsin were 595, 325, and 120 ppm, respectively. The maximum concentration of 595 ppm occurred at station Pk-3 on Pike Creek in the Pike River watershed. The minimum of 120 ppm was determined on a sample collected at station Sk-2 on Sauk Creek. Ranges in bicarbonate concentrations by watershed are listed in Table 13.

Table 13

BICARBONATE CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Bicarbonate Concentration in ppm			Number
	Maximum	Average	Minimum	of Samples
Des Plaines River	390	310	185	18
Fox River	535	330	150	185
Kinnickinnic River	275	235	195	2
Menomonee River	470	330	215	69
Milwaukee River	470	330	190	77
Minor Streams	415	260	150	11
Oak Creek	315	275	205	16
Pike River	595	320	200	32
Rock River	480	320	145	73
Root River	435	320	190	40
Sauk Creek	550	340	120	15
Sheboygan River	410	340	275	2
Total Samples				540

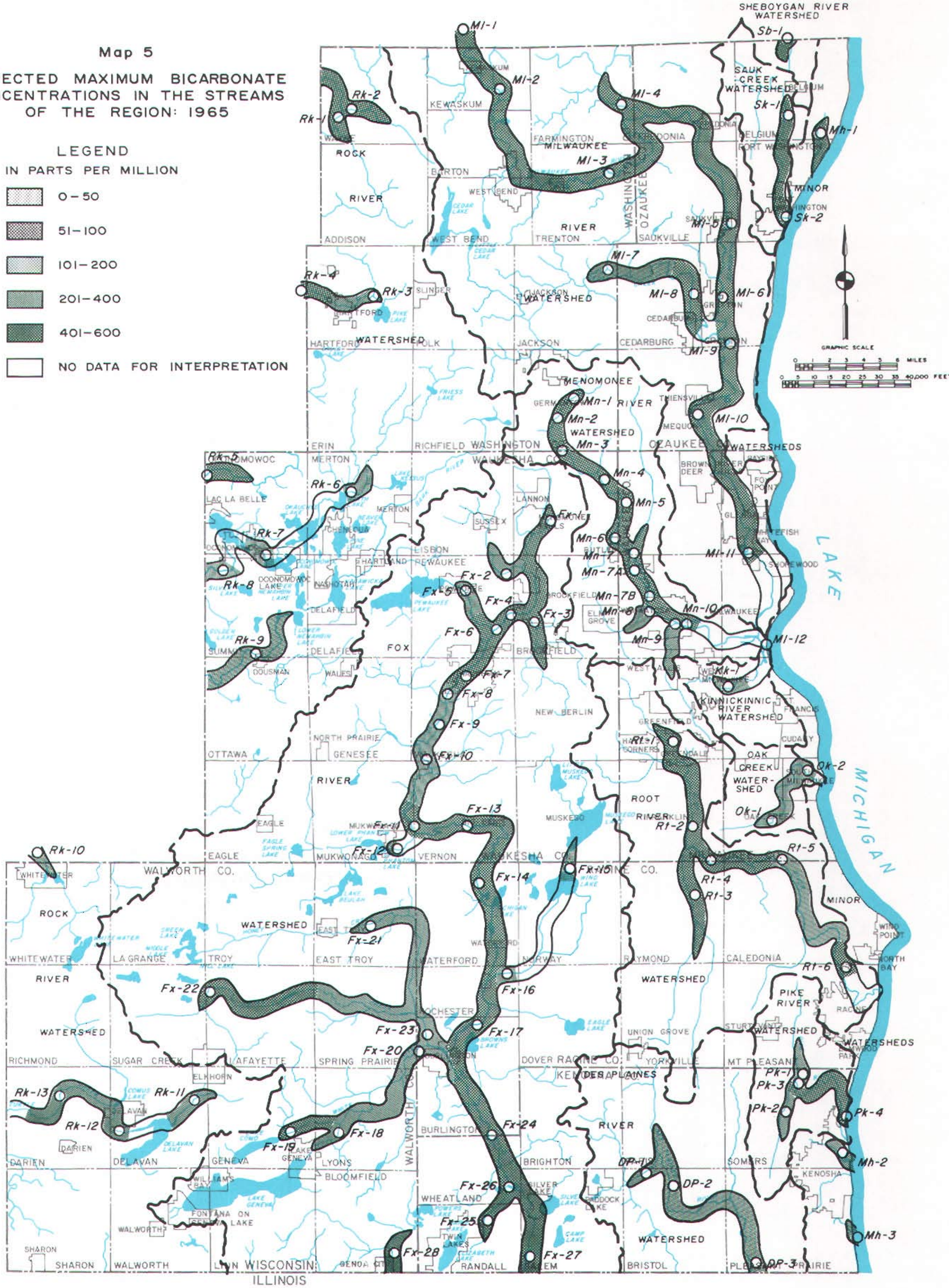
Source: SEWRPC.

Map 5 shows the maximum bicarbonate concentrations that may be expected in the streams of the Region as of 1965. The maximum bicarbonate concentrations may increase with nutrient enrichment of the streams. Heavier concentrations of aquatic plants will increase the carbon dioxide content of the streams, facilitating the solution of carbonate as bicarbonate. However, no radical change in the bicarbonate concentrations can be foreseen; and Map 5 indicates expected maximum conditions for the next 10 years or more.

The bicarbonate concentrations are mapped on a scale ranging from 0 to 600 ppm, with the upper limit of this scale being determined by the maximum concentration (595 ppm) encountered in the Region. This scale is divided into five intervals of concentration, indicating progressively larger concentrations of bicarbonate. The two lower intervals of concentration that range from 0 to 100 ppm are mapped in black patterns, whereas the three intervals ranging from 101 to 600 ppm are shown in color patterns. The color patterns apply to higher concentrations of this parameter, as related to water quality standards. The break between black patterns and color patterns at 100 ppm is intended to visually emphasize those reaches of the streams that are of relatively acceptable quality (black patterns) and those that are relatively unacceptable quality (color patterns). Consideration was taken of the alkalinity (total) standard for carbonated beverages in selecting the break between black and color patterns. The lowest interval of concentration (0-50 ppm) was chosen to show reaches where the expected maximum bicarbonate concentration was less than the limiting concentration for boiler feed water. The minimum bicarbonate concentration encountered in the Region was 120 ppm, and black patterns are significantly absent.

Map 5

EXPECTED MAXIMUM BICARBONATE CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum bicarbonate concentrations for 1965 range from 600 to 250 ppm. Maximum concentrations are anticipated to increase at a low rate. The conditions shown on the map may prevail for the next 10 years.

Carbonate

The carbonate (CO_3^{--}) content of natural waters is commonly less than 10 ppm because many carbonate salts are insoluble. Factors determining the concentration of carbonate in a stream are not only the quantities that enter the stream but also the temperature, pH, presence of metallic ions, and characteristics of other dissolved salts.

Carbonate is a critical constituent in water used for boiler feed and brewing. Under conditions of high temperature in a boiler, the carbonates decompose into hydroxide and carbon dioxide. Corrosion of steam pipes and return lines is in part caused by carbon dioxide. To avoid this cause of corrosion, the carbonate content of boiler feed water should be as low as possible. Bicarbonate also contributes to this problem, because under high temperature conditions it, too, breaks down and forms carbonate and carbon dioxide. The carbonate produced by the temperature breakdown of bicarbonate further decomposes with the carbonates that were originally present in the water. In the brewing industry, free carbon dioxide in water used for preparation of beer reportedly causes bitterness.

In natural waters carbonate ranges in concentrations from 0 to more than 16,000 ppm, although concentrations in streams are commonly very low. Sea water apparently contains no carbonate. Water sampled from Lake Michigan near Milwaukee contained 0 ppm carbonate.

The maximum, average, and minimum carbonate concentrations of 540 stream samples collected at 87 stations in southeastern Wisconsin were 50, 5, and 0 ppm, respectively. The maximum concentration of 50 ppm occurred in the Fox River watershed on the White River at station Fx-1. The minimum value of 0 ppm occurred in all the watersheds of the Region. Ranges in carbonate concentrations of stream samples by watershed are listed in Table 14.

Table 14

CARBONATE CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Carbonate Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	30	5	0	18
Fox River	50	5	0	185
Kinnickinnic River	30	15	0	2
Menomonee River	40	5	0	69
Milwaukee River	40	10	0	77
Minor Streams	20	0	0	11
Oak Creek	30	5	0	16
Pike River	30	5	0	32
Rock River	40	15	0	73
Root River	30	5	0	40
Sauk Creek	30	5	0	15
Sheboygan River	0	0	0	2
Total Samples				540

Source: SEWRPC.

Sulfate

Sulfur occurs in nature combined with other elements to form widely disseminated minerals that occur in soil, mantle, and bedrock and combined with organic substances that make up body tissue of plants and animals. In natural waters sulfur occurs most commonly in the highest state of oxidation as sulfate (SO_4^{--}). Ground water and surface runoff, both of which contribute to and largely sustain the flow of streams, contain sulfates formed by the leaching and oxidation of sulfide and sulfate minerals. In swamps and marshes where decaying vegetation tends to accumulate, sulfates may occur in considerable concentration as a step in the sulfur cycle. Rainwater may also be a minor source of sulfates in that atmospheric dust forms nuclei for condensation, and these nuclei are carried to soil and stream by precipitation. Sulfates may enter streams in wastes discharged from industries that use sulfates or sulfuric acid or that produce sulfates in their manufacturing processes.

As shown in Table 4, Chapter III, few major uses of water are affected by sulfate content. The U. S. Public Health Service Drinking Water Standards 1962 establishes a recommended limiting concentration of 250 ppm to avoid the laxative effect on people unaccustomed to water containing larger concentrations of sulfate. Quality standards with respect to sulfate content of process water used in the dairy industry and in the making of carbonated beverages are listed in Table 4.

Sulfates of the common metallic elements are very soluble in water. Waters low in calcium content and high in magnesium and sodium may contain more than 100,000 ppm sulfate. Some streams contain no sulfate. Sea water contains about 2,560 ppm. Lake Michigan water sampled near Milwaukee contained 19 ppm sulfate.

The maximum, average, and minimum sulfate concentrations of 539 stream samples in southeastern Wisconsin were 910, 134, and 13 ppm, respectively. The maximum concentration of 910 ppm was in a stream sample collected at station Fx-15 on the Muskego Canal. The minimum concentration within the Region was encountered at station Fx-12 on the Mukwonago River. Ranges in concentrations of sulfate by watershed are listed in Table 15.

Table 15

SULFATE CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Sulfate Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	336	235	58	18
Fox River	910	116	13	185
Kinnickinnic River	168	121	75	2
Menomonee River	620	206	75	69
Milwaukee River	200	83	36	76
Minor Streams	420	149	40	11
Oak Creek	224	167	112	16
Pike River	295	195	112	32
Rock River	174	68	19	73
Root River	364	203	75	40
Sauk Creek	250	134	29	15
Sheboygan River	300	234	168	2
Total Samples				539

Source: SEWRPC.

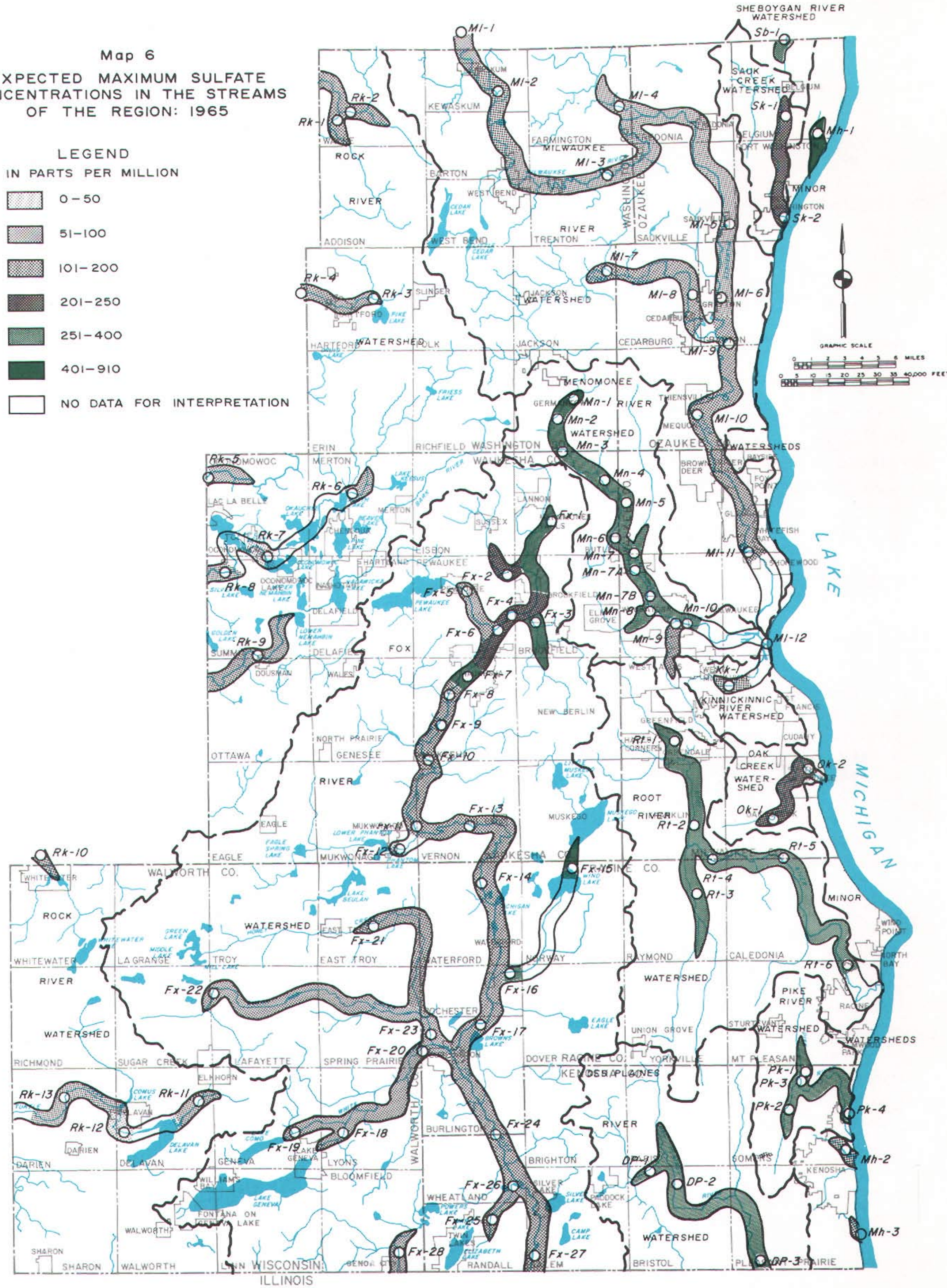
Map 6 shows the expected maximum sulfate concentrations in the streams of the Region as of 1965. The sulfate concentrations are mapped on a scale ranging from 0 to 910 ppm with the upper limit being determined by the maximum concentration of 910 ppm encountered in the Region. This scale is divided into six intervals of concentration, which indicate progressively larger concentrations of sulfate. The four lower intervals of concentration that range from 0 to 250 ppm are mapped in black, whereas the two intervals ranging from 251 to 910 ppm are shown in color. The color patterns indicate sulfate concentrations higher than the water quality standards for this parameter. The change from black to color patterns at 250 ppm was selected to coincide with the recommended limiting sulfate concentration for drinking water. The four lower intervals of concentration were selected to show in more detail the occurrence of waters of relatively low sulfate concentration.

Chloride

The chloride content of the streams of southeastern Wisconsin is derived from five principal sources: leaching of rock minerals by ground water and surface runoff, human sewage, water softening processes, industrial wastes, and salt applications for winter road maintenance. The leaching of rock minerals by

Map 6

EXPECTED MAXIMUM SULFATE CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum sulfate concentrations for 1965 range from 925 to 175 ppm. Maximum concentrations are anticipated to remain generally unchanged. The conditions shown on the map may prevail for the next 10 to 15 years.

ground water and the movement of ground water into a stream channel establishes a "background" chloride concentration that is characteristic of the stream providing that bank storage has been dissipated and that streamflow is maintained by ground water discharge into the stream channel.

Liquid biologic wastes of human origin contain approximately 7,000 to 10,000 ppm chloride and contribute significantly to the buildup of the chloride content of human sewage. Domestic water softeners that operate on the principal of ion exchange with zeolites or resinous exchangers also contribute to the chloride content of sewage during the regeneration cycle. These chlorides remain in solution and ultimately are discharged with the treated sewage into streams. Several industries in the Region discharge wastes that are high in chloride content and that locally build up the chloride concentrations of streams to levels far above those caused by nonindustrial sources. Salt applications to maintain winter road traffic are presumed to have no lasting effect upon the water quality of streams as spring meltwater and rainfall probably remove most of this chloride by runoff.

Many water uses are affected by the chloride content. The U. S. Public Health Service Drinking Water Standards 1962 recommends 250 ppm chloride as the limiting concentration. Water used in industry and for the preservation of fish and wildlife must meet the quality standards listed in Table 4, Chapter III. Chlorides of the common metallic elements are very soluble and tend to stay in solution. Chloride concentration in water is related to dilution because it does not decompose and is not chemically changed or physically removed by natural processes. Natural waters may contain 8,000 ppm or more chloride. Sea water contains approximately 19,000 ppm. Lake Michigan water sampled near Milwaukee contained 7 ppm chloride.

The maximum, average, and minimum concentrations of chloride in the streams of southeastern Wisconsin were 1,270, 70, and 0 ppm, respectively. The maximum concentration of 1,270 ppm chloride was determined on a sample collected at station Mn-9 on Honey Creek in the Menomonee River watershed. The minimum concentration of 0 ppm occurred at station Fx-12 on the Mukwonago River, at station Ml-1 on the Milwaukee River, and at stations Rk-1 and Rk-6 on the East Branch of the Rock River and on the Oconomowoc River, respectively. Ranges in concentrations of chloride by watershed are listed in Table 16.

Table 16

CHLORIDE CONCENTRATIONS IN STREAMS IN THE REGION

(1964 - 1965)

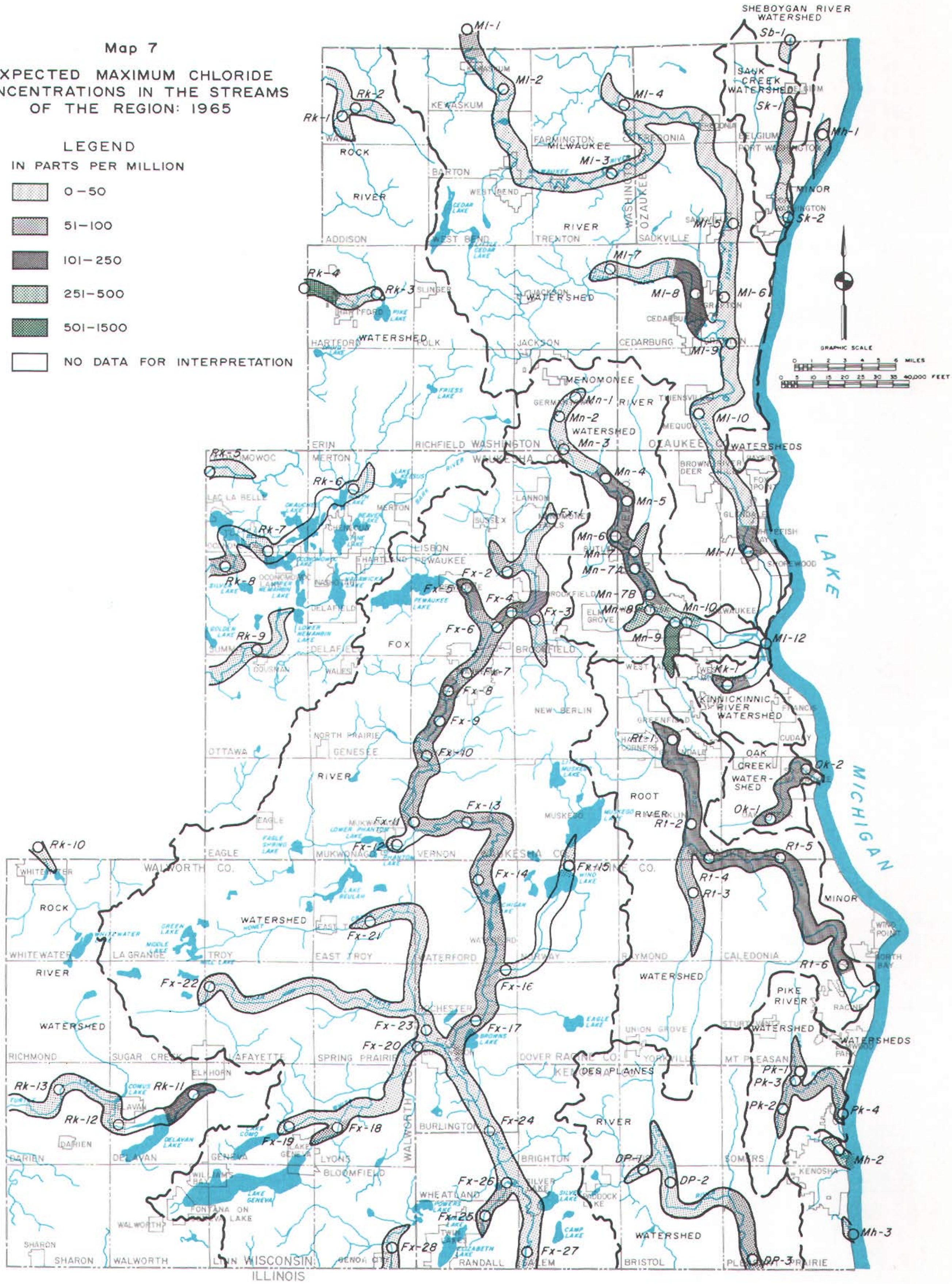
Watershed	Chloride Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	105	55	15	18
Fox River	445	50	0	185
Kinnickinnic River	115	65	20	2
Menomonee River	1,270	145	15	69
Milwaukee River	170	30	0	77
Minor Streams	285	95	20	11
Oak Creek	135	75	30	16
Pike River	90	60	35	32
Rock River	850	95	0	73
Root River	240	110	30	40
Sauk Creek	55	30	20	15
Sheboygan River	30	25	20	2
Total Samples				540

Source: SEWRPC.

Map 7 shows the maximum chloride concentrations that may be expected in the streams of the Region as of 1965. The chloride concentrations of the streams in southeastern Wisconsin that exceed 10-15 ppm may be attributed to artificial sources, such as waste discharges from sewage treatment plants and industries. As the population and industrial activity increase in the Region, the chloride concentrations can be expected

Map 7

EXPECTED MAXIMUM CHLORIDE CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum chloride concentrations for 1965 range from 1,300 to 30 ppm. Maximum concentrations are anticipated to increase perceptibly but not alarmingly within the foreseeable future. The conditions shown on the map may prevail for the next 5 to 8 years.

to increase perceptibly. For this reason, Map 7 indicates expected maximum concentrations of chloride for a period extending no more than five to eight years in the future.

The chloride concentrations are mapped on a scale ranging from 0 to more than 1,500 ppm. The upper part of this scale was selected to be sufficiently larger than the maximum concentration (1,270 ppm) encountered in the Region in order to indicate the possible chloride concentrations upstream from the SEWRPC sampling stations in the direction of sources of pollution. The scale is divided into six intervals of concentration, which indicate progressively larger concentrations of chloride. The three lower intervals that range from 0 to 250 ppm are mapped in black patterns, whereas the three ranging from 251 to more than 1,500 ppm are shown in color. The change from black to colored map symbols at chloride concentrations of 250 ppm coincides with the recommended limiting chloride concentration for drinking water. The three lower intervals of concentration were selected to show in more detail the occurrence of waters of relatively low chloride concentration, whereas the three higher intervals coincide with quality standards pertaining to the preservation and enhancement of fish and aquatic life (500 ppm) and for livestock and wildlife watering (1,500 ppm).

Fluoride

Fluorine is a chemically active nonmetallic element that does not occur in an uncombined form in nature. Fluoride compounds are not naturally abundant except in localized deposits and are not a common constituent of natural surface waters. Ground water is known to have high concentrations of fluoride in certain parts of the country. Although fluoride compounds are used in a number of industrial processes and products, they are not commonly found in industrial wastes except as traces or occasionally as more concentrated slugs due to spillage.

The presence of fluoride in drinking water may be harmful depending on its concentration and on water consumption, which is affected by many factors, including average daily maximum air temperatures. Fluoride concentrations exceeding 0.8 ppm can cause permanent mottling of children's teeth if present in drinking water during formation of the second set. In adults this condition of fluorosis is not likely to occur at concentrations less than 3 or 4 ppm. Although these relatively high concentrations of fluoride in drinking water cause unsightly discoloration of teeth, there are studies that indicate the advantages of maintaining 0.8 to 1.5 ppm fluoride to reduce dental decay. To avoid the adverse effects of fluoride in drinking water, the U. S. Public Health Service places maximum permissible concentrations at 1.7 ppm in regions (including southeastern Wisconsin) where the annual average of maximum daily air temperature is between 50.0 to 53.7°F.

Industrial use of water containing fluoride may be harmful if the water is used in products for human ingestion. Irrigation water containing fluoride concentrations normally encountered in natural waters or even in polluted streams reportedly has no adverse effects on plants. Stock and wildlife are subject to similar physiologic effects as human beings in that teeth are mottled and kidneys are affected. Fluorides have lethal toxic effects on human beings and upon stock and wildlife in high concentrations not encountered except under controlled laboratory conditions or inferred from the severity of sub-lethal concentrations. Fish life is adversely affected at relatively low concentrations of fluoride. For example, the eggs of test fish showed signs of slower and poorer hatching at a concentration of 1.5 ppm fluoride.

Fluoride concentrations in natural waters range from 0 to 50 ppm or more. Most surface waters seldom contain more than 1.0 ppm. Sea water may contain 1.4 ppm fluoride. An analysis of Lake Michigan water sampled near Milwaukee indicated a fluoride content of 0.1 ppm.

The maximum, average, and minimum concentrations of fluoride in the streams of southeastern Wisconsin were less than 1.5, less than 0.7, and less than 0.3 ppm, respectively. The maximum concentration of less than 1.5 ppm was encountered at station Fx-5 on the Pewaukee River and at station Rk-8 on the Oconomowoc River. The minimum concentration of less than 0.3 ppm occurred at station Rk-5 on the Ashippun River. Ranges in concentrations of fluoride by watershed are listed in Table 17.

Table 17

FLUORIDE CONCENTRATIONS IN STREAMS IN THE REGION

(1964 - 1965)

Watershed	Fluoride Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	---	---	<0.7[a]	1
Fox River	< 1.5	< 0.70	<0.35	18
Kinnickinnic River	---	---	<0.7[a]	1
Menomonee River	< 1.15	< 0.85	<0.4	8
Milwaukee River	< 0.55	< 0.50	<0.45	6
Minor Streams	< 0.85	< 0.70	<0.55	2
Oak Creek	---	---	<0.75[a]	1
Pike River	---	---	<0.65[a]	1
Rock River	< 1.5	< 0.65	<0.3	6
Root River	---	---	<0.9[a]	1
Sauk Creek	< 0.70	< 0.65	<0.6	2
Sheboygan River	---	---	<0.65[a]	1
Total Samples				48

[a] *Only one sample collected and analyzed.*

Source: State Laboratory of Hygiene and SEWRPC.

Nitrite

Nitrite (NO_2-) occurs in nature as a chemically unstable substance readily oxidized to nitrate, and for this reason normally occurs in very low concentrations in surface waters. Nitrites are often by-products of bacteriologic action upon ammonia and nitrogenous substances.

Nitrites are toxic but rarely occur in large enough concentrations to cause a health hazard. The brewing and dairy industries require that water contain no nitrites. Nitrites are nutrients and stimulate the growth of algae and other phytoplankton.

Maximum, average, and minimum concentrations of nitrite in 539 stream samples collected at 87 sampling stations were 2.0, 0.1, and 0 ppm, respectively. The maximum concentration of 2.0 occurred at station Fx-5 on the Pewaukee River. The minimum concentration of 0.0 ppm nitrite occurred in all 12 watersheds of the Region. The ranges in nitrite concentrations by watersheds are listed in Table 18.

Nitrate

The principal natural sources of nitrate (NO_3-) in the streams of southeastern Wisconsin are probably the nitrogenous waste products from sewage treatment plants, domestic septic tanks, and food and milk processing industries. Upon adequate aeration these wastes form nitrate as a stable end product. Surface runoff from fields where there has been application of natural or artificial fertilizers may also contribute significant quantities of nitrates to the streams and lakes of the Region. Where inorganic nitrogen (nitrate) and soluble phosphorus occur in concentrations of over 0.30 and 0.015 ppm, respectively, excessive growth of algae and other aquatic plants may occur giving rise to unsightly scum and unpleasant odors. Aquatic plants that grow in the water and terrestrial plants that grow near the waters edge utilize nitrates that are dissolved in the stream water and thus serve to reduce nitrate concentrations.

Quality standards have been established for several water uses with respect to nitrate content. The U. S. Public Health Service Drinking Water Standards 1962 indicates that the maximum permissible concentration of nitrate is 45 ppm. As shown in Table 4, Chapter III, the brewing, dairy, and food processing industries also have quality standards with respect to nitrate concentration.

Within the Region nitrates generally occur in the stream waters in concentrations of less than 5 ppm. Lake Michigan water sampled near Milwaukee generally contains less than 1 ppm nitrate. The maximum,

Table 18

NITRITE CONCENTRATIONS IN STREAMS IN THE REGION
(1964 - 1965)

Watershed	Nitrite Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	0.3	0.0	0.0	18
Fox River	2.0	0.1	0.0	185
Kinnickinnic River.	0.0	0.0	0.0	2
Menomonee River	1.4	0.1	0.0	69
Milwaukee River	0.4	0.0	0.0	77
Minor Streams	0.8	0.2	0.0	11
Oak Creek	0.1	0.0	0.0	16
Pike River.	0.6	0.0	0.0	32
Rock River.	0.8	0.1	0.0	73
Root River.	0.3	0.0	0.0	39
Sauk Creek.	0.1	0.0	0.0	15
Sheboygan River	0.1	0.1	0.0	2
Total Samples				539

Source: SEWRPC.

average, and minimum concentrations of nitrate in 329 stream samples from southeastern Wisconsin were 18.2, 2.8, and 0.0 ppm, respectively. The maximum concentration occurred at station Fx-5 on the Pewaukee River. The minimum concentration of 0.0 ppm occurred on the Oconomowoc River at station Rk-6 and at station Sk-2 on Sauk Creek. The ranges in nitrate concentrations by watershed are listed in Table 19.

Phosphorus

Phosphorus is a chemically active element that does not occur in free form in nature. In many chemical water analyses, the phosphorus content is expressed as orthophosphate ions (PO_4^{---}), although presumably it is not intended to imply that the phosphorus necessarily occurs in this state in the water. The phosphorus analyses for this report were performed by the State Laboratory of Hygiene and expressed as total elemental phosphorus. To convert to orthophosphate, the phosphorus determination is multiplied by 3.07.

Table 19

NITRATE CONCENTRATIONS IN STREAMS IN THE REGION
(1964 - 1965)

Watershed	Nitrate Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	3.2	1.8	0.2	11
Fox River	18.2	3.1	0.1	101
Kinnickinnic River.	1.8	1.3	0.8	3
Menomonee River	8.4	2.9	0.3	44
Milwaukee River	7.1	2.0	0.5	46
Minor Streams	6.1	2.1	0.6	12
Oak Creek	2.8	1.3	0.7	8
Pike Creek.	12.5	3.7	0.1	18
Rock River.	16.9	2.3	0.0	51
Root River.	14.4	4.5	0.6	23
Sauk Creek.	3.4	2.1	0.0	9
Sheboygan River	2.1	1.8	1.4	3
Total Samples				329

Source: SEWRPC.

Phosphorus is a vital nutrient to both plants and animals. Like nitrogen, it is involved in cycles of decomposition and reconversion to cell substance that alternately release and then remove phosphorus in the aquatic environment. The release of organically combined phosphorus to a stream is effected by the decomposition of dead plants and animals and by animal release of body wastes that are further decomposed in the stream environment. In aquatic plants the phosphorus is removed from the aqueous habitat of the plants and is incorporated into cell substance by absorption and photosynthesis. In animals these same processes of removal and incorporation are accomplished by ingestion and digestion. With optimal amounts of nitrates, soluble phosphorus can cause verdant growth of aquatic plants.

The phosphorus content of a stream is derived principally from the phosphorus contained in ground water seepage, surface runoff, treated and untreated sewage, and industrial wastes entering the stream and from the decomposition of aquatic plants and animals. This phosphorus may be inorganic or organic and may occur combined with oxygen, hydrogen, sulfur, halides, and metals.

No water quality standards have been adopted by the SEWRPC concerning the phosphorus content of streams relative to the ten water uses considered important to regional planning, the primary reasons being that phosphorus occurs in many combined forms, each having varying properties in relation to use. The chemical analysis for phosphorus expresses the total inorganic and organic phosphorus present in the sample in solution or combined in living or dead organic matter. The analysis does not indicate the concentration of, for example, inorganic phosphorus or orthophosphate or organic phosphates used as pesticides.

The maximum, average, and minimum phosphorus concentrations determined on 48 stream samples collected at 48 sampling stations in the 12 watersheds of the Region were 5.3, 0.97, and 0.06 ppm, respectively. The maximum concentration of 5.3 ppm was determined on a stream sample collected at station Rk-8 on the Oconomowoc River. The minimum concentration of 0.06 ppm phosphorus was obtained at station Mn-1 on the Menomonee River. Ranges in concentrations of phosphorus by watershed are listed in Table 20.

Table 20

PHOSPHORUS CONCENTRATIONS IN STREAMS IN THE REGION
(1964 - 1965)

Watershed	Phosphorus Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	---	---	0.31[a]	1
Fox River	3.2	0.86	0.14	18
Kinnickinnic River	---	---	0.72[a]	1
Menomonee River	4.6	1.48	0.06	8
Milwaukee River	0.56	0.33	0.20	6
Minor Streams	0.80	0.52	0.24	2
Oak Creek	---	---	0.48[a]	1
Pike River	---	---	1.37[a]	1
Rock River	5.3	1.76	0.12	6
Root River	---	---	1.3[a]	1
Sauk Creek	1.92	1.09	0.26	2
Sheboygan River	---	---	0.52[a]	1
Total Samples				48

[a] *Only one sample collected and analyzed.*

Source: State Laboratory of Hygiene and SEWRPC.

Cyanide

Cyanide does not occur in nature. It is a product of industry and enters streams in the waste discharges from gas works, from coke ovens, from the scrubbing of gases at steel plants, from metal cleaning and electroplating processes, and from chemical industry. The term cyanide includes all compounds of cyanide that are analytically expressed as cyanide ion (CN-) regardless of the salts involved.

Cyanide occurs mostly as HCN, hydrogen cyanide, in water with a pH value of 8 or less. Toxic values expressed as CN- refer principally to HCN. In streams cyanide is broken down by bacterial action, and samples collected for chemical analysis must be treated at the time of sampling to prevent the original cyanide content of the sample from diminishing during sample storage, as discussed in Chapter II under the heading Sampling for Special Chemical Analysis.

Cyanide may interfere with several water uses if it occurs in sufficient concentrations. The U. S. Public Health Service Drinking Water Standards 1962 sets a recommended limit of 0.01 ppm and a maximum permissible limit of 0.2 ppm. The odor threshold for hydrogen cyanide in water is reportedly 0.001 ppm. Toxic and lethal doses for cows, horses, and sheep range from 0.04 grams to 0.92 grams per kilogram of body weight. The toxic effects of cyanide upon fish are determined by a large number of factors. Included among these are fish species, period of exposure, pH, water temperature, dissolved oxygen, and dissolved solids. No standards have been adopted by the SEWRPC, however, for fish, stock, or wildlife because of the diversity of factors that control the toxicity of cyanide. These preclude the adoption of meaningful standards for these use categories. However, it would appear that cyanide concentrations of 0.05 ppm or less are safe for most species of fish that are exposed for no longer than three days.

The maximum, average, and minimum cyanide concentrations of 30 stream samples collected at 30 sampling stations in 11 of the 12 watersheds of southeastern Wisconsin were less than 0.1, less than 0.03, and less than 0.01 ppm, respectively. The maximum concentration of less than 0.1 was obtained on a sample collected on Pike Creek at station Mh-2. The minimum concentration of cyanide of less than 0.01 occurred in the watersheds of the Des Plaines River, Fox River, Menomonee River, Milwaukee River, Rock River, and Sauk Creek. No samples were collected in the Sheboygan River watershed for cyanide analysis. Ranges in cyanide concentrations by watershed are listed in Table 21. Appendix C presents the cyanide analyses by sampling station.

Table 21

CYANIDE CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Cyanide Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	---	---	< 0.01[a]	1
Fox River	< 0.08	< 0.04	< 0.01	10
Kinnickinnic River	---	---	< 0.03[a]	1
Menomonee River	< 0.01	< 0.01	< 0.01	4
Milwaukee River	< 0.01	< 0.01	< 0.01	4
Minor Streams	---	---	< 0.1[a]	1
Oak Creek	---	---	< 0.03[a]	1
Pike River	---	---	< 0.03[a]	1
Rock River	< 0.01	< 0.01	< 0.01	4
Root River	< 0.03	< 0.03	< 0.03	2
Sauk Creek	---	---	< 0.01	1
Total Samples				30

[a] *Only one sample collected and analyzed.*

Source: State Laboratory of Hygiene and SEWRPC.

Oil

Oil is defined as comprising a large group of substances that are liquid at about 70°F, insoluble or poorly soluble in water, and usually lighter than water. Oils may be of mineral, vegetable, or animal origin. Crude mineral oil contains light and heavy oil fractions, gases, and volatile liquids, such as kerosine and gasoline. Refined oils may contain light and heavy fractions but contain little or no dissolved gases or volatile liquids. Animal and vegetable oils are derived from the decomposition of plants and animals.

Oils in the streams of southeastern Wisconsin come principally from industries and from wastes discharged from ships and boats operating in the navigable reaches of the major streams that are tributary to Lake Michigan. Oils of vegetable or animal origin may occur in the streams; but aside from accidental discharges, it is improbable that oils from these two sources would occur in larger than trace quantities.

Oils have a specific gravity less than water and spread out on the water surface floating as a thin film. However, emulsification may disperse minute globules of oil into the aqueous mass of the stream; and oil in this state acts as a suspended liquid in a liquid. Reportedly, certain light petroleum fractions may go into true solution.

The SEWRPC, in its water quality sampling program, attempted to avoid inclusion of floating oil in all samples collected for chemical, biochemical, and bacteriological analysis. This procedure applied also to those samples collected for oil analysis because these analyses were intended to represent the concentration of oil occurring in the stream. At locations where floating oil was observed, the surface film was temporarily dispersed by shallow agitation of the water surface. The sampling bottle was inverted and quickly lowered into the stream to about six-tenths stream depth where the sample was taken. Equal care was taken to avoid contamination of the sample upon withdrawal of the sample bottle from the stream.

All uses of water are impaired by the presence of oil, although numerical quality standards have been established on only a few of the water uses listed in Table 4, Chapter III. Oils in drinking water cause objectionable taste and odor at concentrations ranging from 0.1 to 2.0 ppm, depending upon the type of oil involved and the sensory acuity of people. These concentrations reportedly are far below the chronic toxicity level. Oil in boiler feed water causes a number of serious problems, including overheating of tubes and retardation of heat transfer. Cooling waters used in recirculation systems are subject to progressive concentration of the impurities including oil, causing the cooling water to become slimy. Taste and odor problems arise if water containing oil is used in food processing equipment or is allowed to contaminate the product. Oil films reportedly do not inhibit the growth of crops, and it would appear that oil is not a serious problem in irrigation water. Birds whose feathers become coated with floating oil may not be able to fly. Farm stock will normally avoid drinking oily water unless driven by thirst, in which case the oil may have a laxative effect or cause poisoning. Fish may become asphyxiated by heavy oils adhering to their gills. The food chain may be disrupted causing starvation of adult and fry. Ingested oil may impart an unpalatable taste to the fish flesh. Recreational use of water is seriously impaired by floating oil. Navigation can be hazardous in areas where heavy accumulations of oil may pose a fire threat if ignited. The aesthetic use of water is seriously impaired by the unsightly appearance of floating oil.

The maximum, average, and minimum oil concentration of 48 stream samples collected at 48 sampling stations in the 12 watersheds of the Region were 3, less than 1.4, and less than 0.5 ppm, respectively. The maximum oil concentration of 3 ppm occurred in the Menomonee River watershed at stations Mn-1, Mn-3, Mn-9, and Mn-10. The minimum concentration of less than 0.5 ppm occurred at station Ok-2 on Oak Creek. Ranges in oil concentrations by watershed are listed in Table 22. Appendix C presents the oil concentration by sampling station.

Detergents (synthetic)

Synthetic detergents contain surface active agents that have been developed primarily to avoid cleaning problems related to hard water. Conventional sodium or potassium stearate soaps develop an insoluble curd or scum in hard water causing a dingy appearance in clothes. The calcium, magnesium, and other metallic ions that contribute to hardness in water combine with the stearates and form the insoluble curd. Some of the sodium or potassium in the soap goes into solution by displacement with the hardness ions. In effect, the soap acts as a softening agent until the hardness has been reduced to the point at which the soap can act as a cleaning agent, although its effectiveness is offset by the insoluble curd formed in the softening process. The softening process thus consumes soap without suspending dirt or emulsifying oil, which are the primary cleaning tasks of soap. The cost of cleaning with soap rises with increasing water hardness. Synthetic detergents do not form an insoluble curd in hard water and are, therefore, more economical.

Table 22

OIL CONCENTRATIONS IN STREAMS IN THE REGION
(1964 - 1965)

Watershed	Oil Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	---	---	< 1[a]	1
Fox River	2.0	< 1.4	< 0.5	18
Kinnickinnic River	---	---	< 2[a]	1
Menomonee River	3.0	< 2.0	< 1	8
Milwaukee River	< 2.0	< 1.5	1.4	6
Minor Streams	< 2.0	< 2.0	< 1	2
Oak Creek	---	---	< 0.5[a]	1
Pike River	---	---	< 1	1
Rock River	< 2.0	< 1.0	< 1	6
Root River	---	---	< 1[a]	1
Sauk Creek	< 2.0	< 1.3	< 0.5	2
Sheboygan River	---	---	< 2	1
Total Samples				48

[a] *Only one sample collected and analyzed.*

Source: State Laboratory of Hygiene and SEWRPC.

Until recently the specific surface-active ingredient most commonly used in synthetic detergents was a group of alkyl benzene sulfonates (ABS) having a molecular composition that practically prevents its chemical or bacterial degradation. ABS compounds caused dramatic forms of pollution, ranging from thick extensive foams in rivers and at sewage treatment plants to unseen contamination of ground water supplies. ABS is not known to have adverse physiologic effects, although dermatitis of the hands has increased since synthetic detergents came into general use.

Recently the ABS compounds have, under legislative pressure, begun to be replaced by LAS (linear alkyl sulfonates) that are reportedly degradable. Thus, it appears that the visible pollution problems arising from nondegradable ABS may soon become part of history rather than a persistent problem of the present. This statement is particularly true of streams and lakes. However, the contamination of ground water by past use of ABS can be expected to persist for a much longer period of time.

The study of detergents in the streams of southeastern Wisconsin was made during a time when ABS compounds were still in general use. Maximum, average, and minimum concentrations of detergents encountered in the Region were 4.0, 0.2, and 0.0 ppm, respectively, as based on analyses of 545 samples collected at 87 sampling stations in the 12 watersheds of the Region. The maximum concentration encountered in the Region (4.0 ppm) was in the Menomonee River watershed at station Mn-7B. The minimum concentration of 0.0 ppm occurred in all watersheds except that of the Kinnickinnic River. However, the Kinnickinnic River was sampled only twice. The ranges in concentrations of synthetic detergents by watershed are listed in Table 23.

Map 8 shows the maximum concentrations of synthetic detergents which may be expected in the streams of the Region as of 1965. With the advent of more degradable synthetic detergents, these indicated concentrations may be expected to decline; and the values shown on Map 8 may largely exceed maximum concentrations to be expected in subsequent years.

The detergent concentrations are mapped on a scale ranging from 0 to 4.0 ppm, with the upper limit being determined by the maximum concentration (4.0 ppm) encountered in the Region. The scale is divided into five successive intervals of concentration. The three lower intervals of concentration ranging from 0 to 1.0 ppm are mapped in black, whereas the two intervals ranging from 1.1 to 4.0 ppm are shown in color. The change from black to colored map symbols was selected to coincide with the recommended limiting

Table 23

SYNTHETIC DETERGENT CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Detergent Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	0.1	0.0	0.0	18
Fox River	3.0	0.2	0.0	185
Kinnickinnic River	0.2	0.2	0.1	2
Menomonee River	4.0	0.3	0.0	72
Milwaukee River	0.4	0.1	0.0	78
Minor Streams	3.0	0.5	0.0	10
Oak Creek	0.2	0.1	0.0	16
Pike River	1.5	0.2	0.0	32
Rock River	1.0	0.2	0.0	76
Root River	2.0	0.4	0.0	38
Sauk Creek	0.2	0.1	0.0	16
Sheboygan River	0.1	0.1	0.0	2
Total Samples				545

Source: SEWRPC.

concentration in waters used for navigation. The three lower intervals used in mapping show the occurrence of waters in which the expected maximum detergent concentration would be less than 1.0 ppm and possibly suitable for drinking purposes with respect only to synthetic detergent content. The color symbols denote concentrations exceeding 1.0 ppm.

Dissolved Solids

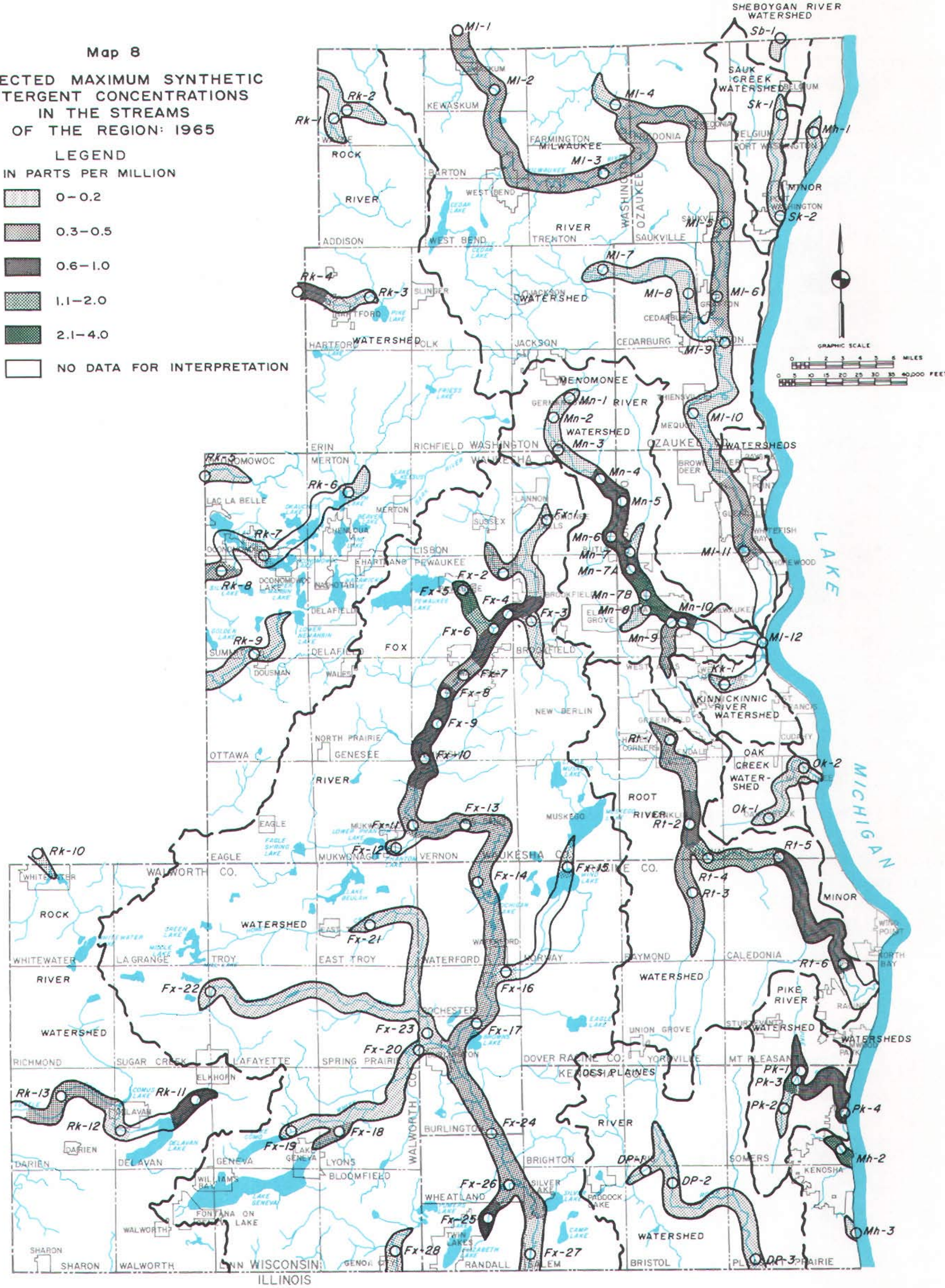
The dissolved solids content of water consists of all inorganic and organic substances that occur dissolved in the water regardless of source. Excluded by this definition are suspended organic or inorganic materials, floating organisms, and dissolved gases. Included are, for example, iron, calcium, bicarbonate, chloride, nitrate, and detergents. In addition to these substances and to those that are commonly determined in a "complete" water analysis, and which typically constitute more than 95 percent of the dissolved solids, there are a multitude of natural and man-made substances that theoretically can occur as dissolved solids in water, ranging from undetectable concentrations (by present methods of analysis) through trace quantities to concentrations measured in whole parts per million. The importance of these minor substances that are not determined in a complete analysis depends upon the substance, its concentration, interrelated physical and chemical conditions of the water, and the particular water uses that are involved.

The dissolved solids content of water has an important bearing upon its suitability for several water uses listed in Table 4, Chapter III. The U. S. Public Health Service Drinking Water Standards 1962 recommends a limiting concentration of 500 ppm dissolved solids, although many public water supplies in the United States provide water of considerably higher mineralization. Quality standards with respect to dissolved solids content of water used for carbonated beverages, food canning, food equipment washing, and general processing are generally higher than for drinking water. Agricultural water use for nonirrigation purposes preferably should contain no more than 7,000 ppm dissolved solids. Many factors are interrelated in determining the suitability of water for irrigation, important among which are the type of crop, the soil composition, drainage conditions, and climate. It would appear that water containing no more than 2,000 ppm dissolved solids is probably suitable for irrigation purposes in southeastern Wisconsin.

Dissolved solids concentrations have a wide range of variation in natural waters. An example of highly mineralized water is the Pecos River near Carlsbad, New Mexico, which has been reported to contain more than 16,500 ppm dissolved solids. Sea water has a dissolved solids content of about 34,300 ppm. Lake Michigan water sampled near Milwaukee had 153 ppm dissolved solids.

Map 8

EXPECTED MAXIMUM SYNTHETIC DETERGENT CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum synthetic detergent concentrations for 1965 range from 4.0 to 0.1 ppm. With the advent of biodegradable synthetic detergents, the expected maximum concentrations shown on the map may exceed maximum concentrations expected to prevail for the next 10 to 15 years.

The maximum, average, and minimum concentrations of dissolved solids encountered in the streams of southeastern Wisconsin were 2,460, 570, and 195 ppm, respectively, based on analyses of 539 samples collected at 87 stations in the 12 watersheds of the Region. The maximum concentration of 2,460 ppm was encountered on Honey Creek in the Menomonee River watershed at station Mn-9. The minimum concentration of 195 ppm occurred at station Rk-1 on the East Branch of the Rock River. Ranges in dissolved solids concentrations by watershed are listed in Table 24.

Table 24

DISSOLVED SOLIDS CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Dissolved Solids Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	825	655	430	18
Fox River	1,420	510	240	185
Kinnickinnic River	680	485	290	2
Menomonee River	2,460	790	345	69
Milwaukee River	730	430	245	76
Minor Streams	790	570	260	11
Oak Creek	755	590	375	16
Pike River	905	630	380	32
Rock River	1,970	525	195	73
Root River	955	720	390	40
Sauk Creek	770	510	200	15
Sheboygan River	675	630	590	2
Total Samples				539

Source: SEWRPC.

Map 9 shows the maximum dissolved solids concentration which may be expected in the streams of the Region as of 1965. The dissolved solids concentrations are mapped on a scale ranging from 0 to 2,500 ppm, with the upper limit being selected to fall near the maximum (2,460 ppm) encountered in the Region. The scale is divided into five successive intervals of concentration. The two lower intervals that span concentrations ranging from 0 to 500 ppm are shown in black symbols, whereas the three upper intervals ranging from 501 to 2,500 ppm are shown in color. The break between black and colored symbols coincides with the recommended limiting concentration of dissolved solids (500 ppm) for drinking water. Water quality indicated in black symbols is acceptable for drinking purposes with respect to its dissolved solids concentrations.

Hardness

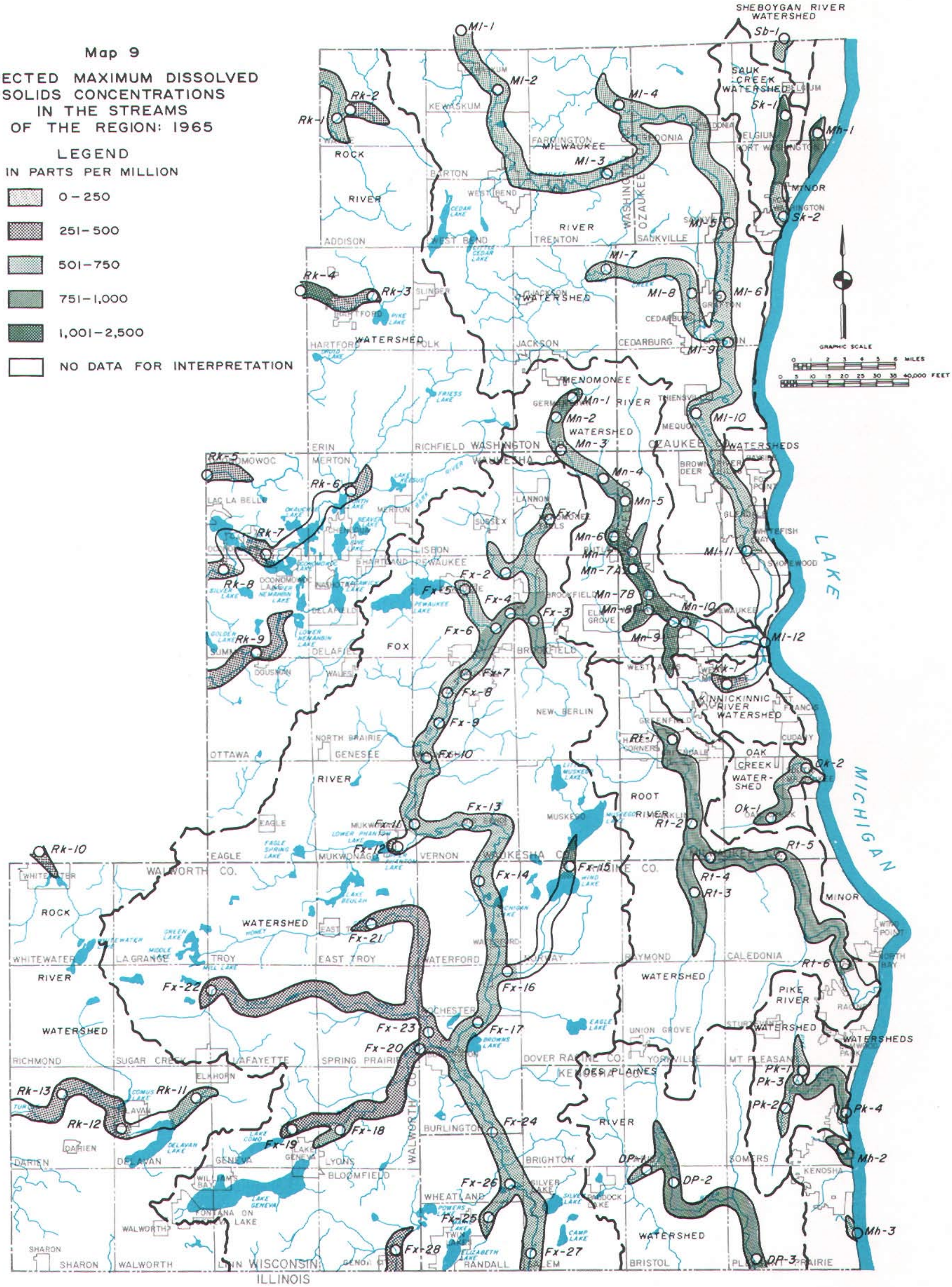
Hardness is a property of water rather than a constituent. This property is commonly related to the use of soap and the formation of boiler scale. Waters are considered to be "hard" when sodium or potassium stearate soaps form little suds and much insoluble curd, which floats upon the water and adheres to sinks and tubs, or when water, upon being heated, forms scales or deposits in boilers, hot-water heaters, and in pipes or on the cooking surfaces of pots. "Soft" water reacts with soap to form much suds and little or no curd. Upon heating, "soft" water does not tend to develop scale.

The principal constituents of water that contribute to the property of hardness are calcium and magnesium. Although all metallic ions other than the alkali metals (such as sodium and potassium) contribute to the hardness of water, they normally occur as trace elements and consequently are often omitted in discussion of hardness.

Hardness interferes with many uses of water. As listed in Table 4, Chapter III, limiting concentrations have been established for many industrial uses of water and for cooling water. The U. S. Public Health Service Drinking Water Standards 1962 neither discusses nor establishes recommended limiting or maximum permissible concentrations of hardness, probably because calcium and magnesium hardness have no

Map 9

EXPECTED MAXIMUM DISSOLVED SOLIDS CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected maximum dissolved solids concentrations for 1965 range from 2,500 to 700 ppm. Maximum concentrations are anticipated to increase at a low rate. The conditions shown on the map are anticipated to prevail for the next 10 years.

known harmful physiological effects upon man in the concentrations that occur in nature. Although water treatment before use increases the cost of the water supply to individual consumers, "hard" water can be efficiently softened to meet the quality requirements of normal domestic and industrial use.

Waters may be classified as soft, moderately hard, hard, and very hard according to the usage of the U. S. Geological Survey listed below:

Designation	Hardness as $CaCO_3$ (in ppm)
Soft water	0 - 60
Moderately hard water	61 - 120
Hard water	121 - 200
Very hard water	More than 200

The hardness of natural surface waters has a wide range of variation. Sea water contains about 400 ppm calcium and 1,270 ppm magnesium, which would give a calculated hardness of 6,200 ppm. Lake Michigan water near Milwaukee had a hardness of about 130 ppm.

The maximum, average, and minimum hardness encountered in the streams of southeastern Wisconsin were 928, 382, and 108 ppm, respectively. The maximum hardness occurred in Muskego Canal at station Fx-15. The minimum hardness was determined on a sample drawn from Sauk Creek at station Sk-2. The ranges in hardness by watershed are listed in Table 25.

Table 25

HARDNESS OF STREAMS IN THE REGION

(1964 - 1965)

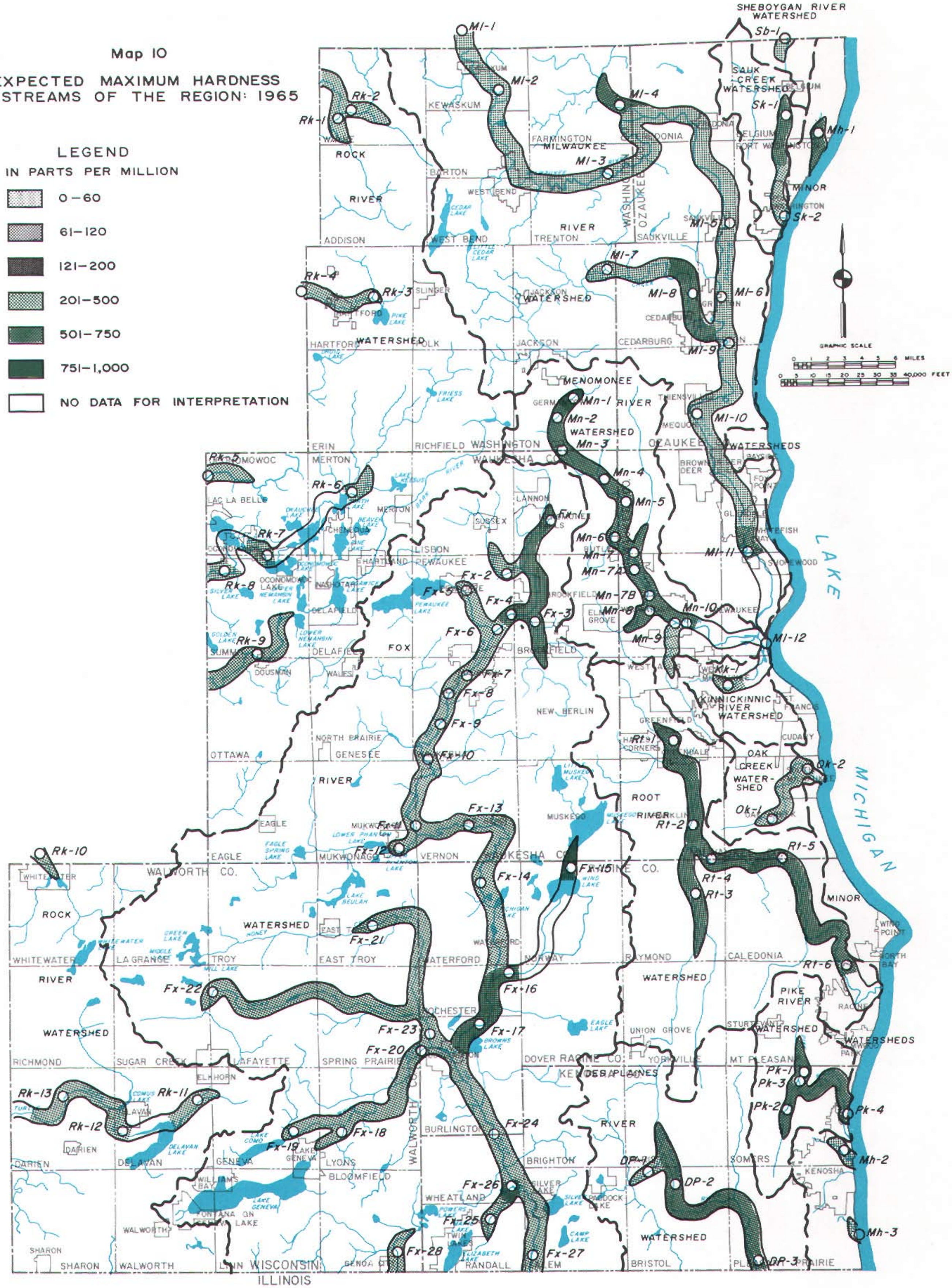
Watershed	Hardness as $CaCO_3$ in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	592	475	294	18
Fox River	928	371	189	185
Kinnickinnic River	435	330	226	2
Menomonee River	866	452	241	69
Milwaukee River	529	337	202	77
Minor Streams	606	346	120	11
Oak Creek	428	350	228	16
Pike River	582	443	236	32
Rock River	476	322	111	73
Root River	592	438	240	40
Sauk Creek	551	377	108	15
Sheboygan River	469	463	457	2
Total Samples				540

Source: SEWRPC.

Map 10 shows the maximum hardness which may be expected of streams in the Region as of 1965. The hardness concentrations are mapped on a scale ranging from 0 to 1,000 ppm, with the upper limit of the scale reflecting the general magnitude of the maximum hardness concentration (928 ppm) encountered in the Region. The scale is divided into six successive intervals of concentration. The three lower intervals of concentration range from 0 to 200 ppm and are indicated in black symbols, whereas the three upper intervals of concentration range from 201 to 1,000 ppm and are indicated in colored symbols. The change from black to colored map symbols at 200 ppm was selected to coincide with the lower limit of the U. S. Geological Survey classification of very hard water (200 ppm). The expected maximum hardness of streams throughout southeastern Wisconsin exceeds 200 ppm, and black symbols are not applicable in Map 10.

Map 10

EXPECTED MAXIMUM HARDNESS OF STREAMS OF THE REGION: 1965



The expected maximum hardness concentrations for 1965 range from 950 to 450 ppm. Maximum concentrations are anticipated to increase at a low rate. The conditions shown on the map may prevail for the next 10 years.

Noncarbonate Hardness

Noncarbonate hardness is a measure of the so-called "permanent" hardness of water. The anionic constituents of water, such as bicarbonate, carbonate, sulfate, and chloride, may cause noncarbonate "permanent" hardness or carbonate "temporary" hardness. The scales that form upon evaporation or heating of water may consist predominantly of sulfate and chloride anions if the bicarbonate and carbonate anions occur in concentrations that are less than those of calcium and magnesium. This hardness is referred to as noncarbonate hardness and is "permanent" because it cannot be removed by acid. Where the bicarbonate anions are equivalent to or larger than the concentrations of the calcium and magnesium cations, the scales may consist of bicarbonate and carbonate anions. These are readily dissolved by acid and are, therefore, referred to as "temporary" or carbonate hardness. Standards for noncarbonate hardness were not included in Table 4, Chapter III, because this parameter is not considered significant from a water quality standpoint. It has been included here as a matter of convenience for those water users who might have a particular interest in this water quality parameter.

The maximum, average, and minimum noncarbonate hardness in the streams of southeastern Wisconsin were 805, 105, and 0 ppm, respectively. Maximum concentrations occurred on the Muskego Canal at station Fx-15. In 7 of the 12 watersheds, the minimum noncarbonate hardness was 0 ppm. Low minimum concentrations (less than 45 ppm) were found in the Menomonee River, Oak Creek, and Sauk Creek watersheds. Relatively high minimum concentrations were found in the Kinnickinnic River watershed (65 ppm) and in the unnamed tributary in the Sheboygan River watershed (120 ppm). The ranges in concentrations of noncarbonate hardness by watershed are listed in Table 26.

Table 26

NONCARBONATE HARDNESS OF STREAMS IN THE REGION
(1964 - 1965)

Watershed	Noncarbonate Hardness as $CaCO_3$ in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	305	215	0	18
Fox River	805	90	0	185
Kinnickinnic River.	160	110	65	2
Menomonee River	625	175	20	69
Milwaukee River	210	55	0	77
Minor Streams	400	130	0	11
Oak Creek	215	110	45	16
Pike River.	335	170	0	32
Rock River.	180	35	0	73
Root River.	410	170	0	40
Sauk Creek.	220	90	10	15
Sheboygan River	245	180	120	2
Total Samples				540

Source: SEWRPC.

Alkalinity

Alkalinity, like hardness, is a property of water rather than a specific constituent. This property involves the ability of water to neutralize acid. The method of determining alkalinity in water analyses, however, uses a pH end point of 4.5 in the alkalinity titration process. A pH of 4.5 is well on the acid side of the pH scale, which ranges from 0 to 14 with 7.0 being the neutral point separating acids from bases. Despite this apparent inconsistency between the stated chemical meaning of the term "alkalinity" and the actual process of analysis, alkalinity is a parameter commonly determined in water quality studies and has been included in the discussion of water quality parameters to provide comparative data for those who are familiar with the direct use of alkalinity.

In the SEWRPC study, alkalinity was determined both as total alkalinity (methyl-orange alkalinity or alkalinity M) and as phenolphthalein alkalinity (alkalinity P). The analytical determination of alkalinity P was used solely as the basis for calculating carbonate. Alkalinity has not been used in this study for water quality mapping purposes.

Quality standards have been established for several industrial water uses relative to total alkalinity. Water used for carbonated beverages, laundering, and tanning have limiting concentrations as indicated in Table 4, Chapter III.

Maximum, average, and minimum concentrations of alkalinity encountered in the streams of southeastern Wisconsin were 510, 270, and 100 ppm, respectively. The maximum concentration occurred at station Pk-3 on Pike Creek in the Pike River watershed. The minimum concentration was found at station Sk-2 on Sauk Creek. Ranges in alkalinity concentrations by watershed are shown in Table 27.

Table 27

TOTAL ALKALINITY OF STREAMS IN THE REGION (1964 - 1965)

Watershed	Alkalinity (total) as $CaCO_3$ in ppm			Number
	Maximum	Average	Minimum	of Samples
Des Plaines River	340	260	160	18
Fox River	440	275	125	185
Kinnickinnic River	255	205	160	2
Menomonee River	385	275	175	69
Milwaukee River	415	275	155	77
Minor Streams	340	215	125	11
Oak Creek	260	235	170	16
Pike River	510	270	165	32
Rock River	395	280	120	73
Root River	355	265	160	40
Sauk Creek	470	285	100	15
Sheboygan River	335	280	225	2
Total Samples				540

Source: SEWRPC.

Specific Conductance

The specific conductance of water is a measure of its ability to conduct an electric current. This current is measured between electrodes spaced one centimeter apart at a temperature of 25°C (77°F). Conductivity is the reciprocal of electric resistance, which is expressed in ohms. Conductance is expressed in micromhos because of the very low conductivity of most natural waters, one micromho being one-millionth of a mho.

Important factors that affect the conductivity of water are the concentration of dissolved solids, the ionic dissociation of these dissolved solids, and the temperature. Inorganic and organic substances may be ionically dissociated or undissociated. The undissociated substances do not conduct an electric current. Increasing mineralization and ionization cause increasing electrical conductivity. Increasing water temperature also causes increasing conductivity; and to obtain comparable results in the measurement of the conductivity of stream samples, conductance is most commonly referred to at a "standard" temperature of 25°C.

Specific conductance was measured to determine the ratio of dissolved solids to specific conductance in anticipation of future SEWRPC water quality studies in which dissolved solids, from a cost standpoint, may not be feasible to determine. The ratio of dissolved solids to specific conductance is not a constant for all ranges in dissolved solids concentration and for all mixtures of dissolved substances. Natural waters are known to have sufficiently diverse physical and chemical properties to cause the ratio to vary from 0.5 to 1.0. For this reason, specific conductance is not a direct measure of the total dissolved solids. It is, however, an indicator of the general magnitude of the dissolved solids concentration that may be expected. The level of accuracy obtained by using specific conductance as a measure of dissolved solids concentration may be quite adequate for many water quality studies, in which case much is gained by using the rapid and efficient electrical method of measuring conductance rather than the analytical determination of actual dissolved solids content by evaporation and weighing of residue. Future water quality studies in southeastern Wisconsin may be greatly facilitated by using specific conductance as an indirect measure of the mineralization of stream samples that would otherwise not be analyzed for dissolved solids.

The ratio of dissolved solids to specific conductance was determined on 539 stream samples collected at 87 stations in the 12 watersheds of the Region. The maximum ratio encountered in the Region was 0.98 at station Mn-1 on the Menomonee River. The minimum ratio was 0.52 at station Rt-1 on the Root River. The average ratio for the Region was 0.67. The maximum, average, and minimum ratios listed by watershed are shown in Table 28.

Table 28

RATIO OF DISSOLVED SOLIDS TO SPECIFIC CONDUCTANCE OF STREAMS IN THE REGION (1964 - 1965)

Watershed	Ratio of Dissolved Solids to Specific Conductance			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	0.85	0.71	0.58	18
Fox River	0.91	0.67	0.53	185
Kinnickinnic River.	0.68	0.67	0.65	2
Menomonee River	0.98	0.69	0.55	69
Milwaukee River	0.83	0.66	0.56	76
Minor Streams	0.77	0.68	0.59	11
Oak Creek	0.82	0.70	0.63	16
Pike River.	0.77	0.68	0.54	32
Rock River.	0.78	0.65	0.56	73
Root River.	0.77	0.68	0.52	40
Sauk Creek.	0.81	0.74	0.66	15
Sheboygan River	0.89	0.82	0.74	2
Total Samples				539

Source: SEWRPC.

Specific conductance was measured on 556 stream samples collected at 87 stations in all 12 watersheds of the Region. The maximum, average, and minimum specific conductance readings based on these samples were 4,320, 905, and 258 micromhos/cm, respectively. The ranges in specific conductance by watershed are shown in Table 29.

Hydrogen Ion Concentration (pH)

The hydrogen ion concentration or hydrogen ion activity of a solution is expressed in pH units which are equal to the logarithm of the reciprocal of the hydrogen ion concentration. This system of denotation was devised to avoid negative coefficients and numbers with many decimals. The p stands for potenz, which is German for power, and H is the chemical symbol for hydrogen. Thus a pH value of 7.0 is equal to a numerical value of 0.0000001 hydrogen ion concentration in grams per liter of solution. As already noted, the pH scale ranges from 0 to 14, with 7.0 marking the neutral point separating acids with values of less than 7.0 from bases with values of more than 7.0.

The hydrogen ion concentration is dependent upon the dissolved substances, both solids and gases, that occur in the water. Many natural surface waters tend to have a neutral pH. Waste discharges can alter the pH of the stream depending on the complex of chemical, physical, and biological conditions that exist separately in the receiving water and in the waste discharge and that combine to interact upon blending of these waters. Most domestic (municipal) sewage is neutral or slightly basic. A pH range of 5 to 9 units is generally favorable for the biologic decomposition of organic wastes. Many industrial wastes are markedly

Table 29

SPECIFIC CONDUCTANCE OF STREAMS IN THE REGION (1964 - 1965)

Watershed	Specific Conductance in Micromhos/cm at 25°C			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	1,220	938	572	18
Fox River	2,000	762	390	189
Kinnickinnic River	1,040	734	426	2
Menomonee River	4,320	1,560	500	76
Milwaukee River	1,150	648	384	78
Minor Streams	1,300	848	414	11
Oak Creek	1,020	852	544	16
Pike River	1,330	936	522	32
Rock River	3,390	830	258	76
Root River	1,600	1,080	566	40
Sauk Creek	992	690	292	16
Sheboygan River	800	778	756	2
Total Samples				556

Source: SEWRPC.

basic or acid and may greatly affect the pH of a receiving stream. The streams of the Region are characteristically calcium bicarbonate waters that act as chemical buffers tending to neutralize acids or bases.

Most of the water uses listed in Table 4, Chapter III, are affected by pH. As shown in this table, the recommended pH concentrations are pH ranges or values that must exceed specified minimums.

The Kiskiminetas River near Leechburg, Pennsylvania, has had a pH as low as 2.5. Lake Michigan water sampled near Milwaukee had a pH of 8.2.

The maximum, average, and minimum pH values encountered in the streams of southeastern Wisconsin were 8.9, 7.8, and 6.7, respectively. The maximum of 8.9 was determined on a sample collected at station Ml-3 on the Milwaukee River. The minimum concentration of 6.7 pH units was obtained on a sample collected at station Fx-1 on the Fox River. The ranges in pH concentrations by watershed are listed in Table 30.

Table 30

HYDROGEN ION CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Hydrogen Ion (pH) Concentration in Units			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	8.6	7.8	7.2	18
Fox River	8.8	7.8	6.7	185
Kinnickinnic River	8.0	7.6	7.3	2
Menomonee River	8.8	7.8	7.0	74
Milwaukee River	8.9	7.8	7.0	77
Minor Streams	8.7	7.6	7.2	11
Oak Creek	8.5	7.8	7.3	16
Pike River	8.2	7.6	6.9	32
Rock River	8.8	7.9	6.8	76
Root River	8.5	7.7	7.0	40
Sauk Creek	8.7	8.0	7.1	16
Sheboygan River	8.3	7.9	7.5	2
Total Samples				549

Source: SEWRPC.

Color

The apparent color of water depends upon the presence of inorganic and organic materials either in suspension or solution. Compounds of iron and manganese; decomposition products of dead vegetation, such as peat, algae, weeds, and humus; suspended live algae and sand, silt, and clay; and dissolved or suspended wastes from industries and sewage treatment plants may contribute to the color of water.

In the chemical analysis of water samples, the true color of water is considered attributable only to dissolved matter. The color of water cannot be accurately measured if the water contains suspended matter in significant quantities. Color determinations can be affected by this turbidity, which must be eliminated to obtain reliable readings. Color is measured in units and determined colorimetrically using the APHA platinum cobalt standard filter and a color meter scale range of 0-500 units.

Color is of significance to several of the ten major water uses considered in this report. Color is not desirable in drinking water supplies, as indicated in Table 4, Chapter III. Industrial water use, such as brewing, carbonated beverage production, dairy industry, food equipment washing, and general processing, also have limiting standards for concentrations of water color, as has the use of water for whole-body contact recreation.

The maximum, average, and minimum color densities of 557 stream samples collected at 87 sampling stations in the 12 watersheds of the Region were 375, 40, and 0 units, respectively. The ranges in color density by watershed are listed in Table 31.

Table 31

COLOR OF STREAMS IN THE REGION
(1964 - 1965)

Watershed	Color Density in APHA Platinum Cobalt Standard Units			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	80	40	5	18
Fox River	300	40	0	203
Kinnickinnic River	35	28	20	2
Menomonee River	375	45	0	69
Milwaukee River	270	55	5	76
Minor Streams	125	35	0	11
Oak Creek	50	20	5	16
Pike River	140	40	10	32
Rock River	135	25	0	73
Root River	85	35	15	40
Sauk Creek	110	40	0	15
Sheboygan River	110	75	45	2
Total Samples				557

Source: SEWRPC.

Turbidity

The turbidity of a stream is caused by suspended matter of coarse to colloidal size which imparts a murky appearance to the stream and decreases light penetration. Substances which commonly cause turbidity are suspended clay, silt and sand particles, micro-organisms, organic debris, sewage, and industrial wastes. The measurement of water turbidity is similar to color determination in that the kind and amount of substances causing turbidity are not determined, but rather the amount of optical obstruction of light passing through a test sample. Turbidity is expressed in Jackson candle units.

Turbidity is an undesirable property for many water uses. The U. S. Public Health Service Drinking Water Standards 1962 specifies that turbidity shall not exceed 5 ppm. Water quality standards for many industrial uses, for cooling purposes, for fish and wildlife, and for recreation specify maximum turbidities, as indicated in Table 4, Chapter III.

Maximum, average, and minimum values of turbidity determined on 560 stream samples collected in southeastern Wisconsin were 150, 8, and 0 Jackson candle units. The maximum value of 150 occurred at sampling station Mh-2 on Pike Creek, a minor stream tributary to Lake Michigan. The minimum value of 0 units occurred in 4 of the 12 watersheds of the Region. Ranges in turbidity by watershed are listed in Table 32.

Table 32

TURBIDITY OF STREAMS IN THE REGION
(1964 - 1965)

Watershed	Turbidity in Jackson Candle Units			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	55	15	1	20
Fox River	25	6	0	190
Kinnickinnic River.	65	40	15	2
Menomonee River	50	8	1	75
Milwaukee River	45	5	0	78
Minor Streams	150	35	2	12
Oak Creek	45	15	5	16
Pike River.	65	9	2	32
Rock River.	15	5	0	76
Root River.	65	15	2	40
Sauk Creek.	100	10	0	17
Sheboygan River	7	5	3	2
Total Samples				560

Source: SEWRPC.

Biochemical Oxygen Demand

The myriad of microscopic and macroscopic plants and animals found in streams range from minute algae and protozoa to large aquatic plants and fishes of many species. These organisms constitute a biologic community in which the many life forms are mutually interdependent. An important aspect of this interdependence is the natural purification of the stream which occurs when dead organisms, such as fish and algae, are fed upon and ultimately decomposed by bacteria to chemically stable inorganic salts, such as nitrates or sulfates. This process of self-purification is principally biologic, in that saprophytic bacteria attack dead organic matter and produce simpler stable substances that do not foul the aquatic environment.

The entire biologic community living in a stream is dependent upon the availability of dissolved oxygen, which is not only vital to fish but equally so to aerobic bacteria. This normal assemblage of organisms places a demand upon the dissolved oxygen content of the stream. This demand commonly is met by natural processes of stream aeration. The biologic stream community is balanced in terms of the general population densities of the many animal and plant species and the availability of oxygen to support this life. Mass deaths of individual species or of large parts of the community are accidental, usually temporary; and the original favorable conditions are restored naturally with time.

When organic wastes from sewage treatment plants enter streams, these wastes can provide a massive addition to the normal food supply for decay bacteria. The bacterial population increases in response to this artificially increased food supply, and the dissolved oxygen demand of the entire biologic community also increases. If the organic sewage wastes continue to enter the stream in sufficient concentration, the dissolved oxygen content can be lowered to levels of concentration that are inadequate to sustain the normal aquatic life of the stream. A complete change then takes place in the type of organisms living in the stream; and instead of having, for example, bluegill fish, clams, and normal aerobic decay bacteria that produce stable inorganic end products, the stream becomes the habitat of bloodworms, sludge worms, leeches, rattailed maggots, and anaerobic bacteria that produce unstable organic acids and foul odors.

Biochemical oxygen demand (BOD) is a determination of the oxygen used over a 5-day period at 20°C in the aerobic bacterial decomposition of the organic wastes in a water sample. Thus, BOD may be thought of as a measure of the concentration of decomposable organic substances. It should be noted that BOD is not a pollutant, the reasons being that it is not a specific chemical substance, physical property, or an organism or group of organisms; and it is measurable only in the presence of aerobic decay bacteria under a standard set of controlled test conditions of internal physical, chemical, and biological environment that does not prevail in nature. BOD is a measure of a biochemical process as determined by the amount of oxygen required by aerobic decay bacteria to decompose organic substances in the test sample over a given length of time at a given constant temperature without being exposed to the many external influences that prevail in nature.

BOD determinations are important in water quality studies to the extent that they may indicate areas of pollution and the potential decrease in dissolved oxygen concentration that may occur in a stream. Without knowledge of the reaeration characteristics of a stream, BOD values cannot be used, except in a very general way, to determine where dissolved oxygen concentration may reach critically low levels for the preservation of fish life.

The maximum, average, and minimum biochemical oxygen demand of 1,064 stream samples collected at 87 sampling stations in the 12 watersheds of the Region were more than 87.7, 4.8, and 0.4 ppm, respectively. The maximum biochemical oxygen demand was determined on a water sample collected at station Pk-3 on Pike Creek in the Pike River watershed. The minimum demand was encountered at station Fx-2 on Sussex Creek in the Fox River watershed. Ranges in biochemical oxygen demand by watershed are listed in Table 33.

Table 33

BIOCHEMICAL OXYGEN DEMAND OF STREAMS IN THE REGION
(1964 - 1965)

Watershed	Biochemical Oxygen Demand in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	15.1	3.1	0.5	35
Fox River	32.8	4.5	0.4	354
Kinnickinnic River	9.1	5.3	2.6	11
Menomonee River	33.9	5.0	0.5	132
Milwaukee River	11.6	3.4	0.5	148
Minor Streams	25.9	7.1	1.1	32
Oak Creek	9.9	3.2	0.5	25
Pike River	>87.7	>10.3	0.9	52
Rock River	>20.6	> 4.4	0.6	163
Root River	65.3	5.9	0.6	77
Sauk Creek	20.0	5.8	0.5	25
Sheboygan River	>24.0	> 5.3	1.7	10
Total Samples				1,064

Source: State Laboratory of Hygiene and SEWRPC.

Map 11 shows the maximum biochemical oxygen demand that may be expected in the streams of the Region as of 1965. Increasing population and industrial activity in southeastern Wisconsin will cause an increasing BOD unless technological advances in the treatment of human sewage and industrial wastes can decrease the BOD of liquid waste discharges in future years. Because of increasing urbanization, Map 11 should not be considered indicative of general BOD conditions in southeastern Wisconsin for more than the next five to eight years.

The concentrations of BOD are mapped on a scale ranging from 0 to 200 ppm, with the upper limit of the scale having the general magnitude as the BOD of raw sewage. The scale is divided into seven successive intervals of concentration. The three lower intervals of concentration range from 0 to 15.0 ppm and are indicated in black map symbols, whereas the four upper intervals range from 15.1 to 200 ppm and are shown in color. The change from black to colored map symbols at 15.0 ppm is arbitrary and is not related to the BOD standards adopted by the SEWRPC as shown in Table 4, Chapter III. Due to different stream reaeration conditions, it should be recognized that a given BOD loading in one stream or in one reach of a stream may induce a considerably different decrease in dissolved oxygen than the same BOD loading in another stream or in a different reach of the same stream. The use of black and color symbols, therefore, is applicable only in a broad relationship to water quality evaluation. The range of the lower intervals of concentration, however, was chosen to be sufficiently narrow to permit reasonably reliable mapping of the lower BOD concentrations. Normally, concentrations of this order would indicate that the stream is of generally acceptable quality in relation to the selected water quality standards.

Dissolved Oxygen

The natural dissolved oxygen concentration in a stream is determined by a large number of interacting factors, which may be divided into four major categories: 1) physical, 2) chemical, 3) biochemical, and 4) biological. Important physical factors pertain to: the volume of water in the stream as evidenced by stream depth, cross-sectional area, and flow rate; stream turbulence induced by wind action or resulting from channel characteristics; stream temperature; atmospheric pressure; and the oxygen content of surface runoff, ground water, and direct precipitation that contribute to the flow of the stream. Chemical factors include: the dissolved solids content of the water and those chemical reactions that may occur without biologic interaction in a stream between the dissolved oxygen and the inorganic and organic substances in solution or suspension. Biochemical reduction in the dissolved oxygen content of a stream results from the demand for oxygen by micro-organisms involved in the biologically induced decomposition of organic or chemical wastes. The biological factors affecting the dissolved oxygen content of a stream include the oxygen consumed in the respiration of aquatic animals and the daily variation of the dissolved oxygen content because of the diurnal variations in the photosynthetic processes of aquatic plants.

The principal significance of dissolved oxygen in stream water is biologic. As discussed under the preceding section on Biochemical Oxygen Demand, the oxygen content of a stream determines the type of aquatic life that can exist in the stream. Under aerobic conditions the stream can support numerous species of beneficial and desirable forms of animal and plant life. Aerobic bacteria carry on the decay process of complex organic compounds to produce stable inorganic salts, such as nitrates and phosphates. Where streams contain no dissolved oxygen, decay of organic wastes is carried on by anaerobic bacteria causing putrifaction. Organic acids and foul odors are the end products of this anaerobic decay. Life forms that inhabit the streams under this condition of deoxygenation are useless to man and unpleasant to behold.

An important biologic effect upon the dissolved oxygen content of a stream is the diurnal variations caused by the photosynthetic processes of aquatic plants. During daylight hours, sunlight promotes the contribution by these plants of oxygen to the stream, particularly on cloudless days. During the night and on cloudy days, the respiratory use of dissolved oxygen by plants and animals may counterbalance the oxygen production during the daylight hours. Under special temperature and pressure conditions and uniform conditions of water salinity, temporary conditions of supersaturation or oxygen depletion may occur diurnally. An example of the diurnal fluctuation of dissolved oxygen concentration is shown by data collected at station Fx-10 by the U. S. Public Health Service in Table 34.

Table 34

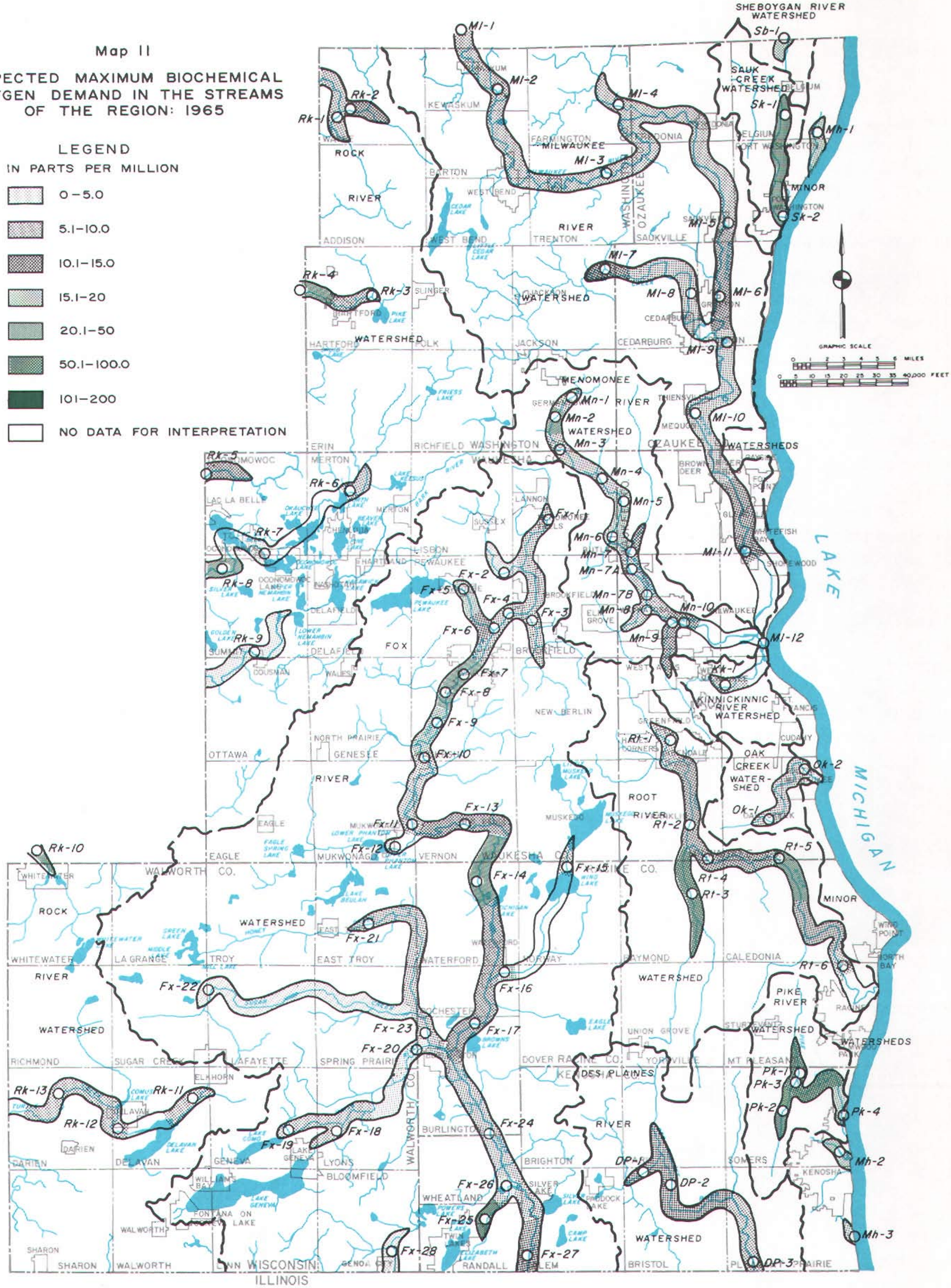
DIURNAL DISSOLVED OXYGEN VARIATIONS AT SAMPLING STATION FX-10 ON AUGUST 18, 1964

Time	Dissolved Oxygen Concentration in ppm
6 a.m.	3.3
8 a.m.	2.4
10 a.m.	4.0
12 noon	6.4
2 p.m.	10.4
4 p.m.	16.3
6 p.m.	18.1

Source: U.S. Public Health Service.

Map 11

EXPECTED MAXIMUM BIOCHEMICAL OXYGEN DEMAND IN THE STREAMS OF THE REGION: 1965



The expected maximum BOD values for 1965 range from more than 85 ppm to 10 ppm. Maximum values are anticipated to increase at a low rate until pollution abatement measures become effective.

The maximum, average, and minimum dissolved oxygen concentrations in 1,066 stream samples collected at 87 sampling stations in the 12 watersheds of the Region were 24.2, 8.9, and 0 ppm, respectively. The maximum concentration of 24.2 occurred at station Ml-3 on the Milwaukee River. The minimum concentration of 0 ppm dissolved oxygen occurred in the watersheds of the Fox River, the Menomonee River, the Milwaukee River, the Rock River, and the Root River. Ranges in dissolved oxygen concentrations by watershed are listed in Table 35.

Table 35

DISSOLVED OXYGEN CONCENTRATIONS IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Dissolved Oxygen Concentration in ppm			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	13.9	8.8	2.1	36
Fox River	21.6	9.1	0.0	353
Kinnickinnic River	13.3	10.6	7.3	11
Menomonee River	20.4	8.3	0.0	133
Milwaukee River	24.2	9.0	0.0	148
Minor Streams	21.7	8.3	0.3	32
Oak Creek	13.7	11.1	6.4	25
Pike River	13.2	5.4	0.1	52
Rock River	17.1	10.4	0.0	163
Root River	14.6	6.6	0.0	77
Sauk Creek	19.3	11.4	0.1	25
Sheboygan River	16.5	9.7	1.0	11
Total Samples				1,066

Source: SEWRPC.

Map 12 shows the minimum dissolved oxygen concentrations which may be expected in the streams of the Region as of 1965. Unusually heavy precipitation in July 1964, following a long period of less than average rainfall, was accompanied by what appeared to be exceptionally low dissolved oxygen concentrations over long reaches of the major streams of the Region. These conditions may have produced some of the lowest concentrations of dissolved oxygen that may be expected from predominantly natural causes.

The dissolved oxygen concentrations are mapped on a scale extending from 0 to more than 10.0 ppm and arranged in reverse order to that used in all previous or subsequent maps that do not pertain to dissolved oxygen. Whereas all other parameters adversely affect water use as their concentrations increase, dissolved oxygen does not follow this general rule; and water quality deteriorates with decreasing dissolved oxygen. The two lower intervals of concentration range from 0 to 5.0 ppm and are indicated by colored map symbols. Low concentrations in the interval of 0 to 3.0 ppm are lethal to, or at best marginal for, aerobic forms of life. The interval of 3.1 to 5.0 ppm spans a dissolved oxygen range that is thought to be generally adequate to preserve desirable forms of aquatic life if all other factors are favorable.

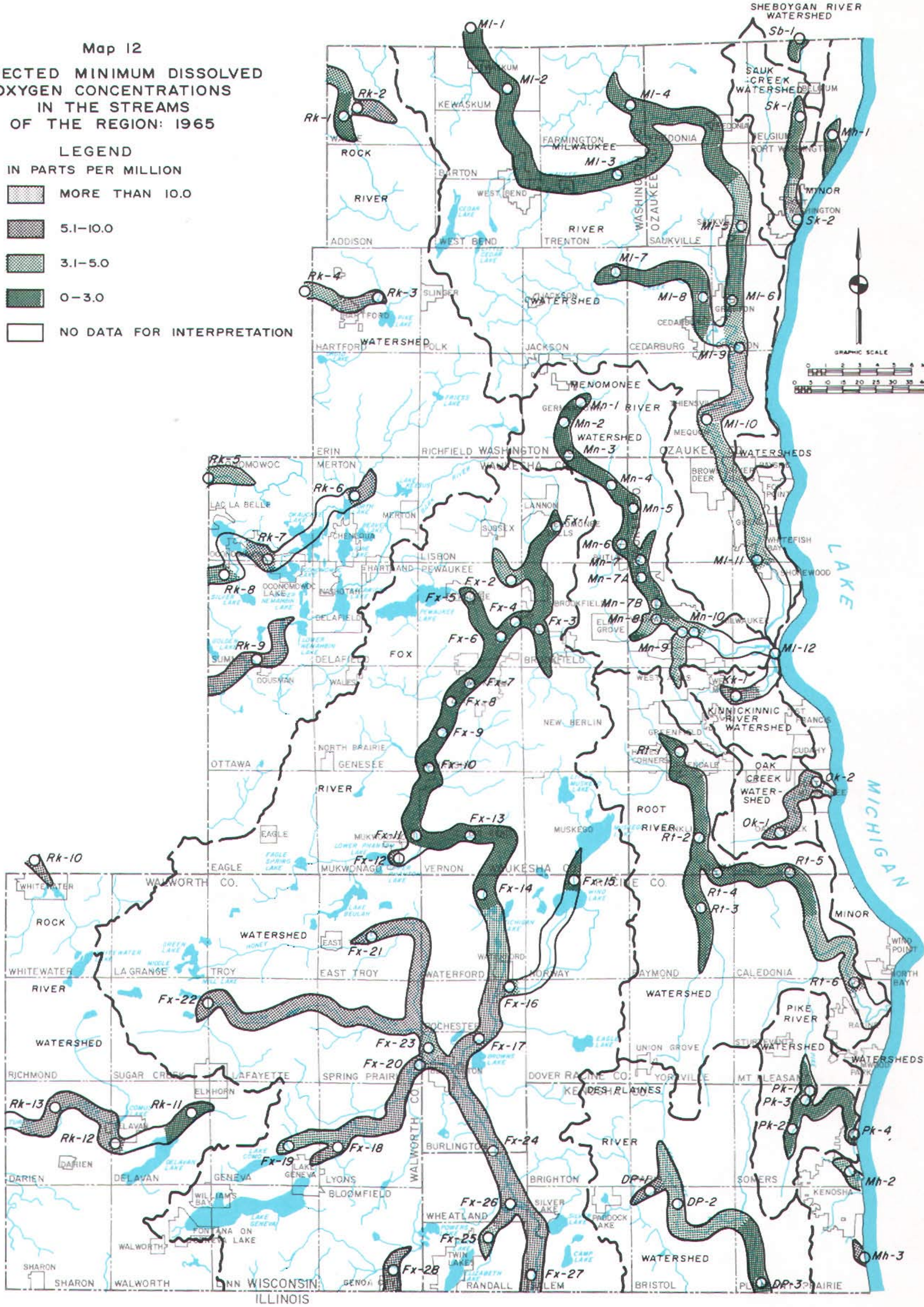
Map 13 shows the minimum dissolved oxygen concentrations in the streams of the Region during the period from January 1964 through February 1965 excluding July 1964. Because of the exceptionally low dissolved oxygen concentrations in many streams of southeastern Wisconsin following the unusually heavy rains of the 17th and 18th of July, Map 13 shows minimum dissolved oxygen concentrations in the streams with the data for July omitted. The concentrations are mapped according to the same scale as shown in Map 12. Dissolved oxygen content, like BOD is affected by increased population and industrial activity within a watershed; and Map 12 should not be considered indicative of general dissolved oxygen conditions within the Region for more than the next five to eight years.

Coliform Bacteria

Coliform bacteria comprise a group of microscopic fungi that occur in the intestinal tracts of human beings and of other warm-blooded animals, in sewage, in freshwater lakes and streams, in soil, and on

Map 12

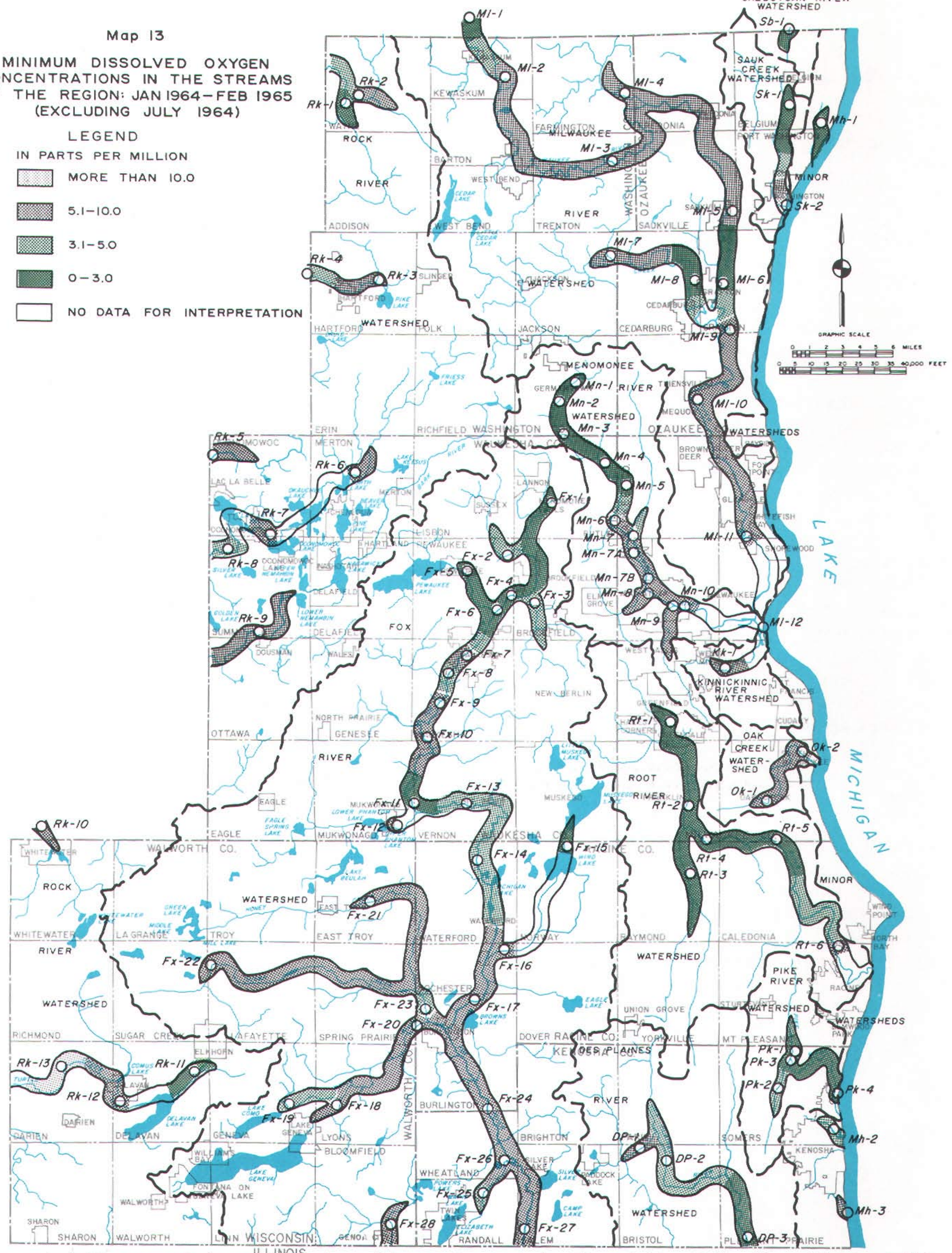
EXPECTED MINIMUM DISSOLVED OXYGEN CONCENTRATIONS IN THE STREAMS OF THE REGION: 1965



The expected minimum dissolved oxygen concentrations for 1965 range from 7.5 to 0 ppm. Minimum concentrations are anticipated to decline at a low rate until pollution abatement measures become effective.

Map 13

MINIMUM DISSOLVED OXYGEN CONCENTRATIONS IN THE STREAMS OF THE REGION: JAN 1964 – FEB 1965 (EXCLUDING JULY 1964)



Heavy rainfall occured in southeastern Wisconsin on July 17 and 18, 1964. The effect of this rainfall, which ranged from 7.25 inches at West Bend to 1.28 inches at Whitewater, was to flush vast quantities of dead and decaying organic materials from the marshy and swampy areas into many streams. This, in turn, presumably caused moderate to sharp declines in the dissolved oxygen concentrations for many days over extensive reaches of at least 16 of 29 streams sampled in July subsequent to the heavy rainfall. Fourteen streams were sampled in July prior to the heavy rainfall.

vegetation. Originally, the coliform group of bacteria were thought to comprise but a single bacterial species, later referred to as Bacillus coli (B. coli). Further investigation indicated that the Bacillus coli included many different bacterial species and subspecies or variants. The present concept concerning the coliform group is defined in Standard Methods as including "... all of the aerobic and facultative anaerobic, Gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35^{o}C." The Bacillus coli are equivalent to the coliform group.

According to Roy J. Christoph,[3] the presence of coliform bacteria in the human intestine is incidental; and their physiologic significance to man is a matter of continued study. Certain strains of coliform bacteria are thought to promote digestion by bacterial decomposition of partly digested food and to promote physical regularity by maintaining adequate moisture conditions in the intestine. Vitamin K (the vitamin which inhibits bleeding by coagulating blood) is produced as a by-product of coliform activity in the colon. Thus, the coliform group would appear to constitute an intestinal flora that is beneficial to man.

The coliform group is subdivided into two bacterial categories, which include species of presumed fecal or nonfecal origin. Escherichia coli, for example, is thought to be of fecal origin, whereas Aerobacter aerogens usually is not considered to be of direct fecal origin. Human feces, however, tends to include considerable numbers of Aerobacter aerogens. The significance of these closely related types of coliform bacteria is not well established, and routine water analyses determine the group as a whole without specifying individual bacterial species.

The presence of coliform bacteria in streams is generally considered to be an indication of pollution if the coliform counts are persistently high and appear to be closely associated to man-related waste sources, such as to the effluent of a sewage treatment plant or to the fecal wastes from other warm-blooded animals, such as a herd of cattle occupying agricultural land along a stream. Water-borne diseases are mostly of intestinal origin. Therefore, to safeguard public health, it is assumed that where coliform bacteria occur there is also the possibility of the presence of infectious micro-organisms and viruses. Micro-organisms or viruses are the causative agents of such diseases as typhoid fever, paratyphoid fever, amoebic dysentery, and infectious hepatitis.

As already noted, in routine bacteriological analyses of water samples, specific bacterial species or viruses are not determined. Instead, the coliform count is taken as a measure of the concentration of bacteria of the coliform group that occur in a given amount of sample, commonly 100 ml. Because of the intestinal origin of the coliform group in many areas of bacteriological stream pollution, the coliform count is an important water quality parameter indicating the disease potential to man.

A number of statements can be made concerning the significance of the coliform bacteria in relation to stream quality. It is generally assumed that, if the coliform group is not present, water is bacteriologically safe. If coliform bacteria are present, the coliform count should be generally proportional to the amount of human fecal pollution where such pollution can be reasonably attributed to a human source. Where disease bacteria of intestinal origin are present, they are always associated with much larger numbers of coliform bacteria. The coliform bacteria appear to survive better in the aquatic environment of a stream than pathogenic bacteria and may be subject to aftergrowth in polluted waters. The limitations of accuracy that are involved in obtaining representative samples, the problems of sample storage prior to analysis, and the inherent problems of bacteriological determinations place reservations upon interpretations of coliform counts. Nevertheless, coliform counts are considered to be a most important parameter relating to human sources of fecal pollution.

As related to water uses, the coliform count of a good source of water for municipal supply must be less than 20 percent over 5,000 MFCC/100 ml. Prechlorination reduces the coliform count, which must not exceed 1 MFCC/100 ml in the treated supply. As shown in Table 4, Chapter III, water used in the dairy industry must contain no more than 100 MFCC/100 ml. Water used for food canning, freezing, and for food equipment washing must contain no more than 1 MFCC/100 ml. General processing has more liberal

[3] *Personal communication, 1965, Roy J. Christoph, Professor of Biology, Carroll College, Waukesha, Wisconsin.*

quality standards permitting water containing as much as 5,000 MFCC/100 ml. Whole-body and partial-body recreational use of water have coliform standards of 2,400 and 5,000 MFCC/100 ml, respectively.

The maximum, average, and minimum coliform counts found in 1,050 stream samples collected at 87 sampling stations in the 12 watersheds of the Region were 3,000,000, 51,000, and less than 100 MFCC/100 ml, respectively. The maximum coliform count of 3,000,000 MFCC/100 ml was encountered at station Fx-5 on the Pewaukee River. The minimum coliform count of less than 100 MFCC/100 ml occurred in the watersheds of the Des Plaines River, the Fox River, the Menomonee River, the Milwaukee River, the minor streams tributary to Lake Michigan, the Rock River, and the Root River. Ranges in coliform counts by watershed are listed in Table 36.

Table 36

COLIFORM COUNT IN STREAMS IN THE REGION (1964 - 1965)

Watershed	Coliform Count in MFCC/100 ml			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	56,000	7,000	100	36
Fox River	3,000,000	39,000	100	337
Kinnickinnic River	340,000	77,000	4,000	11
Menomonee River	1,100,000	51,000	100	133
Milwaukee River	170,000	18,000	100	148
Minor Streams	740,000	52,000	100	32
Oak Creek	33,000	8,000	500	25
Pike River	1,800,000	173,000	1,200	52
Rock River	2,300,000	66,000	100	163
Root River	1,700,000	105,000	100	77
Sauk Creek	200,000	16,000	200	25
Sheboygan River	200,000	24,000	2,000	11
Total Samples				1,050

Source: State Laboratory of Hygiene and SEWRPC.

Map 14 shows the maximum coliform count which may be expected in the streams of the Region as of 1965. Since high coliform counts are directly related to human activity within a watershed, and since such activity may change rapidly over time, Map 14 should not be considered indicative of general conditions within the Region for more than the next five to eight years. The coliform counts are mapped on a scale ranging from 1 to 100,000 MFCC/100 ml or more. The upper scale interval of 100,000 MFCC/100 ml or more was chosen to span all very high coliform counts to avoid needless differentiation of counts that range in the hundreds of thousands and in the millions. The scale is divided into six intervals of concentration. The lower two intervals range from 1 to 2,400 MFCC/100 ml and are indicated in black map symbols. Concentrations ranging from 2,500 to 100,000 MFCC/100 ml or more are shown in color. The change from black to colored symbols was chosen at 2,400 MFCC/100 ml, which coincides with the maximum permissible concentration for full-body contact in the recreational use of water.

Map 15 shows the average coliform count in the streams of the Region during the period from January 1964 through February 1965. The coliform counts are mapped according to the same scale as shown in Map 14.

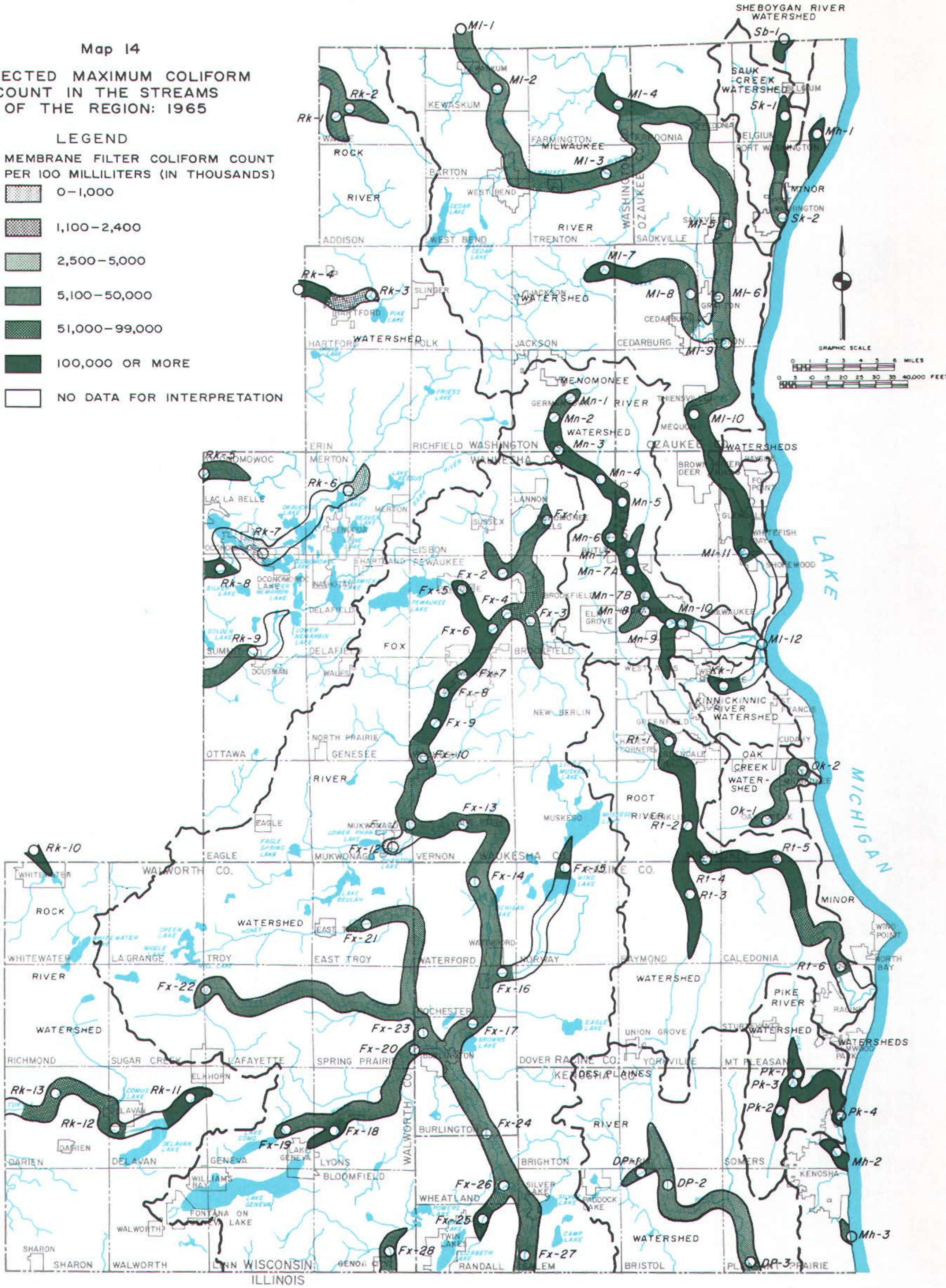
Temperature

The temperature of a stream is a measure of its heat energy as expressed in degrees Fahrenheit or in degrees centigrade. Natural stream temperature in southeastern Wisconsin is ultimately controlled by climatic conditions through the heat exchange between a stream and its land and atmospheric environment, rather than by subterranean thermal sources.

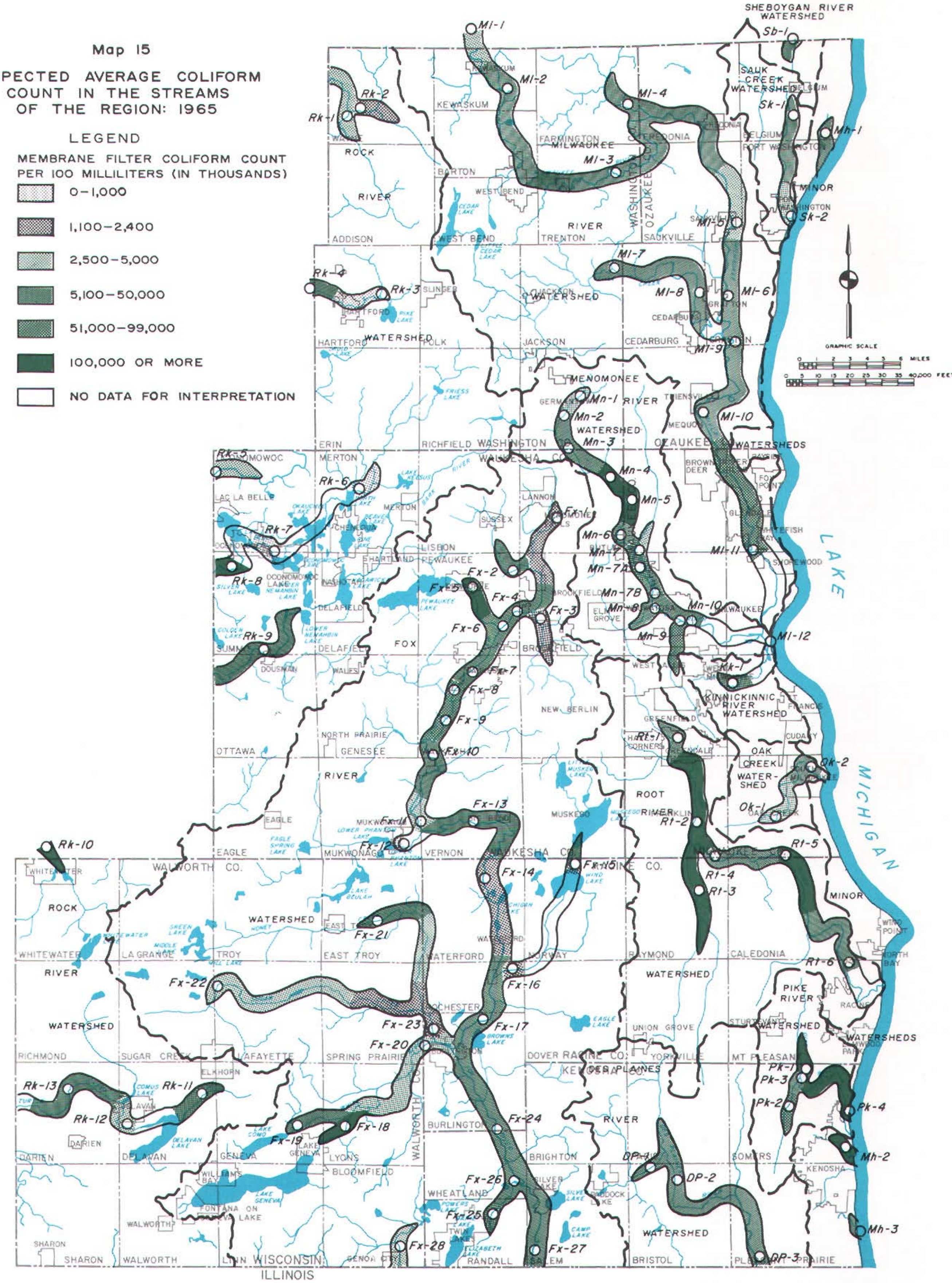
The most important factor affecting stream temperature is sunlight. The direct penetration of sun rays into a stream results in the conversion of electromagnetic waves to heat energy facilitated by turbidity. The width, depth, volume, and velocity of a stream determine to a large extent how the stream temperature will be affected by sunshine. The warming of a stream depends upon the quantity of water being exposed to a given intensity of sunshine over a given area of exposure. Trees growing at and near the waters edge and extending leaf-filled branches over the stream may intercept sunshine, which is then not

Map 14

EXPECTED MAXIMUM COLIFORM COUNT IN THE STREAMS OF THE REGION: 1965



The expected maximum coliform counts for 1965 range from 3,000,000 to 1,000 MFCC/100 ml. Maximum concentrations are anticipated to increase at a moderate rate until pollution abatement measures become effective.



The average coliform counts are based on analyses of 1,050 samples collected at 87 stations on 43 streams in the Region. The maximum, average, and minimum number of samples collected generally once a month at these 87 stations are 14, 12, and 7, respectively.

available to the stream. Cloud cover and haze may weaken solar radiation. Daily and seasonal changes in radiation intensities result in diurnal and seasonal fluctuations in water temperatures under the influence of other environmental factors.

Significant among other environmental factors is the temperature of ground water that discharges by seepage and by springs into the stream channel from intersected water-bearing rock units or from temporary bank storage built up during periods of higher stream stage at the then prevailing water temperature. Ground water makes up part or almost all the water of a stream, depending upon the frequency and intensity of precipitation and surface runoff that would not only add to the flow but also affect the stream temperature. Ground water temperatures in the glacial drift and Niagara aquifer generally range from 48° to 52°F with an average of 51°F.

Air temperature, humidity, and velocity also affect stream temperature. Wave action caused by air in motion creates a larger contact surface between water and atmosphere, facilitating more rapid heat exchange. Air humidity affects vapor pressure and the rates of evaporation from the stream surface which, in turn, affects water temperature.

In addition to the climatic conditions that affect the natural stream temperature, hot liquid wastes from industry and spent cooling water discharged into a stream can affect the stream temperature to the extent that these wastes become thermal pollutants. The effluent from sewage treatment plants may also affect stream temperature; but it would appear that, because of normal sewage temperatures, this effect is not severe.

Temperature is an important water quality parameter for several water uses. The suitability of water for general industrial processing, for cooling purposes, and for sustenance of aquatic life depends upon the temperature of water. Water for drinking purposes is usually satisfactory at 50°F but generally causes complaints at 66°F or above. Survival time of infectious bacteria and ova of parasitic worms decreases with increasing water temperature, an advantageous aspect of increasing water temperatures. However, increasing water temperatures stimulate algae growth and odor-producing organisms. High water temperatures may reduce the dissolved oxygen content of the water to critically low levels for survival of fish and other aquatic life or may produce an unfavorable heat environment that aquatic life cannot survive regardless of the abundance of dissolved oxygen.

The maximum, average, and minimum water temperatures found in streams of the Region were 91°, 50°, and 32°F. The maximum temperature of 91°F occurred on Cedar Creek at station Ml-7 in the Milwaukee River watershed. The minimum of 32°F occurred in all 12 watersheds of the Region. Stream temperatures by watershed are listed in Table 37.

Table 37

TEMPERATURE OF STREAMS IN THE REGION
(1964 - 1965)

Watershed	Temperature in °F			Number of Samples
	Maximum	Average	Minimum	
Des Plaines River	84	52	32	35
Fox River	80	50	32	341
Kinnickinnic River	82	57	32	11
Menomonee River	79	48	32	131
Milwaukee River	91	51	32	149
Minor Streams	78	56	32	32
Oak Creek	73	48	32	24
Pike River	75	49	32	52
Rock River	80	49	32	163
Root River	78	52	32	77
Sauk Creek	86	51	32	24
Sheboygan River	87	53	32	11
Total Samples				1,050

Source: SEWRPC.

Chapter V

CONDITIONS OF STREAM QUALITY AND STREAMFLOW IN THE MAJOR WATERSHEDS OF THE REGION

STREAM QUALITY AND STREAMFLOW

The streams of southeastern Wisconsin are small and, therefore, subject to a relatively large variability in natural water quality. This variability is evident when comparing one stream with another and when comparing quality conditions of different reaches of the same stream. Large streams, such as the Mississippi River, typically have a high degree of uniformity in water quality. Because of the relatively narrow range in the variation between extreme quality conditions over extensive reaches of such large streams, consideration of average water quality conditions may be adequate for planning purposes. In southeastern Wisconsin stream quality conditions vary between relatively wide ranges, and water quality averages alone are not particularly meaningful for planning purposes; therefore, careful consideration must be given to extremes in the ranges.

To classify streams in terms of their variations in overall chemical quality, this report uses a scale of reference based on the ratio of the maximum to the minimum dissolved solids concentration of all SEWRPC samples collected from each stream during the 14-month period of study. The classification is as follows:

1. A stream has relatively constant overall chemical quality when the ratio of the maximum to the minimum dissolved solids concentration is 1.0 to 1.9.

2. A stream is subject to small changes in overall chemical quality when the ratio of the maximum to the minimum dissolved solids concentration is 2.0 to 2.9.

3. A stream is subject to medium changes in overall chemical quality when the ratio of the maximum to the minimum dissolved solids concentration is 3.0 to 3.9.

4. A stream is subject to large changes in overall chemical quality when the ratio of the maximum to the minimum dissolved solids concentration is 4.0 or more.

Of the 43 streams studied by the SEWRPC, 41 rise in southeastern Wisconsin. Only the Milwaukee River and the North Branch of the Milwaukee River have their sources outside the seven-county Region. Five of the 12 watersheds of the Region are contained entirely within the regional boundaries. Twenty-six streams have their watershed areas entirely inside the Region. The longest stream is the Milwaukee River, with 82 miles of its total 101-mile length lying within the Region. According to U. S. Geological Survey records to February 1965, the maximum mean daily flow of any stream was 15,100 cfs or about 6.8 million gpm, which occurred on the Milwaukee River in 1918. Minimum flow of 0 cfs has undoubtedly occurred on a number of streams in the Region besides the Des Plaines River and the Milwaukee River for which measurements are available. By way of comparison, the Wisconsin River (the largest river with its headwaters in Wisconsin) had a maximum flow of 80,800 cfs (36.3 million gpm) in 1952. The maximum flow of the Mississippi River at a location 2.6 miles upstream from the mouth of the Wisconsin River was 197,500 cfs (88.7 million gpm) in the same year.

THE WATERSHED AS A STUDY UNIT

In an effort to relate the regional stream quality study findings to a meaningful geographic planning unit, the results of the study were analyzed, interpreted, and presented by watershed. This selection of the watershed as the basic geographic area of study and reference was made only after careful consideration of the comprehensive planning as well as of the hydrologic and geologic factors involved.

Resource and resource-related studies and planning efforts can conceivably be carried out on the basis of various geographic areas. Such areas may be delineated on the basis of governmental jurisdiction, economic linkage, common areawide development problems, or topography, the latter type of delineation including the watershed. None of these geographic areas are perfect for selection as a resource and resource-related planning unit. There are many advantages, however, to the selection of the topographically defined watershed as a study and planning unit since many resource problems are surface water oriented.

A natural stream channel network forms a system into which overland runoff from rainfall or snowmelt drains and moves downstream under the influence of gravity. The land area which contributes the overland runoff comprises the tributary watershed, the boundary of which is defined by the topographic divide separating those land areas where overland runoff flows to the stream system under consideration from those land areas where runoff flows to other stream systems. Thus, the watershed may be defined as a geographic area, the topographic boundaries of which delimit the catchment area contributing overland runoff to a given stream system.

The watershed forms a meaningful geographic planning unit, not only for the consideration of storm water drainage and flood control problems which must be considered on a watershed basis, but also for the consideration of other land and water use problems closely related to drainage and flood control, including flood plain utilization, park and open-space reservation, fish and wildlife conservation, and stream pollution.

Water supply and sewerage facility planning may involve problems that cross watershed boundaries, but the watershed must be recognized as a planning unit if surface streams are utilized as the source of supply or if the sewerage systems discharge pollutants into the stream system. Changes in land use and transportation requirements are ordinarily not controlled primarily by watershed factors but can greatly influence watershed development. The land use and transportation pattern determines the amount and spatial distribution of the hydraulic and pollution loadings to be accommodated by the stream system of a watershed. In turn, the drainage, flood control, and water quality control facilities and their effect upon the historic floodways and flood plains and upon surface water quality determine to a considerable extent the use of riverine areas of the watershed. Finally, it should be noted that the related physical problems of a watershed tend to create a strong community of interest among the residents of the watershed; and citizen action groups can readily be formed to assist in solving water-related problems. It may be concluded, therefore, that the watershed is a suitable unit of area to be selected for resource planning purposes, provided that the relationships existing between watershed and region are recognized. Accordingly, the results of the stream quality study were analyzed and interpreted, utilizing watersheds as the basic geographic area of study and reference.

In considering stream quality within the context of a watershed, however, it must always be recognized that, in addition to overland runoff, ground water seepage, artificial discharges from human sources (such as sewage treatment plants and industries), and direct precipitation into the stream channels also contribute to the total flow of the stream system. In southeastern Wisconsin the base flow of perennial streams is determined largely by ground water seepage into the stream channels. Runoff contributes to the flow of streams only during and immediately following rainfall or snowmelt. During periods of heavy runoff, stream stages rise; temporary bank storage occurs; and normal ground water gradients may be reversed so that ground water recharge may occur. Dissipation of the runoff may last only two to four days following rainfall or snowmelt. Water in temporary bank storage moves back into the stream channels until ground water gradients are reestablished toward the channels, and ground water basin storage again contributes to the perennial streamflow.

The gravitational movement of ground water is determined by the hydraulic gradients established by the net effect between the geographical distribution of ground water recharge and discharge. Where ground water occurs under water table conditions in relatively permeable surficial deposits, such as sands and gravels, or in the underlying Niagara aquifer, the configuration of this water table tends to be a subdued image of the surface topography. Under this condition the topographic divides that form the watershed boundaries will generally coincide with the underlying ground water divides. Where surficial deposits are composed of relatively impermeable deposits, such as clay or till, these deposits may tend to absorb relatively little precipitation, thereby augmenting surface runoff and providing relatively little local ground water storage to maintain base flows. The ground water divide under these conditions generally does not coincide with the watershed divide.

In studies and applications where water quality and stream pollution are matters of primary concern, the significance of any incongruities between watershed and ground water divides is more than academic. Stream base flow conditions provide the best available data on the background quality conditions of the streams, because it is under base flow conditions that the water in a stream is comprised almost entirely of ground water seepage into the stream channel, together with whatever artificial discharges may occur from man-made sources. If the ground water divides extend far beyond the watershed boundaries, ground water may be moving into or out of the watershed under the influence of subterranean hydraulic gradients; and the water quality of the stream system may be affected by ground water originating outside the watershed.

The inorganic chemical quality of the streams of southeastern Wisconsin is determined to a considerable extent by the geochemistry of the soil and geologic terrane in relation to precipitation and runoff. Soil types also determine to a very large degree the runoff characteristics of a watershed and thus ultimately affect streamflow, flooding, basin storage, ground water recharge rates, and water quality changes. In the presentation and discussion of the present stream quality within each of the 12 watersheds of the Region, few statements are made regarding the predominant types of soil covering the tributary watershed area and the geologic formations that yield water to the surface drainage system and sustain the base flow of the perennial streams. It should be understood that it is not within the scope of this study either to determine or discuss specific cause and effect relationships between "natural" stream quality and watershed runoff characteristics and the soil and geologic terrane.

Precipitation data are included as part of the documentation of basic information. No attempt has been made to present the correlation of these data with streamflow and water quality except in the broadest terms.

Map 16 shows the location of U. S. Weather Bureau stations in southeastern Wisconsin. Precipitation data are included in this report from those Weather Bureau stations designated on Map 16. Map 17 shows the location of selected sewage treatment plants in the Region.

ALTERNATIVE REGIONAL LAND USE PLANS

The SEWRPC has prepared three alternative regional land use plans: a Controlled Existing Trend Plan, a Corridor Plan, and a Satellite City Plan. In addition, a fourth alternative future land use pattern was explored that would result from continuation of existing development trends in the absence of any attempt to guide regional development. This alternative is not a plan but a forecast of unplanned development and serves not as a recommendation but as a basis of comparison for the true land use plans. Each of the three alternative plans represents an attempt to meet established regional development objectives with a basically different design. All three plans and the uncontrolled forecast meet the same future regional population level of 2,678,000 by the year 1990, an increase of slightly more than one million inhabitants over the estimated 1963 population of 1,674,000. Although each plan provides for the same increase in the regional population and although the distribution of the total population within the Region and within each watershed of the Region varies from one plan to the other, each plan does not necessarily have a significantly different effect upon the streams in each watershed.

Table 38 indicates the estimated 1963 and 1990 population level of southeastern Wisconsin by watershed according to each of the alternative land use plans. Whereas the population estimates for the Controlled Existing Trend Plan, the Corridor Plan, and the Satellite City Plan have been included in the table, the estimates for the fourth alternative, the uncontrolled existing trend alternative, have not been included.

The uncontrolled existing trend alternative is based upon an assumed continuation of the development trends which occurred in the Region from 1950 to 1963. This development was characterized by primary emphasis upon highly dispersed, low-density residential land use development with water supply and sewage disposal provided by shallow private wells and domestic septic tank systems. Continuation of these trends to 1990 would envision continued emphasis upon low-density residential development with a proportionately greater population served by private wells and septic tank systems than by centralized municipal water and sewerage systems. The impact of such development upon stream quality would not only be extremely difficult to forecast but might be misleading as a basis for alternative plan evaluation. Unlike sewage treatment plant effluent, septic tank effluent is not discharged directly into streams. Septic tank systems that are properly constructed will function effectively only if the system is located where the local soil conditions, geology, and ground water levels are favorable for this method of sewage disposal. There are, however, extensive areas in southeastern Wisconsin where soil permeability is low. Under this condition, the capacity of the disposal field is largely limited to that of the drain tile trenches which may become continually or intermittently waterlogged, causing soggy soil, foul odors, surface seeps that contribute undesirable wastes to local streams or lakes, and health hazards. Where soil and unconsolidated rock form a relatively thin veneer over fractured bedrock, septic tank systems may function poorly in that water percolating from the disposal field may be inadequately filtered and may pollute the ground water supply that sustains local wells. Where the water table is shallow, septic tank systems function poorly and are often sources of ground water pollution and cause surface seeps due to waterlogging of the disposal field. Moreover, other environmental problems attendant to the widespread utilization of on-site septic tank sewage disposal facilities and of private wells would probably be far more serious than the adverse effects of the use of such sewage disposal facilities on stream quality. Continued widespread use of shallow wells could be expected to result in a continued decline of ground water levels in the shallow aquifers under and near areas of heavy collective withdrawals, with the attendant creation of water supply problems. Continued widespread use of septic tanks could be expected to subject these shallow aquifers to pollution in more numerous locations involving larger and larger areas, with serious attendant public health problems. Odor and drainage problems could be expected to continue to arise where homes are located on soils poorly suited for septic tank systems. Such soils are widespread, covering over 50 percent of the total land area of the Region.

Consequently, although the uncontrolled existing trend alternative might possibly have less direct effect on the water quality of streams as compared to the other three alternative land use plans, this consideration becomes academic when considered in light of the adverse effects such a plan would probably have upon the ground water resources and public health. It is for these reasons that predictions of stream quality based on the uncontrolled existing trend alternative were not made for this report.

FORECAST STREAM QUALITY—ASSUMPTIONS AND RATIONALE

The presentation and discussion of the existing stream quality within each major watershed in the Region are concerned primarily with the main stream in each watershed and secondarily with the major tributaries. Five parameters have been selected to describe stream conditions within each watershed: chloride,

Table 38

ESTIMATED POPULATION BY WATERSHED IN THE REGION: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

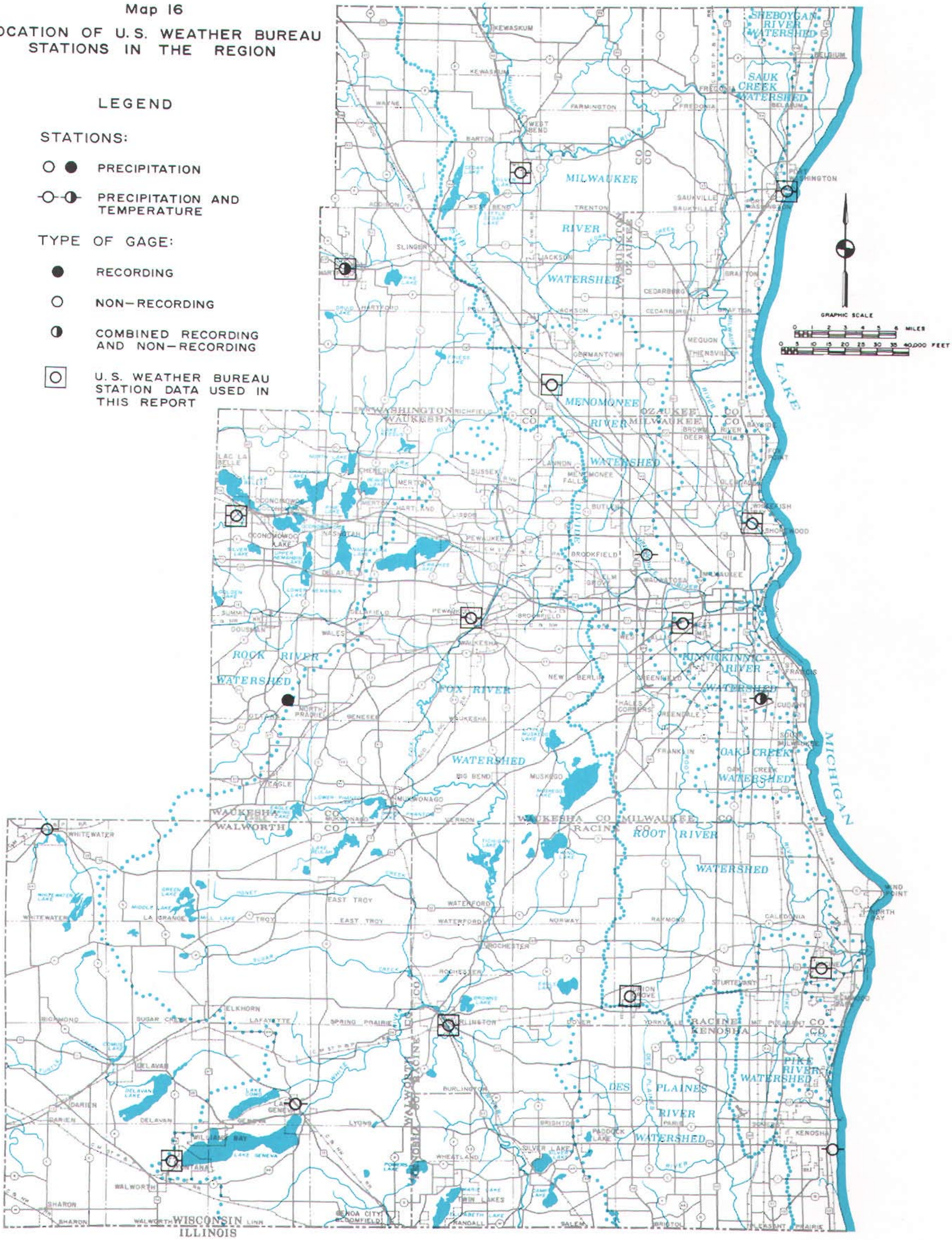
Watershed	Area[a] (sq. mi.)	Existing 1963	Estimated Population For 1990: Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Des Plaines River	132.9	11,200	20,000	27,000	23,000
Fox River	941.6	160,000	359,000	377,000	334,000
Kinnickinnic River	25.7	186,900	219,000	228,000	222,000
Menomonee River	134.5	338,600	487,000	470,000	459,000
Milwaukee River	431.7	508,600	635,000	628,000	665,000
Minor Streams	93.0	218,200	312,000	298,000	323,000
Oak Creek	26.7	28,500	95,000	93,000	95,000
Pike River	50.9	13,000	88,000	93,000	84,000
Rock River	609.4	68,800	123,000	137,000	181,000
Root River	197.9	134,200	330,000	303,000	252,000
Sauk Creek	34.5	5,400	8,000	20,000	38,000
Sheboygan River	10.3	1,000	2,000	4,000	2,000
Total	2,689.1	1,674,400	2,678,000	2,678,000	2,678,000

[a] *In the seven-county Region.*

Source: SEWRPC.

Map 16

LOCATION OF U. S. WEATHER BUREAU STATIONS IN THE REGION



Precipitation and temperature data were obtained from the U. S. Weather Bureau, which has 18 stations in the Region. The weather stations referred to in this report are indicated on the map.

Map 17

LOCATION OF SELECTED SEWAGE TREATMENT PLANTS IN THE REGION

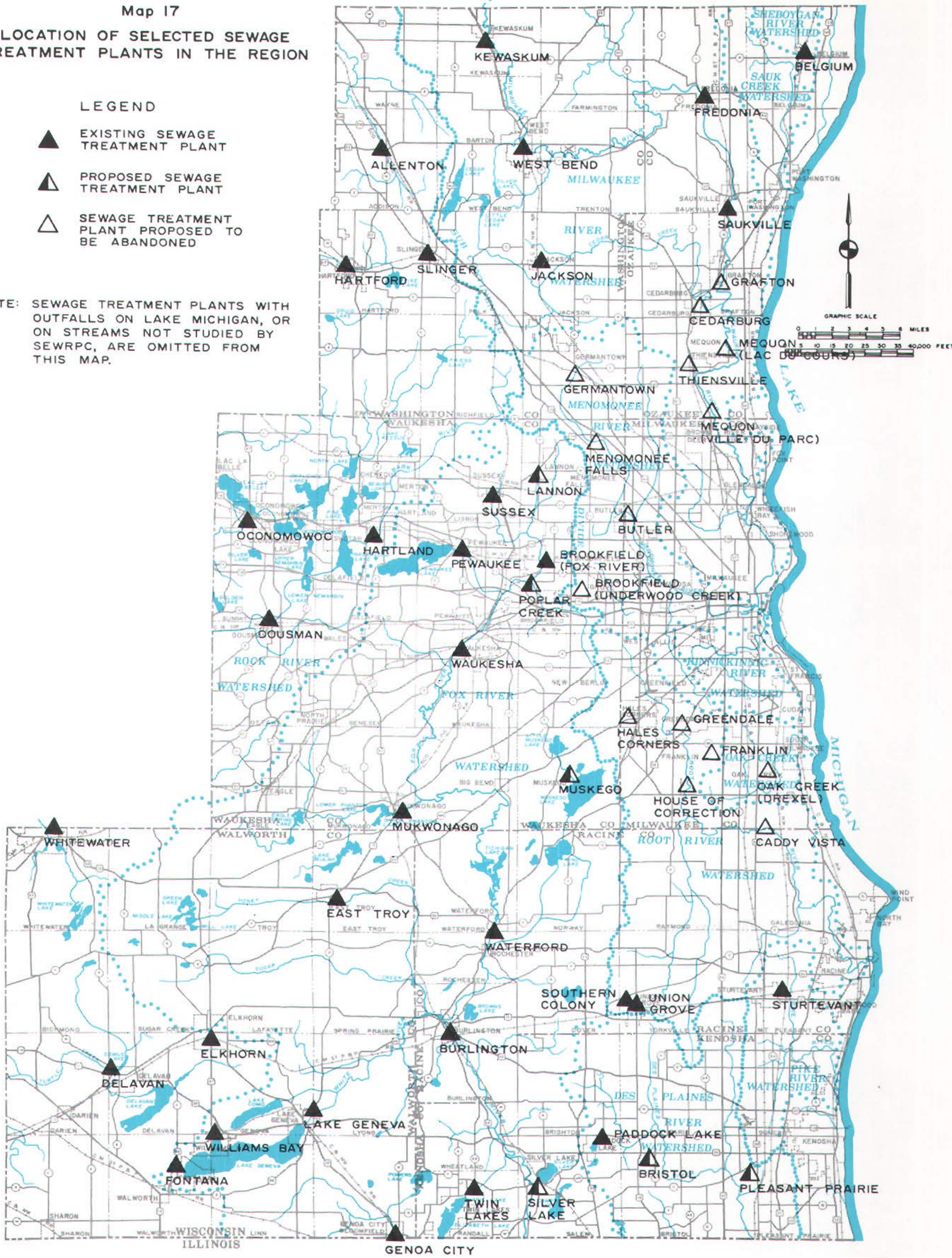
LEGEND

▲ EXISTING SEWAGE TREATMENT PLANT

PROPOSED SEWAGE TREATMENT PLANT

△ SEWAGE TREATMENT PLANT PROPOSED TO BE ABANDONED

NOTE: SEWAGE TREATMENT PLANTS WITH OUTFALLS ON LAKE MICHIGAN, OR ON STREAMS NOT STUDIED BY SEWRPC, ARE OMITTED FROM THIS MAP.



Forty four sewage treatment plants in the Region have outfalls located on streams. These plants service approximately 168,000 persons. Nine sewage treatment plants discharge directly into Lake Michigan and service approximately 1,196,000 persons.

dissolved solids, coliform count, dissolved oxygen, and stream temperature. Chloride normally occurs in the streams of southeastern Wisconsin in higher than "background" concentrations (ranging from 0 to 15 ppm), primarily as a result of discharges of treated human sewage, water-softener regeneration brine, industrial wastes, and seasonal runoff from salted streets and highways. Chloride is an inorganic substance that does not decompose, is not chemically changed or physically removed by natural processes, and adversely affects a number of water uses in concentrations exceeding the quality standards. Dissolved solids is a measure of the mineralization and overall water quality condition. Coliform count is a biological water quality parameter which is of significance in identifying stream reaches that are subject to pollution from sources of human wastes, primarily sewage treatment plants. Dissolved oxygen, although always determined in this study on samples collected during daylight hours and, therefore, not reflecting the nocturnal decrease in dissolved oxygen, is the most important single parameter which could be used to measure water quality in relation to the presèrvation and enhancement of fish and other desirable forms of aquatic life. Stream temperature is an adjunct to chemical, biochemical, and bacteriological analyses and is important in relation to dissolved oxygen and to overall stream quality conditions.

The forecast stream quality presented herein for each of the land use patterns proposed by the Controlled Existing Trend Plan, the Corridor Plan, and the Satellite City Plan are approximations and, while believed to be realistic, are predicated upon certain assumptions. These predications are made in light of present sewage treatment and disposal techniques and practices and do not take into account any possible changes in the effectiveness of these techniques and practices. Although recent research in advanced waste treatment techniques has provided some reason to anticipate future improvement in effluent quality, the rate at which improved treatment methods may be developed to a practical level and applied within the Region cannot be foreseen at this time. Moreover, the study was made during a period in which precipitation and streamflow were generally below normal. Assuming that normal discharges of polluting wastes occurred during this same period, the measured conditions of stream quality may be somewhat lower than might be encountered during a period of more normal precipitation and streamflow. The forecast is, therefore, believed to properly reflect stream quality conditions of most concern for planning purposes. To provide a better understanding of the meaning of these forecasts, the assumptions and rationale upon which they are based are presented as follows:

1. Estimates of future chloride concentration levels are made only for streams where the chlorides are presumed to be principally of domestic origin, that is, derived from liquid body wastes and from waste waters of the regeneration cycle in the water-softening process. These liquid wastes are discharged directly to a receiving stream from sewage treatment plants or reach the stream by seepage from septic tank systems or by surface runoff.

2. Chloride concentrations in treated municipal sewage are assumed to be principally of domestic origin if these concentrations do not exceed 250 ppm and average between 150 and 200 ppm. Municipal sewage treatment plants are assumed to discharge an average of 100, 120, or 180 gallons of water per day per person when the total connected populations are 1,000 or less, between 1,000 to 5,000, or more than 5,000 persons, respectively.

3. Estimates of chloride concentrations in streams receiving discharges from septic tanks are based first on a quality "impact" calculation relative to the 1963 estimated population connected to septic tank systems. The corresponding 1990 population, according to the three alternative land use plans, is secondly assumed to effect an increase in chloride concentration in proportion to the ratio between the 1963 and the 1990 population of each plan.

4. The chloride "impact" calculation is based upon assumptions regarding the "background" chloride concentration of the stream, which is determined by the chloride concentrations of the ground water that sustains the base flow of the stream. Inspection of chemical water analyses of stream samples collected during low-flow conditions and inspection of analyses of available ground water tapping the glacial drift and the shallow bedrock aquifer permit the selection of a chloride concentration that is presumed to represent the natural "background" concentration of chloride in the stream. The buildup from domestic sources of the chlorides in a stream is related to an estimated population for 1990 using septic tank systems and is assumed to cause a chloride "impact"

proportional to that caused by the present population under low-flow conditions. The "background" chloride concentration of the stream is added to the impact concentration caused by domestic wastes from the estimated 1990 population giving the estimated chloride concentration of the stream at a specified sampling station during low-flow conditions.

5. Stream quality impact by nondomestic chloride wastes is not estimated in this study. Included in this category are liquid wastes from agricultural activities and from industrial processes. Regional effects of agricultural chloride sources on streams are not known to occur in detectable concentrations in southeastern Wisconsin, nor is it anticipated that these economic endeavors will significantly affect regional chloride concentrations in streams by 1990. Industrial chloride wastes adversely affect water quality in certain reaches of several streams in the Region. It is, however, impossible either to forecast or to specify in a regional land use plan what industries may be located in the Region by 1990. Moreover, even if this information were available, all of the many complex factors determining what ultimate effect the liquid wastes from these industries may have on the chloride concentrations of the stream would have to be investigated. Such investigations are beyond the scope of the present study, and for these reasons no stream quality predictions were related to industrial waste sources.

6. Estimates of future dissolved solids concentrations are made only for streams where the dissolved solids are presumed to be affected by liquid wastes of domestic origin.

7. The dissolved solids concentration of treated municipal sewage is assumed to be on the average about twice the dissolved solids concentration of the water supply sustaining the community served by the sewage treatment plant.

8. Estimates of dissolved solids concentrations in streams receiving discharges from septic tanks by surface seeps or by surface runoff are based on the complete chemical analysis for September or October 1964. The chloride and sodium concentrations that are above "background" concentrations of these two parameters are subtracted from the dissolved solids, giving a base figure. The predicted chloride and sodium "impact" concentrations for 1990 are added to this base figure, giving the minimum future dissolved solids concentration that may be expected at the specified sampling station during low-flow conditions.

9. In the calculations discussed above, sodium is presumed to occur with chloride in a ratio determined by their combining weights in sodium chloride salt ($NaCl$). Given a chloride concentration in parts per million, the corresponding concentration of sodium in parts per million equals the chloride concentration multiplied by the factor 0.6484.

10. Estimates of future dissolved oxygen levels are made on the basis of average or minimum dissolved oxygen concentrations encountered during the four-month period of June through September 1964 in relation to the present population (1963).

11. Estimates of the 1990 populations of each watershed according to the three alternative plans, the locations of existing and proposed sewage treatment plants, the estimated connected populations of these treatment plants, the flow characteristics of the stream, and the general evaluations of dissolved oxygen concentrations in relation to present waste loading and algae growth all combine to form a basis upon which intuitive and subjective judgment is expressed in generalized predictions of ranges in dissolved oxygen concentrations at a specified sampling station under low-flow conditions during the four-month period of June through September.

12. Estimates of the coliform counts for 1990 are made according to three procedures depending upon whether the stream is affected by wastes from septic tank systems, by the effluent from municipal sewage treatment plants, or by a combination of both sources of wastes.

13. Where the coliform count of a reach of stream is principally affected by wastes from septic tank systems, the ratio between present average coliform counts at a stream sampling station and the estimated population contributing to this waste loading is applied when calculating the coliform count at the same station based on the population estimate for 1990.

14. Where the coliform count of a reach of stream is principally the result of discharges from sewage treatment plants, the estimates of the coliform counts for 1990 are based upon present effects in relation to forecast connected populations for 1990 under similar conditions of natural streamflow.

15. Where the coliform count of a reach of stream is the combined effect of discharges from sewage treatment plants and septic tank systems, the estimate of the 1990 quality condition is based first upon the effect of anticipated sewage treatment plant discharges. If the estimates are more than 5,000 MFCC/100 ml, the additional effect of septic tank discharges is disregarded because the principal source of coliform bacteria has been sufficient to exceed the numerical value of the recommended limiting or maximum permissible concentrations for partial-body contact recreation. Where the 1990 coliform counts are estimated to be less than 5,000 MFCC/100 ml, the impact from septic tank systems is estimated according to the procedure discussed under Item 13 above. This value is then added to that estimated for the effect from sewage treatment plants.

16. The estimates for 1990 of chloride, dissolved solids, and dissolved oxygen concentrations and of coliform counts are rounded as indicated below:

    Chloride concentrations

    0 to 100 ppm - nearest 10 ppm
    100 ppm or more - nearest 25 ppm

    Dissolved solids concentrations

    0 to 1,000 ppm - nearest 50 ppm
    1,000 or more - nearest 100 ppm

    Dissolved oxygen concentrations

    Although recorded to 1/10 ppm, dissolved oxygen is expressed in generalized terms of expected concentrations

    Coliform counts

    0 to 5,000 MFCC/100 ml - nearest 500 MFCC/100 ml
    5,000 to 10,000 MFCC/100 ml - nearest 1,000 MFCC/100 ml
    10,000 to 100,000 MFCC/100 ml - nearest 10,000 MFCC/100 ml
    100,000 MFCC/100 ml or more - indicated as 100,000 MFCC/100 ml or more

The procedures in rounding estimated numerical values suggest levels of accuracy in predicting the 1990 conditions that are not necessarily inherent in the methods used. It should be kept in mind that the procedures applied in making these predictions are based upon empirical methods and involve all of the uncertainties inherent in any forecasting procedure.

STREAM QUALITY GRAPH SYMBOLS

To readily display in summary form the water quality of nine larger streams of southeastern Wisconsin, use has been made of stream quality graphs. These interpretive graphs show the varying concentrations of chloride, dissolved solids, dissolved oxygen, and coliform count in the Fox, Menomonee, Milwaukee, Oconomowoc, Root, and Rubicon rivers and in Jackson Creek, Delavan Lake Outlet, and Turtle Creek during each of the 14 months of field investigation from January 1964 through February 1965. The water quality data recorded on these graphs at the several sampling stations are interpreted in relation to major sources of water entering the streams from tributaries or from sewage treatment plants. There are no known sources of industrial waste waters that are discharged directly into these streams and that consistently affect the regional stream quality.

The stream channels are shown diagrammatically as straight vertical columns, having uniform width and having a length in graph miles measured midstream along the meandering channels either from their source or from the SEWRPC sampling station farthest upstream through all lakes along the watercourse either to where the rivers reach the downstream boundaries of the Region or to the farthest downstream SEWRPC sampling station. The location of sampling stations, the discharge location of sewage treatment plant effluent, and the confluence with selected tributaries are noted in the left margin of the graphs and are indicated by short horizontal "tick" marks at the left edge of each columnar stream graph. The concentrations of each of the four parameters (chloride, dissolved solids, dissolved oxygen, and coliform count) are shown at each sampling station adjacent to the right edge of each column across from the sampling station "tick" marks at the left edge of each channel column. The graphs are displayed in Figure 2 and explained below. Downstream direction is always toward the bottom of each stream channel column.

Graph 1. Indicates reach of a stream with uniform water quality conditions throughout. Location of a SEWRPC stream sampling station is indicated by tick mark at left edge of stream column. Parameter concentration is indicated by numeral 120 at right edge of column across from location mark of stream sampling station. Water quality is uniform in the sense that the sampled quality falls within a single interval of parameter concentration, such as within the interval of 101 to 250 ppm chloride.

Graph 2. Indicates reach of stream with two intervals of parameter concentration. Straight line contact between intervals denotes estimated approximate location of transitional water quality area between the upstream and downstream intervals of concentration, such as between the interval 0 to 50 ppm and the interval 51 to 100 ppm chloride.

Graph 3. Indicates reach of stream where a sewage treatment plant is inferred to be a source of waste discharges that significantly affect the quality of the stream. This condition is signified by the curvilinear contact between the upstream interval of parameter concentration and the presumed interval of concentration downstream from the tick-marked location of the sewage treatment plant outfall.

Graph 4. Indicates reach of stream and a tributary of similar quality. A tributary is designated graphically by a small opening between two tick marks always in the left edge of the stream channel column.

Graph 5. Indicates reach of stream wherein tributary quality is dissimilar to that of main stream and is inferred to have significant effect upon the quality of the main stream from the confluence to at least the nearest sampling station downstream. This condition is signified by the curvilinear contact between the upstream interval of parameter concentration and the presumed interval of concentration downstream from the tick-marked location of the tributary. Parameter concentration (412) of the tributary is shown at right edge of stream column. Where no water quality symbol is shown on a lateral tributary, this tributary may still be interpreted as a possible source of water that could account for significant changes in the water quality of the main stream.

Graph 6. Indicates reach of stream wherein a tributary has a quality dissimilar to that of the main stream and is inferred to have a significant effect upon the water quality of the main stream. The stream quality at the closest sampling station downstream from the junction with the tributary is intermediate between the quality of the main stream above the confluence with the tributary and that of the tributary itself. This condition is signified by the water quality symbol of the tributary extending a very short distance downstream.

Graph 7. Indicates a reach of stream wherein a tributary does not significantly affect the quality of the main stream. The lobate water quality symbol extending from the tributary to part way into, the channel column and then tapering off to the left edge of the column in the downstream direction signifies the tributary discharging water of dissimilar quality into the main stream, its blending within the main channel, and the dissipation of its quality characteristics in the mass of the main stream.

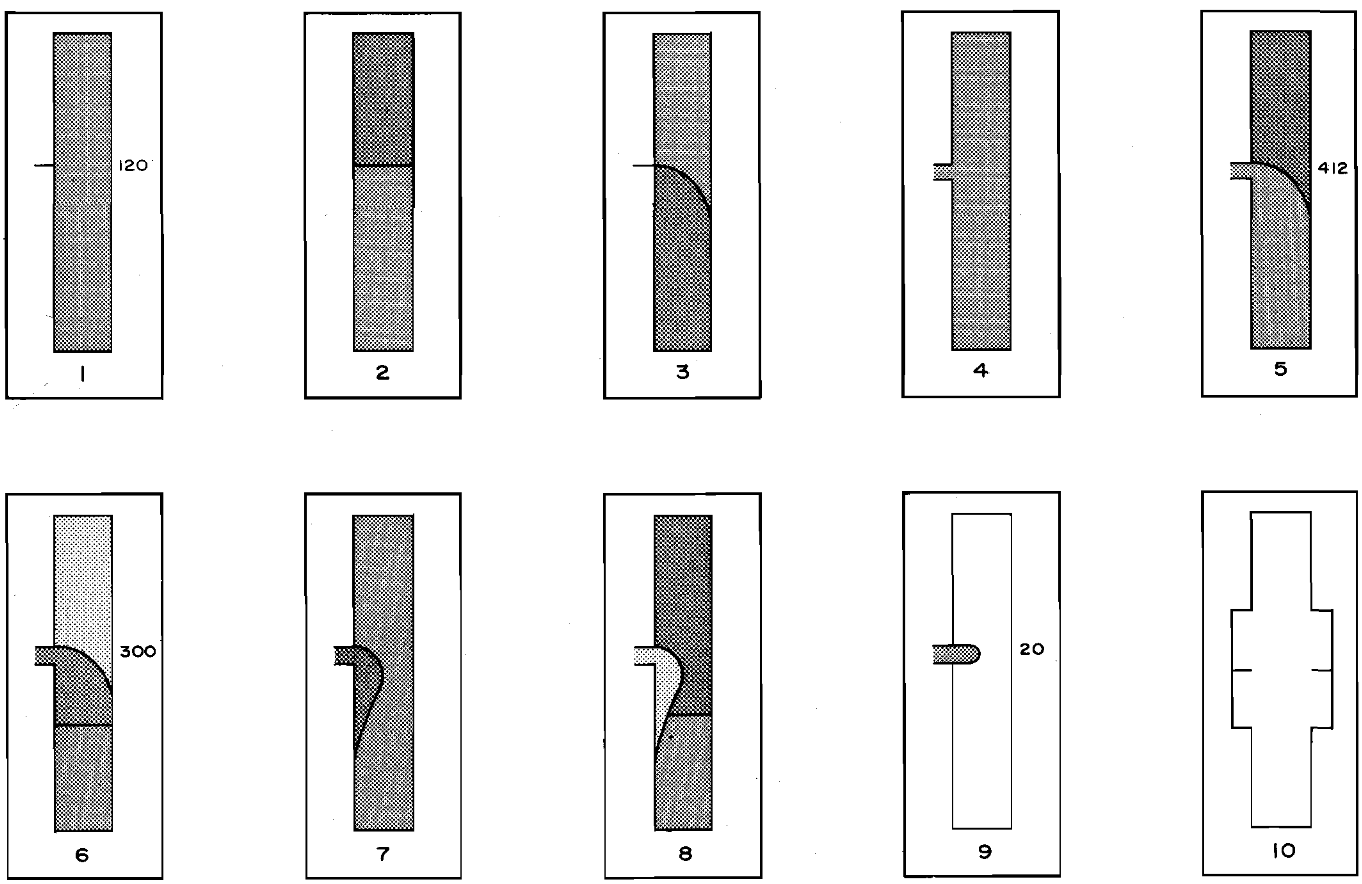
Graph 8. Indicates a reach of stream where a tributary does not significantly affect a water quality transition that occurs coincidently near the confluence of main stream and tributary.

Graph 9. Indicates a reach of stream of unknown or unspecified water quality and a tributary of known quality having an indeterminate effect upon the quality of the main stream.

Graph 10. Indicates a reach of stream flowing through two lakes (expanded area) that are adjacent to each other. The two "internal" tick marks indicate the limits of each lake. When a stream flows through one lake, the internal tick marks are not used. Lake symbols are used only on the Oconomowoc River.

Figure 2

STREAM WATER-QUALITY GRAPH SYMBOLS



The discussions of stream quality and pollution presented in this chapter are based upon water analyses run by the State Laboratory of Hygiene and the SEWRPC on stream samples collected at 87 sampling stations on 43 streams and watercourses from January 1964 through February 1965. As previously noted, a condition of pollution does not exist unless the adverse stream quality condition results from human activity and unless the specific water quality parameter in question exceeds the permissible or recommended maximum or minimum limiting concentrations for the desired water uses as set forth in Table 4. Where a parameter concentration in a stream is increased by human activity to above the presumed natural "background" levels of concentration but below the adopted standard for a designated water use, there is a parameter impact upon the stream from a human source; and this condition of waste assimilation is herein identified by that term.

DES PLAINES RIVER WATERSHED

The Des Plaines River watershed ranks tenth in population and sixth in size as compared to the other 11 watersheds of the Region. An estimated 11,200[1] persons reside within this watershed, which has a total area of 132.9 square miles and an average population density of 84 people per square mile. Principal land uses include agricultural, woodland, wetland, and unused land, which together comprise 92.2 percent of the area of the watershed. The area within the watershed devoted to each of eight major land use categories is listed in Table 39.

Two streams were studied by the SEWRPC in the Des Plaines River watershed: the Des Plaines River and Brighton Creek. The Des Plaines River rises in the Region near the Village of Union Grove in south-central Racine County and flows approximately 22 miles to the south and east before crossing the state line into Illinois. Brighton Creek, a first rank tributary of the Des Plaines River, has its headwaters in the marshes northeast of the Village of Brighton in north-central Kenosha County and flows approximately ten miles to its confluence with the Des Plaines River at a point 6.4 miles downstream from the source of the Des Plaines River.

The course of the Des Plaines River and of Brighton Creek is apparently determined by the location of end-moraines deposited as low ridges paralleling Lake Michigan during recessional phases of the Lake Michigan ice lobe during the Wisconsin ice age. These morainal deposits consist largely of glacial till with much clay content giving rise to gently rolling silty clay loams over silty clay. The soils and underlying parental till probably cause more rapid runoff of rainfall and snowmelt than the soil and geologic terranes of areas west of the morainal ridges. Moreover, these soils and till presumably decrease the vertical recharge potential of underlying water-bearing units. The perennial flow of the Des Plaines River and its tributaries is presumably sustained largely by ground water seepage from glacial drift having relatively low storage capacity, which would account for the generally sluggish flow of streams in this watershed.

Des Plaines River

Present Stream Quality: Two sampling stations, DP-2 and DP-3, were established on the Des Plaines River. DP-2 is located 8.6 miles downstream from the source. DP-3 is 11.3 miles downstream from DP-2 and 0.8 miles upstream from the state line. The total length of the stream in southeastern Wisconsin is 20.7 miles.

The Des Plaines River has relatively constant overall chemical quality and is predominantly a calcium bicarbonate stream. Of 16 complete chemical analyses, calcium (ranging from 131 to 64 ppm) was the most abundant cation in 15 analyses; and bicarbonate (ranging from 390 to 185 ppm) exceeds all other anion concentrations in 14 analyses. One sample of the Des Plaines River was a sodium bicarbonate water (DP-3 for January 1964) with a sodium concentration of 110 ppm. Two samples were a calcium sulfate

[1] *Based on SEWRPC estimate for 1963.*

Table 39

EXISTING LAND USE IN THE DES PLAINES RIVER WATERSHED: 1963

Land Use	Area: Square Miles	Area: Acres	Percent of Total Watershed
Agricultural	100.2	64,161	75.4
Woodland, Wetland, and Unused Land	22.4	14,316	16.8
Transportation - Communication	5.4	3,476	4.1
Residential	4.0	2,536	3.0
Park and Recreational	0.4	230	0.3
Governmental - Institutional	0.3	179	0.2
Industrial	0.1	78	0.1
Commercial	0.1	56	0.1
Total	132.9	85,032	100.0

Source: SEWRPC.

water (DP-2 for April 1964 and DP-3 for March 1964). Sulfate occurred in maximum, average, and minimum concentrations of 336,318, and 300 ppm, respectively, at DP-2 and 286, 230, and 125 ppm, respectively, at DP-3. Maximum nitrate concentrations at DP-2 and DP-3 are 3.0 and 3.2 ppm, respectively. On October 20, 1964, the total phosphorus was 0.31 ppm at station DP-3. Selected water analyses of the Des Plaines River at sampling station DP-3 are included in Table 40.

Water quality conditions of the Des Plaines River are indicated in Table 41. The average numerical values are weighted averages.

The variations in the chloride concentration of the Des Plaines River are shown graphically in Figure 3. Although the concentration of this parameter is not detrimental to the present or potential uses of the river, the levels of concentration reflect a chloride impact upon the stream from human sources. This is concluded not only from sparse data indicating the probability of low chloride concentration of generally less than 10 ppm in water from those rock units that sustain the flow of the Des Plaines River but more reliably from the magnitude of the variations of chloride concentration in the stream itself and from the

Table 40

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION DP-3 ON THE DES PLAINES RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	5	4-9-64	2	10-20-64
Iron	0.05	"	0.04	"
Manganese	--	--	0.03	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	81	4-9-64	106	"
Magnesium	46	"	66	"
Sodium (and potassium)	15	"	65	"
Bicarbonate	195	"	365	"
Carbonate	0	"	0	"
Sulfate	176	"	252	"
Chloride	55	"	85	"
Fluoride	--	--	<0.7	"
Nitrite	0.0	4-9-64	0.0	"
Nitrate	--	--	0.6	"
Phosphorus	--	--	0.31	"
Cyanide	--	--	<0.01	11-11-64
Oil	--	--	<1	10-20-64
Detergents	0.0	4-9-64	0.0	"
Dissolved Solids	475	"	755	"
Hardness	390	"	538	"
Noncarbonate Hardness	230	"	240	"
Calcium Hardness	202	"	266	"
Magnesium Hardness	188	"	272	"
Alkalinity P	0	"	0	"
Alkalinity M	160	"	300	"
Specific Conductance	796	"	1,110	"
pH	8.0	"	8.0	"
Color	50	"	25	"
Turbidity	4	"	15	"
Biochemical Oxygen Demand	2.4	"	1.8	"
Dissolved Oxygen	10.3	"	10.8	"
Coliform Count	1,300	"	200	"
Temperature (°F)	43	"	46	"

Source: SEWRPC.

Table 41

WATER QUALITY CONDITIONS OF THE DES PLAINES RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	105	50	20	16
Dissolved Solids (ppm)	825	700	430	16
Dissolved Oxygen (ppm)	13.9	8.6	2.1	25
Coliform Count (MFCC/100 ml) .	32,000	8,100	<100	25
Temperature (^{o}F)	81	51	32	25

Source: SEWRPC.

condition under which high and low concentrations occur. The chloride concentration apparently increases in a downstream direction between stations DP-2 and DP-3. This condition may indicate that the tributaries discharging into the Des Plaines River between sampling stations DP-2 and DP-3 (Center Creek and Kilbourn Road Ditch) may be contributing additional chlorides to the main stream.

The variations in the dissolved solids concentration in the Des Plaines River are shown in Figure 3. Few of the possible water uses listed in Table 4 would be adversely affected by the dissolved solids concentration of the Des Plaines River, and these few probably do not constitute reasonable uses. The flow (quantitative) conditions of this river alone would preclude, for example, its use as a source of municipal water supply. The dissolved solids concentration of the Des Plaines River is higher than the presumed dissolved solids concentration of the Niagara aquifer by about 100 to 450 ppm. This may be due in part to human sources of waste entering the river and in part to natural processes of concentration through evaporation and transpiration and by solution occurring in the river channel. It is probable, also, that the analyses of water from the Niagara aquifer are not representative of the quality of all water seeping from the glacial till into the river channel.

The sulfate concentration of the Des Plaines River is consistently higher than that of the Niagara aquifer (by about 200 to 300 ppm). However, the surficial glacial till, which is composed of much relatively dense clay, may yield water of high sulfate content as compared to the Niagara aquifer that underlies the glacial drift and acts upon the overlying drift with artesian pressure, thus reducing possible movement of presumed high sulfate water from above into the Niagara aquifer. It may be tentatively concluded that the high dissolved solids content of the Des Plaines River is largely affected by the quality of water from swamps and marshes and of seepage water from the glacial till, to a lesser extent by waste discharges from human sources, and to a minor extent by additional solution that occurs in the channel and by concentration through evaporation and transpiration.

The variations in dissolved oxygen concentration of the Des Plaines River are shown in Figure 4. Substandard concentrations of dissolved oxygen for the preservation of fish life (5.0 ppm to 3.1 ppm) occurred during July, August, and September of 1964 at sampling station DP-3. The dissolved oxygen concentration at sampling station DP-2 varied similarly to that at station DP-3 but reached a substandard level of concentration only during September. Critical concentrations (3.0 ppm or less) occurred at sampling station DP-3 during July 1964.

The condition that lowered the dissolved oxygen concentration of the Des Plaines River to 5.0 ppm or less during daylight hours in the summer and early fall of 1964 prevailed over a distance of approximately 13 miles. The nature of this condition is conjectural in that the specific polluting agents are not known. The temperature and BOD of the river do not correlate adequately with dissolved oxygen to explain the decline of this parameter to substandard concentrations. The coliform counts are relatively high during these warm months, which would suggest that sewage wastes may be the source of the pollutant. However, this is not substantiated by the BOD determinations.

Figure 3

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN STREAMS OF THE DES PLAINES RIVER WATERSHED

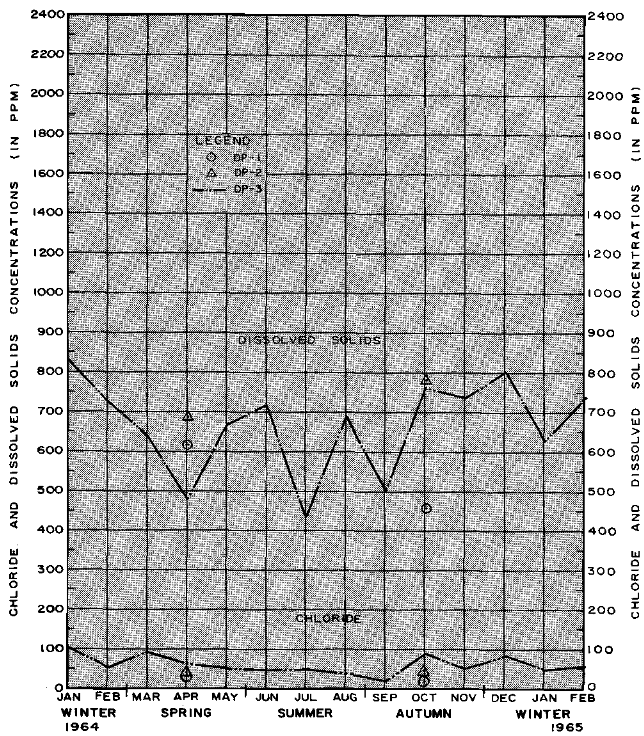
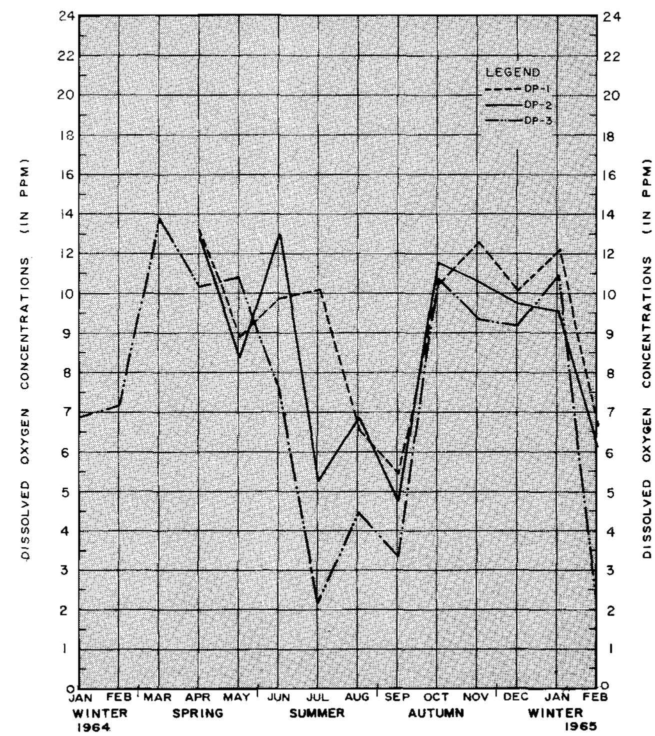


Figure 4

DISSOLVED OXYGEN CONCENTRATIONS IN STREAMS OF THE DES PLAINES RIVER WATERSHED



Nocturnal dissolved oxygen concentrations are presumably less than those measured during daylight hours (which were measured no earlier than 9:15 a. m. and no later than 12:53 p. m.) in July, August, and September 1964. During these monthly samplings, the dissolved oxygen concentration at sampling station DP-3 was 2.2, 4.5, and 3.4 ppm, respectively. It would appear that the dense growths of algae and of duckweed observed on this river during very low flow in August and September were not adequate to build up the daytime dissolved oxygen concentration in the river to above standard quality from the presumed low nocturnal levels of concentration induced by the respiration of these plants.

The variations in coliform count in the Des Plaines River are shown graphically in Figure 5. The maximum coliform count of 32,000 MFCC/100 ml occurred at sampling station DP-3 in September 1964 and again in January 1965. Summer and early autumn were periods of relatively high counts, which made much of the river unsuitable for whole-body or partial-body contact recreational use. In May and June, the stream was generally suitable for body contact sports. As already noted, the use of the Des Plaines River as a source of municipal water supply or for industrial use is considered unreasonable because of the flow regimen of this river.

The temperature variations of the Des Plaines River are shown graphically in Figure 6. The maximum temperature of 81°F occurred in July 1964 at sampling station DP-2. The average temperature for the period of June through September 1964 at stations DP-2 and DP-3 were both 70°F. The temperature of the river is climatically influenced, and there are no known regional effects of temperature pollution.

Streamflow and Precipitation: The Des Plaines River has two prominent flow characteristics, the first being the rapid response of its stream stages to rainfall and meltwater runoff and the second being the rapid reversion of its flow to "normal" sluggishness during periods of dry weather. This indicates that the geologic terrane of the watershed contributes relatively little ground water to support the flow of the river during periods of no surface runoff.

During the present study, the flow of the Des Plaines River was measured by the SEWRPC at sampling station DP-3 in April and October of 1964 during periods of high and low flow. At sampling station DP-3,

Figure 5

COLIFORM COUNTS IN STREAMS OF THE DES PLAINES RIVER WATERSHED

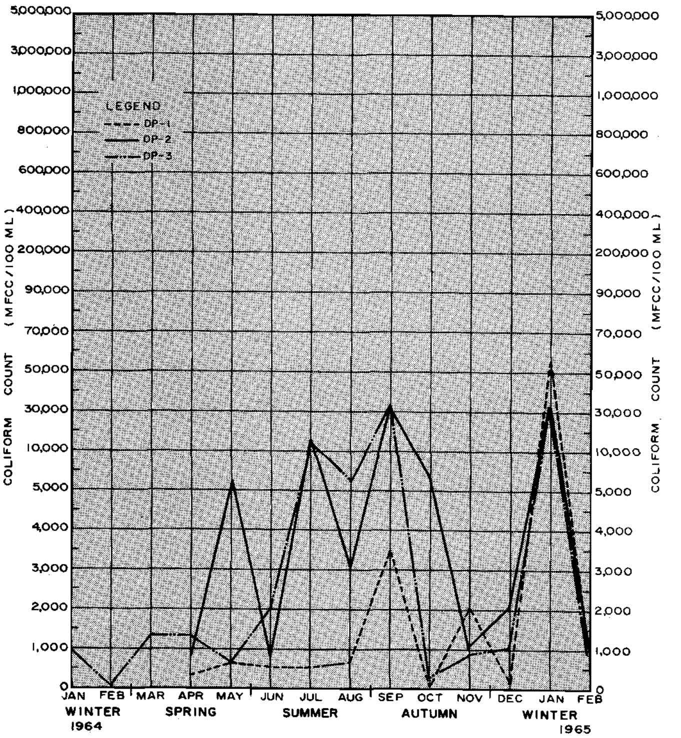
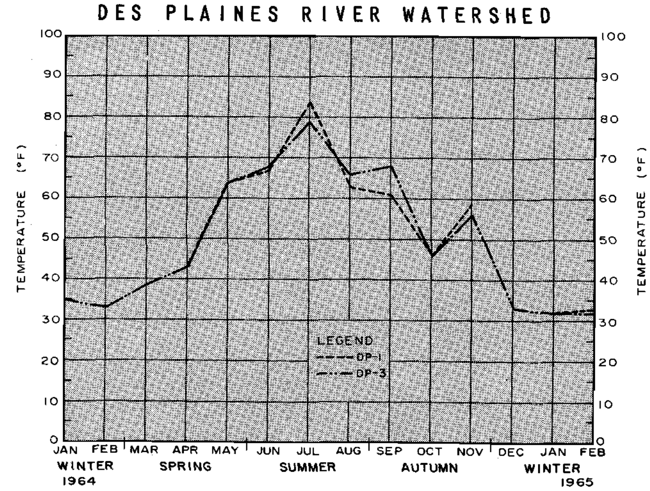


Figure 6

TEMPERATURES OF STREAMS IN THE DES PLAINES RIVER WATERSHED



a distance 19.9 miles from the source, the Des Plaines River had a maximum depth of 2.1 feet and was approximately 118 feet wide when measured under low-flow conditions in October 1964. Flow measurements taken at bridge crossings of CTH MB and CTH ML (sampling station DP-3) by the Surface Water Branch of the U. S. Geological Survey and by the SEWRPC in late 1963 and in 1964 are listed in Table 42. Daily precipitation at Union Grove, Wisconsin, from January 1964 through February 1965 is indicated in Table 43.

Forecast Quality of the Des Plaines River for the Year 1990: Population studies by the SEWRPC indicate that the population of the Des Plaines River watershed was 11,200 in the year 1963. Alternative regional land use plans prepared by the SEWRPC [2] indicate that the population of the watershed by 1990 may be expected to be 20,000 under the Controlled Existing Trend Plan, 27,000 under the Corridor Plan, and 23,000 under the Satellite City Plan. In 1963 the only sewage treatment plant in the watershed served an estimated 60 people at the Village of Paddock Lake. By the year 1990, two additional sewage treatment plants may be in existence within the watershed, one located in the Village of Bristol and the other in the Town of Pleasant Prairie, and both may be discharging treated wastes into minor first-rank tributaries of the Des Plaines River. The probable future connected populations of these three sewage treatment plants according to the SEWRPC alternative regional land use plans are listed in Table 44.

The effects which the present population has upon the quality of the Des Plaines River is almost exclusively due to discharge from private septic tank systems. Only an estimated 60 people (0.5 percent) of a total estimated watershed population of 11,200 were connected to sewage treatment plant facilities in 1963. It is estimated that by the year 1990 approximately 20.5, 60.8, or 47.7 percent of the watershed population will be connected to sewage treatment plants according to the Controlled Existing Trend, Corridor, and Satellite City land use plans, respectively.

According to procedures discussed in the beginning of this chapter, estimated future stream quality conditions, as expressed in terms of the concentrations of four water quality parameters, are listed in Table 45.

[2] *See SEWRPC Planning Report No. 7, Volume 2, Forecasts and Alternative Plans--1990, for a complete description of alternative regional land use plans.*

Table 42

STREAMFLOW MEASUREMENTS OF THE DES PLAINES RIVER: 1963 AND 1964

Date of Measurement	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]	Location of Measurement	Source of Measurement
10-11-63	0.26	0	CTH MB	USGS
11-13-63	0	0.18	DP-3	USGS
4-10-64	122	1.83	DP-3	SEWRPC
7- 1-64	2.16	0	CTH MB	USGS
8-13-64	0.34	0.43	CTH MB	USGS
10-13-64	0.64	0.17	DP-3	USGS
10-20-64	0	0	DP-3	SEWRPC

[a] *Measured at U. S. Weather Bureau station at Union Grove, Wisconsin.*

Source: U. S. Weather Bureau, USGS, and SEWRPC.

Table 43

PRECIPITATION[a] AT UNION GROVE, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.14	--	--	--	--	--	--	--	0.17	0.25
2	--	--	--	0.08	0.13	--	0.02	--	--	--	0.38	0.13	0.41	--
3	--	--	--	0.40	--	0.18	--	--	--	--	0.15	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	0.12	--	--
5	--	--	0.77	0.55	--	--	--	--	--	--	--	--	--	--
6	--	--	--	0.38	0.11	--	0.18	--	--	--	--	--	--	--
7	--	--	--	0.50	--	--	0.20	--	--	--	--	--	0.02	0.03
8	--	--	0.05	--	0.29	--	--	--	--	0.17	--	--	0.10	--
9	0.04	--	0.26	--	--	--	--	--	0.03	--	--	--	--	0.15
10	--	--	--	--	--	--	--	0.29	0.19	--	--	--	--	0.06
11	--	--	--	--	--	--	0.39	0.14	--	--	--	0.18	--	--
12	--	0.12	--	--	--	0.23	--	--	--	--	0.19	--	--	0.18
13	--	0.12	--	--	0.57	--	0.18	--	--	--	--	0.11	--	--
14	--	--	0.32	--	--	--	0.24	--	--	--	--	--	--	--
15	--	--	--	--	--	1.01	--	--	--	--	0.96	--	0.10	--
16	--	0.05	--	--	0.76	0.03	--	--	--	--	--	--	--	--
17	--	--	0.02	--	--	--	--	0.11	--	--	--	--	--	--
18	--	--	--	--	0.02	--	4.00	--	0.66	--	--	--	--	--
19	0.01	--	--	--	--	--	--	--	0.03	--	--	--	--	--
20	0.45	--	0.40[b]	0.25	--	0.22	--	--	--	--	0.01	0.07	--	--
21	--	--	0.01	0.49	--	0.02	0.01	1.10	0.21	--	--	--	--	--
22	--	--	--	--	--	0.07	0.42	0.68	1.06	--	--	--	0.50	--
23	--	--	--	--	--	1.27	--	0.02	0.45	--	--	--	0.69	0.04
24	0.04	--	0.38	--	0.23	--	--	--	--	--	--	0.02	0.58	0.13
25	0.43	--	0.11	--	--	--	0.11	0.02	--	--	--	--	--	--
26	--	--	0.18	--	0.03	--	--	--	0.39	--	--	--	0.33	--
27	--	--	0.05	0.23	--	--	--	--	0.08	0.03	0.02	--	--	--
28	--	--	--	0.05	--	--	0.28	--	--	--	1.19	--	--	--
29	--	--	0.05	0.28	--	--	0.02	--	--	--	--	0.05	--	--
30	--	--	--	0.15	--	--	--	0.22	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	0.97	0.29	2.60[b]	3.36	2.28	3.03	6.05	2.58	3.10	0.20	2.90	0.68	2.90	0.84

[a] *Precipitation measured in inches. Trace quantities not included.*

[b] *Water equivalent of snowfall wholly or partly estimated, using a ratio of 1 inch water equivalent to every 10 inches of new snowfall.*

Source: U. S. Weather Bureau.

Table 44

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR SEWAGE TREATMENT PLANTS IN THE DES PLAINES RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Paddock Lake	60	2,500	5,100	2,300
Village of Bristol.	0	1,600	1,300	1,600
Town of Pleasant Prairie. . . .	0	0[a]	10,000	7,100
Total Connected Population	60	4,100	16,400	11,000
	Estimated Average Daily Sewage Flow Rate			
Village of Paddock Lake	6,000[b] 0.01[c]	455,400 0.70	925,200 1.43	415,800 0.64
Village of Bristol.	0	282,600[b] 0.44[c]	228,600 0.35	282,600 0.44
Town of Pleasant Prairie	0	0 0	1,800,000[b] 2.78[c]	1,274,400 1.97
SEWRPC Station DP-3[d]	Estimated Sewage Effluent Contribution at Station DP-3			
	0	1.14[c]	4.56	3.05
	Estimated Low Streamflow at Station DP-3			
	0	0.88[c]	3.72	2.44

[a] *Population connected to sewage system of the City of Kenosha.*

[b] *Gallons per day.*

[c] *Cubic feet per second.*

[d] *Water sampling station only; no sewage treatment plant in this location.*

Source: SEWRPC.

Brighton Creek

Present Stream Quality: One sampling station, DP-1, was established on Brighton Creek and is located 8.3 miles downstream from the source. Brighton Creek enters the Des Plaines River 2.2 miles upstream from sampling station DP-2. Salem Branch is a tributary of Brighton Creek, joining it 1.2 miles upstream from sampling station DP-1. The sewage treatment plant for Paddock Lake discharges its effluent into Brighton Creek approximately 2.5 miles upstream from sampling station DP-1.

Two complete chemical analyses were run on water sampled from Brighton Creek in April and October of 1964. The stream is of variable quality and shifted from calcium sulfate water in April to sodium bicarbonate water in October. The sulfate concentration in April was 300 ppm and in October 58 ppm. Brighton Creek has its source in marshes which presumably have waters that are high in sulfates. During spring snowmelt and periods of rainfall, the standing marsh water tends to be flushed out, thus increasing the sulfate concentration of the downstream reaches. This phenomenon occurs on all streams in southeastern Wisconsin that originate in marshes. Selected water analyses of Brighton Creek at sampling station DP-1 are indicated in Table 46. Water quality conditions of Brighton Creek are indicated in Table 47.

The variations in chloride concentration of Brighton Creek are shown in Figure 3. Of the two determinations of chloride, the high concentration of 30 ppm occurred in April 1964 during conditions of high flow

Table 45

FORECAST QUALITY OF THE DES PLAINES RIVER AT SAMPLING STATION DP-3: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Des Plaines River	DP-3	Chloride (in ppm)	45[a]	170	170	170
		Dissolved Solids (in ppm)	650[a]	750	750	750
		Dissolved Oxygen (in ppm)	4.4[b]	Less than 2.0 ppm can be expected to occur frequently		
		Coliform Count (in MFCC/ 100 ml)	8,500[b]	More than 25,000		

[a] *Based on analysis for October 1964.*

[b] *Based upon average for period June through September 1964.*

Source: SEWRPC.

from surface runoff. A probable source of this chloride is from improperly operating septic tanks in areas where surface runoff moves these wastes into the drainage system. The lower concentration of 15 ppm, determined during low-flow conditions, may be approaching the "background" concentration of this parameter, which is assumed to be 10 ppm. If this is correct, conditions in Brighton Creek reflect a chloride impact from human sources. The prime source of these chlorides is thought to be the Paddock Lake sewage treatment plant and unsewered areas of urban development at Brighton, Salem, Salem Oaks, and Paddock Lake. None of the water uses listed in Table 4 are adversely affected by present concentrations of chloride in Brighton Creek.

The variations in the dissolved solids concentration in Brighton Creek are also shown in Figure 3. None of the water uses listed in Table 4 would be adversely affected by the dissolved solids concentration of Brighton Creek. The principal sources of the dissolved solids concentration is the geologic terrane and soil environment (including wetland areas) and to a much lesser extent the waste discharges from human sources.

The variations of dissolved oxygen concentration in Brighton Creek are shown in Figure 4. During the 14 months of study, the dissolved oxygen concentration was not found to be below 5.5 ppm. Waste assimilation does not suppress the dissolved oxygen concentrations to substandard levels during daylight hours.

The variations in the coliform count in Brighton Creek are shown graphically in Figure 5. The counts were generally very low and exceeded 2,400 MFCC/100 ml only in September 1964 and January 1965. Human sources would appear not to be involved in contributing to the coliform counts in this stream except during

Table 46

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION DP-1 ON BRIGHTON CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-9-64	16	10-20-64
Iron	0.01	"	0.14	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	85	4-9-64	56	10-20-64
Magnesium	41	"	40	"
Sodium (and Potassium)	60	"	60	"
Bicarbonate	195	"	380	"
Carbonate	0	"	30	"
Sulfate	300	"	58	"
Chloride	30	"	15	"
Fluoride	--	--	--	--
Nitrite	0.0	4-9-64	0.0	10-20-64
Nitrate	--	--	0.3	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.0	4-9-64	0.0	10-20-64
Dissolved Solids	615	"	460	"
Hardness	382	"	305	"
Noncarbonate Hardness	220	"	0	"
Calcium Hardness	212	"	141	"
Magnesium Hardness	170	"	164	"
Alkalinity P	0	"	15	"
Alkalinity M	160	"	340	"
Specific Conductance	724	"	586	"
pH	8.3	"	7.8	"
Color	70	"	15	"
Turbidity	2	"	7	"
Biochemical Oxygen Demand	2.0	"	$<$ 0.5	"
Dissolved Oxygen	13.3	"	10.6	"
Coliform Count	300	"	$<$100	"
Temperature (°F)	43	"	46	"

Source: SEWRPC.

Table 47

WATER QUALITY CONDITIONS OF BRIGHTON CREEK (1964-1965)

Parameter	Numerical Value Maximum	Numerical Value Average	Numerical Value Minimum	Number of Analyses
Chloride (ppm)	30	25	15	2
Dissolved Solids (ppm)	615	540	460	2
Dissolved Oxygen (ppm)	13.3	9.7	5.5	11
Coliform Count (MFCC/100 ml)	56,000	5,900	100	11
Temperature (°F)	84	55	32	10

Source: SEWRPC.

January 1965. However, the higher "background" chloride content of Brighton Creek in April 1964 at a time when the coliform count was 300 MFCC/100 ml would suggest that chloride wastes from human sources were in the stream, although the low coliform counts may be entirely from the soil environment of the creek.

The temperature variations of Brighton Creek are shown graphically in Figure 6. Although this stream was 1°F and 5.3°F warmer than the Des Plaines River in July and November 1964 and in February 1965, respectively, this higher temperature was not interpreted to indicate temperature impact from human sources, but rather to result from ground water temperature and seepage conditions in relation to climate and flow conditions of the stream.

The waste assimilation capacity of Brighton Creek at sampling station DP-1 is presently not being persistently exceeded. Chloride concentrations are well below limiting concentrations for the preservation of fish life. Dissolved oxygen concentrations are sufficiently high to maintain fish life. However, the generally shallow depth of Brighton Creek imposes limitations on the size of fish that can inhabit the stream.

Streamflow and Precipitation: Brighton Creek is a shallow meandering stream occupying a very narrow channel. At sampling station DP-1, a distance 8.3 miles from the source, this stream had a maximum depth of 0.35 feet and was 3.6 feet wide when measured under low-flow conditions in October 1964. The small size and low flow of this stream preclude its use for all but three of the ten major uses listed in Table 4. These three uses are waste assimilation, preservation and enhancement of aquatic life, and aesthetic use.

Table 43 indicates the daily precipitation at Union Grove, Wisconsin, from January 1964 through February 1965 and the days of monthly sampling in the Des Plaines River watershed. These data are chosen to represent precipitation in the watershed.

The flow of Brighton Creek was measured by the SEWRPC at station DP-1 in April and October 1964 as listed in Table 48.

Forecast Quality of Brighton Creek for the Year 1990: The anticipated increase by 1990 in the connected population of the sewage treatment plant at Paddock Lake will have adverse effects on the water quality of Brighton Creek, as indicated in Table 49. The critical aspects in the change in stream quality will be the probable decrease of dissolved oxygen to substandard levels (5.0 to 3.1 ppm) and the increase in coliform counts to above the 5,000 MFCC/100 ml limiting concentration for partial-body contact recreation.

FOX RIVER WATERSHED

The Fox River watershed ranks fifth in population and first in size as compared to the other 11 major watersheds of the Region. An estimated 160,000[3] persons reside within this watershed, which has a total area of 941.6 square miles and an average population density of 170 people per square mile. Principal land uses include agricultural, woodland, wetland, and unused land, which together comprise 88.7 percent of the area of the watershed. The area devoted to each of eight major land use categories is listed in Table 50.

[3] *Based on SEWRPC estimate for 1963.*

Table 48

STREAMFLOW MEASUREMENTS OF BRIGHTON CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
DP-1	4-10 10-20	22 0.3	1.83 0

[a] *Measured at U. S. Weather Bureau Station at Union Grove, Wisconsin.*

Source: U. S. Weather Bureau, USGS, and SEWRPC.

Table 49

FORECAST QUALITY OF BRIGHTON CREEK AT SAMPLING STATION DP-1: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Brighton Creek	DP-1	Chloride (in ppm)	15[a]	60	85	45
		Dissolved Solids (in ppm)	550[a]	650	700	600
		Dissolved Oxygen (in ppm)	8.0[b]	Less than 5.0 ppm can be expected to occur frequently.		
		Coliform Count (in MFCC/ 100 ml)	1,300[b]	8,000	12,000	6,000

[a] *Based on water analysis for October 1964.*

[b] *Based on average for period June through September 1964.*

Source: SEWRPC.

Table 50

EXISTING LAND USE IN THE FOX RIVER WATERSHED: 1963

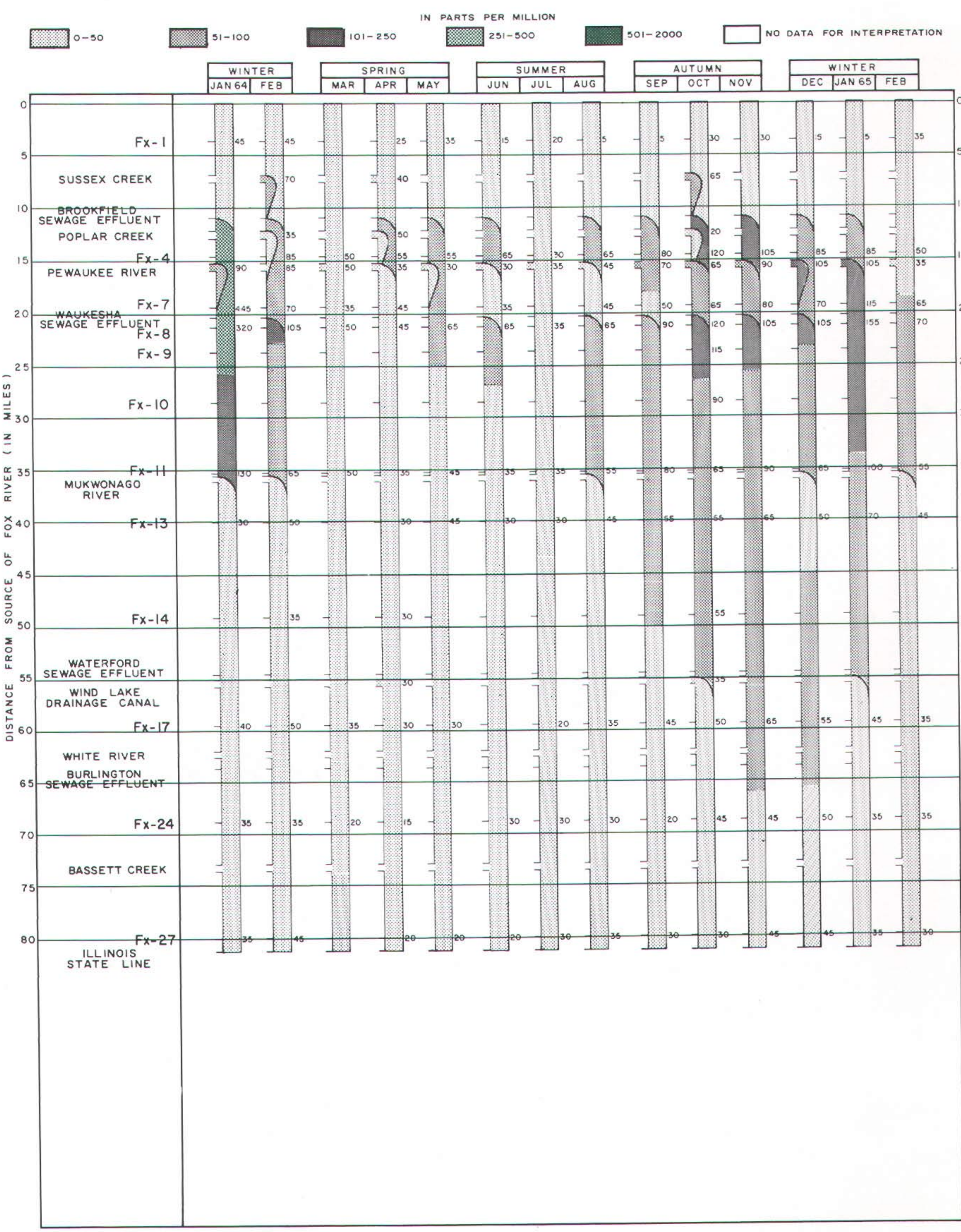
Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	609.5	390,068	64.7
Woodland, Wetland, and Unused Land . . .	226.2	144,748	24.0
Residential	48.0	30,760	5.1
Transportation-Communication	36.5	23,349	3.9
Park and Recreational.	10.1	6,466	1.1
Industrial	6.4	4,099	0.7
Governmental-Institutional	3.3	2,090	0.3
Commercial	1.7	1,086	0.2
Total	941.7	602,666	100.0

Source: SEWRPC.

Thirteen streams and watercourses were studied by the SEWRPC in the Fox River watershed: the Fox River itself and the following first, second, and third rank tributaries: Sussex Creek, Poplar Creek, Pewaukee River, Mukwonago River, Muskego Canal, Wind Lake Drainage Canal, White River, Como Creek, Honey Creek, Sugar Creek, Bassett Creek, and Nippersink Creek. The Fox River rises in the Region near the Village of Lannon in northeastern Waukesha County and meanders approximately 81 miles southward before entering Illinois. An unnamed tributary that flows from Tamarac Swamp joins the Fox River immediately north of Mill Road. This tributary is thought to impart much of the background quality to the

Figure 7

CHLORIDE CONCENTRATION IN THE FOX RIVER



upper reaches of the Fox River. Data pertaining to the Fox River and selected tributaries are listed in Table 51.

The Fox River watershed occupies a broad basin of irregular topography. The eastern boundary of the watershed falls near the western edge of the end-moraine system that roughly parallels Lake Michigan. The northern boundary falls within an area where the end-moraine system joins with the interlobate moraine that was formed along the contact between the Green Bay and Lake Michigan ice lobes. From this area of junction, the western boundary trends southwestward along the interlobate moraine from south-central Washington County to northwestern Walworth County from where the western boundary changes to a southeasterly direction along the inner and then the outer edge of the Darien moraine and Marengo Ridge. The southern limit of the watershed in Wisconsin is the Illinois State Line.

Fox River

Present Stream Quality: Twelve sampling stations, Fx-1, Fx-4, Fx-7 through Fx-11, Fx-13, Fx-14, Fx-17, Fx-24, and Fx-27, were established on the Fox River proper at points upstream and downstream from the Brookfield, Waukesha, Waterford, and Burlington sewage treatment plant outfalls and from the confluence of the Fox River with Sussex Creek, Poplar Creek, Pewaukee River, Mukwonago River, Wind Lake Drainage Canal, White River, and Bassett Creek. The 12 sampling stations, the four sewage treatment plant outfalls, and the confluences of the seven tributaries are significant points of reference on the Fox River and are listed in Table 52 in terms of their distances downstream from the river source and the distances between consecutive points of reference.

The Fox River is subject to large changes in overall chemical quality and is predominantly a calcium bicarbonate stream. Of 122 complete chemical analyses, calcium (ranging from 128 to 25 ppm) was the most abundant cation in 114 analyses; and bicarbonate (ranging from 510 to 170 ppm) exceeded all other anion concentrations in 121 analyses. Sodium occurred as the most abundant cation in eight analyses (at all stations on the Fox River from Fx-7 through Fx-13) at concentrations ranging from 340 to 45 ppm. Sulfate concentrations were relatively high in the upper reaches of the Fox River from Fx-1 through Fx-13. In this reach sulfate concentrations at these eight sampling stations ranged from a maximum of 300 ppm through an average of 138 ppm to a minimum of 67 ppm. Downstream from station Fx-13, at sampling stations Fx-14, Fx-17, Fx-24, and Fx-27, the maximum, average, and minimum sulfate concentrations were 103, 97, and 50 ppm, respectively. Maximum nitrate concentrations of 18.2, 13.2, and 10.6 ppm occurred at Fx-5, Fx-4, and Fx-8, respectively. On October 7, 1964, total phosphorus was 0.16 ppm at station Fx-1, 2.0 ppm at Fx-4, 0.26 ppm at Fx-7, 2.3 ppm at Fx-8, 1.12 ppm at Fx-13, 0.46 ppm at Fx-17, 0.46 ppm at Fx-24, and 0.42 ppm at Fx-27. Selected water analyses of the Fox River at sampling stations Fx-1, Fx-8, and Fx-27 are indicated in Tables 53, 54, and 55, respectively. Water quality conditions of the Fox River are indicated in Table 56. The average numerical values are weighted averages.

The variations in the chloride concentration in the Fox River are shown by a series of 14 interpretive water quality graphs in Figure 7. In January 1964 a "slug" of water high in chloride concentration (445 ppm maximum) significantly affected the stream quality from sampling station Fx-7 to station Fx-11 (a distance of 15.9 miles). The assumed source of this slug was the Brookfield sewage treatment plant (thus extending the reach affected to a total of 24.2 miles). The chloride concentration of this slug would be detrimental if the stream in this 24.2-mile reach were used for municipal or industrial water supply. However, no such use is presently being made of the stream; nor would it appear likely that these two use categories would be potential uses under foreseeable conditions. Fish life presumably would not have been adversely affected by this slug.

The general levels of chloride concentration in the Fox River are indicative of chloride impact upon the stream from human sources that are located largely in the upper reaches of the river from the confluence with Sussex Creek to the sewage treatment plant at Waukesha. During the spring, summer, and autumn of 1964, except during the months of March and July 1964 (when large runoff caused dilution of the chloride concentration of the Fox River throughout its entire length in southeastern Wisconsin), the buildup of chloride concentration levels in the upper reaches extended continuously farther downstream. For example, by November 1964 the reach of the Fox River having a chloride concentration larger than 50 ppm extended

Figure 8

DISSOLVED SOLIDS CONCENTRATION IN THE FOX RIVER

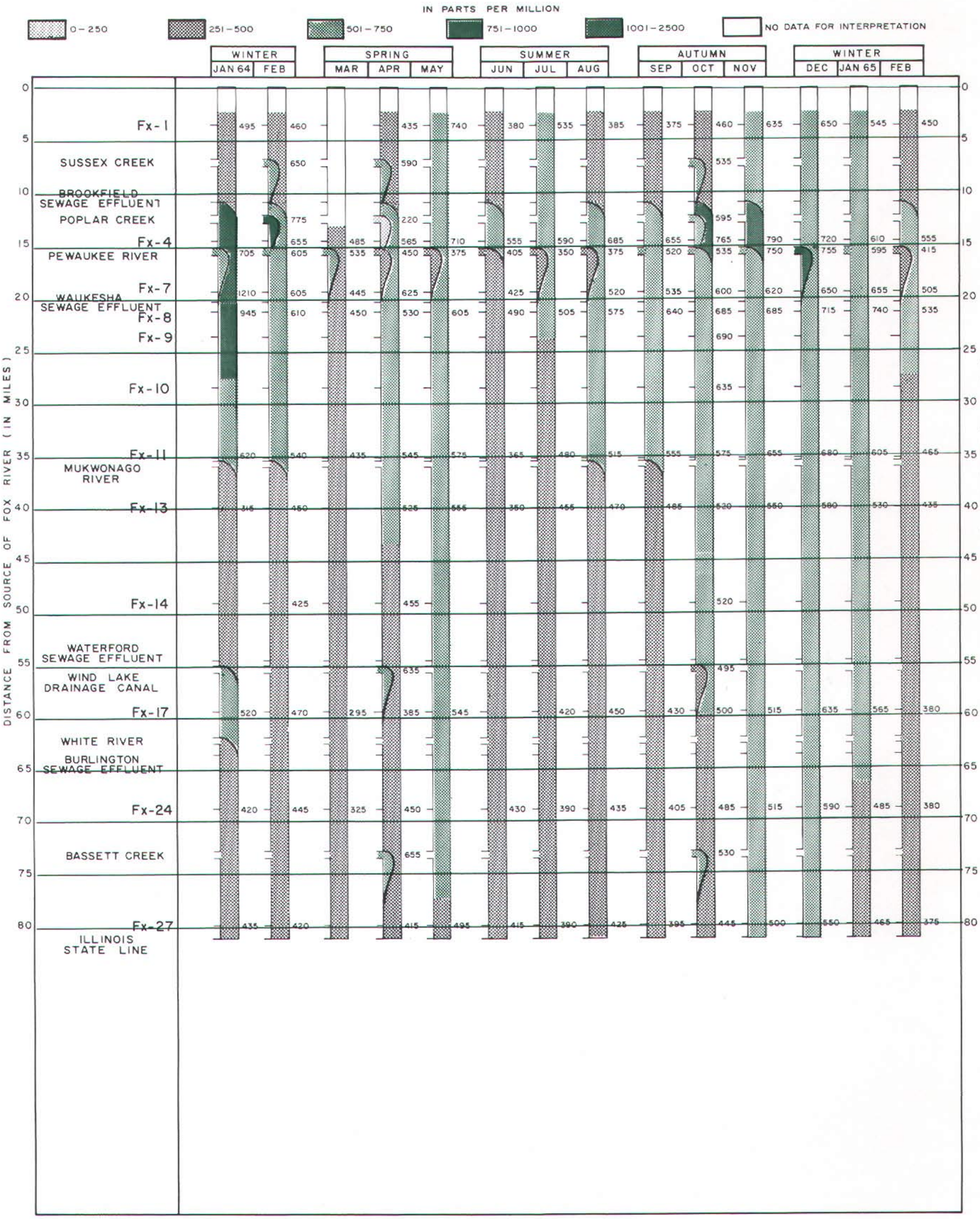
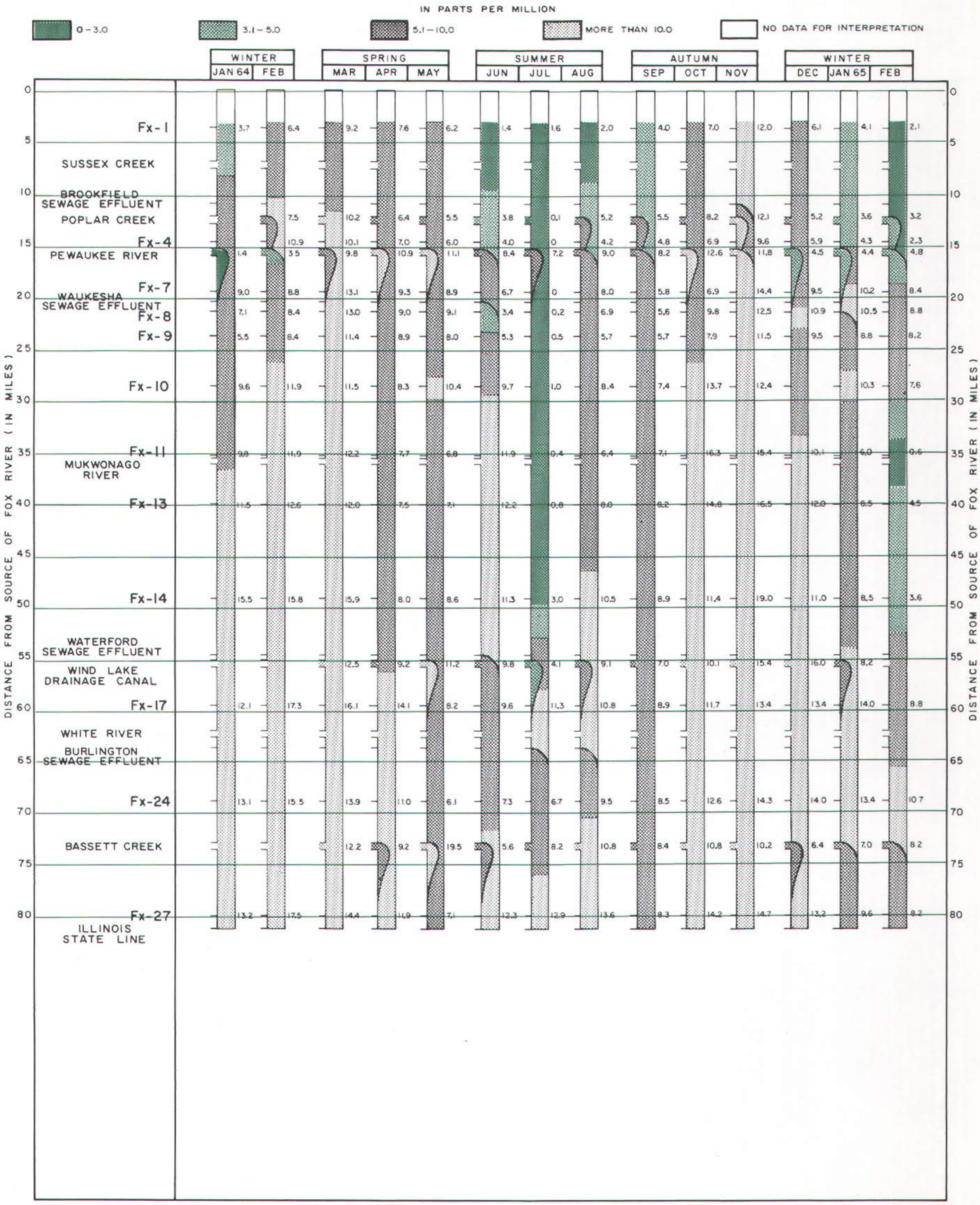


Figure 9

DISSOLVED OXYGEN CONCENTRATION IN THE FOX RIVER



from the assumed initial source (the Brookfield sewage treatment plant) to an inferred point about three miles upstream from station Fx-24, a distance of about 54.8 miles.

Three inferred sources of liquid wastes of regional significance on the Fox River are the sewage treatment plants at Waukesha, Brookfield, and Pewaukee. It would appear that the flow of the Fox River during the period of study was sufficient to dilute the effluents from Waterford and Burlington to levels below 50 ppm.

The variations in dissolved solids concentration in the Fox River are shown by a series of 14 interpretive water quality graphs in Figure 8. In January 1964 the slug of water that was high in chloride concentration (445 ppm) was also exceptionally high in sodium concentration (340 ppm). The sodium and chloride ions together increase the dissolved solids concentration of the Fox River to 1,210 ppm, 700 ppm above the average of 510 ppm dissolved solids. The Brookfield sewage treatment plant discharges its effluent into the Fox River at a point 10.9 miles downstream from the source of the river. The flow of the Fox River is relatively low near the treatment plant, and waste discharges at this point have a more severe impact upon the river than would be the case where the flow is much greater. During 9 of the 13 months for which stream quality data are available for interpretation along this upper reach of the Fox River, the effluent from the Brookfield sewage treatment plant built up the dissolved solids content of the stream. The Mukwonago River enters the Fox River 35.7 miles downstream from the source of the Fox River and dilutes the dissolved solids concentration of the Fox River. However, the relatively high concentrations of the upper reaches of the Fox River tend to spread southward during summer, autumn, and winter.

The variations in dissolved oxygen concentration in the Fox River are shown by a series of 14 interpretive stream quality graphs in Figure 9. Substandard concentrations for the preservation of fish life (5.0 ppm or less) occurred 7 out of 14 times near the headwaters of the river at sampling station Fx-1. Critical concentrations of dissolved oxygen (3.0 ppm or less) occurred four times at sampling station Fx-1, reaching a minimum of 1.4 ppm.

In July 1964 the dissolved oxygen concentration of the Fox River was critical for the preservation of fish life from sampling station Fx-1 over a distance of 45.6 miles to Fx-14. Within this distance the maximum concentrations were 1.6 and 3.0 ppm at Fx-1 and Fx-14, respectively. At the seven intervening sampling stations, the maximum, average, and minimum concentrations of dissolved oxygen were 1.0, 0.4, and 0 ppm, respectively. It would appear that the lowering of the dissolved oxygen concentration in most of the upper 50 miles of the Fox River resulted from the effects of heavy rainfall on the 17th and 18th of July 1964, which totalled 7.05 inches at Germantown (24 percent of the total annual precipitation at this location for 1964). The heavy precipitation flushed vast quantities of vegetal material out of marshy areas into the Fox River, where this material, together with foul odors and dense stream coloration, was carried continuously

Table 51

LENGTH OF STREAMS AND WATERCOURSES IN THE FOX RIVER WATERSHED

Stream or Watercourse	Source	Length (in Miles)
Fox River	Area northeast of Lannon	81.2
Sussex Creek.	Area north of Sussex	5.5
Poplar Creek.	Northwest New Berlin	7.5
Pewaukee River.	Lake Pewaukee	6.0
Mukwonago River	Eagle Spring Lake	11.2
Muskego Canal	Muskego Lake	1.5
Wind Lake Drainage Canal.	Wind Lake	7.3
White River	Lake Geneva	13.3
Como Creek.	Lake Como	3.8
Honey Creek	Mill Lake	18.5
Sugar Creek	Area northwest of Elkhorn	19.5
Bassett Creek	Area south of Bassett	4.5
Nippersink Creek.	Area north of Genoa City	5.2

Source: SEWRPC.

Table 52

DISTANCES OF SELECTED POINTS OF REFERENCE ON THE FOX RIVER FROM THE RIVER SOURCE AND BETWEEN CONSECUTIVE POINTS OF REFERENCE

Point of Reference	Distance from River Source (in Miles)	Distance between Points of Reference (in Miles)
River Source	0	--
Fx-1	3.6	3.6
Sussex Creek	7.5	3.9
Brookfield STPO[a]	10.9	3.4
Poplar Creek	12.8	1.9
Fx-4	14.5	1.7
Pewaukee River	15.9	1.4
Fx-7	19.2	3.3
Waukesha STPO	20.2	1.0
Fx-8	21.2	1.0
Fx-9	23.8	2.6
Fx-10	28.6	4.8
Fx-11	35.1	6.5
Mukwonago River	35.7	0.6
Fx-13	40.0	4.3
Fx-14	49.2	9.2
Waterford STPO	54.8	5.6
Wind Lake Drainage Canal	55.8	1.0
Fx-17	59.6	3.8
White River	62.5	2.9
Burlington STPO	63.5	1.0
Fx-24	68.7	5.2
Bassett Creek	73.5	4.8
Fx-27	80.0	6.5
State Line	81.2	1.2

[a] *STPO - Sewage treatment plant outfall.*

Source: SEWRPC.

downstream. This vegetal loading from Tamarac Swamp and from other swampy or marshy areas, together with the possible effects of waste loading from overland runoff and from temporary storm effects upon sewage treatment plant operations, probably caused the critical decline in the dissolved oxygen concentration of the stream.

The SEWRPC sampled the Fox River on July 29, twelve days after the beginning of the large rainfall which occurred over the entire watershed but was heaviest north of Waukesha. The observable vegetal loading and odor were still heavy. The color of the Fox River was rust brown and still quite dense as indicated in Table 57.

The relatively low-color density of sampling station Fx-1 in July as compared to downstream densities at stations Fx-4 through Fx-13 may be due in part to the dense color of Poplar Creek (300 ppm), which enters the Fox River 1.7 miles upstream from sampling station Fx-4, and in part to a decline in the color density of water entering the Fox River from Tamarac Swamp as compared to what had previously entered the river from that source. The increase in color density between sampling stations Fx-8 and Fx-11 in June and between Fx-10 and Fx-11 in July was probably due to water draining into the Fox River from Vernon Marsh.

The variations in the coliform count in the Fox River are shown in Figure 10. As can be seen in the 14 water quality graphs, the bacteriological quality at sampling station Fx-1 ranges from 18,000 to less than 100 MFCC/100 ml. Excluding the data for July 1964, the stream quality 3.6 miles downstream from the source of the Fox River at Fx-1 is of acceptable quality for whole-body contact recreation. The treated

Table 53

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-1 ON THE FOX RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-22-64	2	10-7-64
Iron	0.00	"	0.06	"
Manganese	--	--	0.02	"
Chromium	--	--	<0.02	"
Hexavalent Chromium	--	--	0.00	"
Calcium	81	4-22-64	74	"
Magnesium	43	"	45	"
Sodium (and Potassium)	10	"	35	"
Bicarbonate	270	"	380	"
Carbonate	0	"	0	"
Sulfate	142	"	88	"
Chloride	25	"	30	"
Fluoride	--	--	<0.4	"
Nitrite	0.0	4-22-64	0.0	"
Nitrate	--	"	1.2	"
Phosphorus	--	"	0.16	"
Cyanide	--	"	--	--
Oil	--	"	<0.5	10-7-64
Detergents	0.0	"	0.2	"
Dissolved Solids	435	"	460	"
Hardness	380	"	370	"
Noncarbonate Hardness	160	"	60	"
Calcium Hardness	202	"	185	"
Magnesium Hardness	178	"	185	"
Alkalinity P	0	"	0	"
Alkalinity M	220	"	310	"
Specific Conductance	676	"	700	"
pH	8.0	"	7.8	"
Color	60	"	10	"
Turbidity	1	"	3	"
Biochemical Oxygen Demand	4.1	"	1.8	"
Dissolved Oxygen	7.6	"	7.0	"
Coliform Count	100	"	800	"
Temperature (^{o}F)	50	"	42	"

Source: SEWRPC.

waste discharges, assumed to be from the Brookfield sewage treatment plant, increase the coliform count of the Fox River north of sampling station Fx-4 to concentrations generally unsuited even for partial-body contact. The effluent from the Waukesha sewage treatment plant persistently contributes further to maintaining high coliform counts in the Fox River. This polluted condition of the stream (with respect to coliform count and recreational use of the river) extends to sampling station Fx-11, where the coliform count is sufficiently low for partial-body contact recreation. From sampling station Fx-11 to the Waterford sewage treatment plant (a distance of 26.2 miles), the coliform counts are generally sufficiently low for whole-body contact recreation from June through August and possibly through September. From the Waterford sewage treatment plant downstream to points of about one to three miles north of sampling station Fx-27, the quality of the Fox River with respect to coliform count is unsuitable for recreational use.

The coliform counts in the Fox River are detrimental to whole- or partial-body contact recreation over an aggregate distance of approximately 31 miles of the 81.2-mile length of the river in Wisconsin. Favorable reaches occur during summer and early autumn in the headwater area to immediately above the Brookfield sewage treatment plant, from Fx-11 to immediately above the Waterford sewage treatment plant, and one to three miles north of sampling station Fx-27 to the state line.

Figure 10
COLIFORM COUNT IN THE FOX RIVER

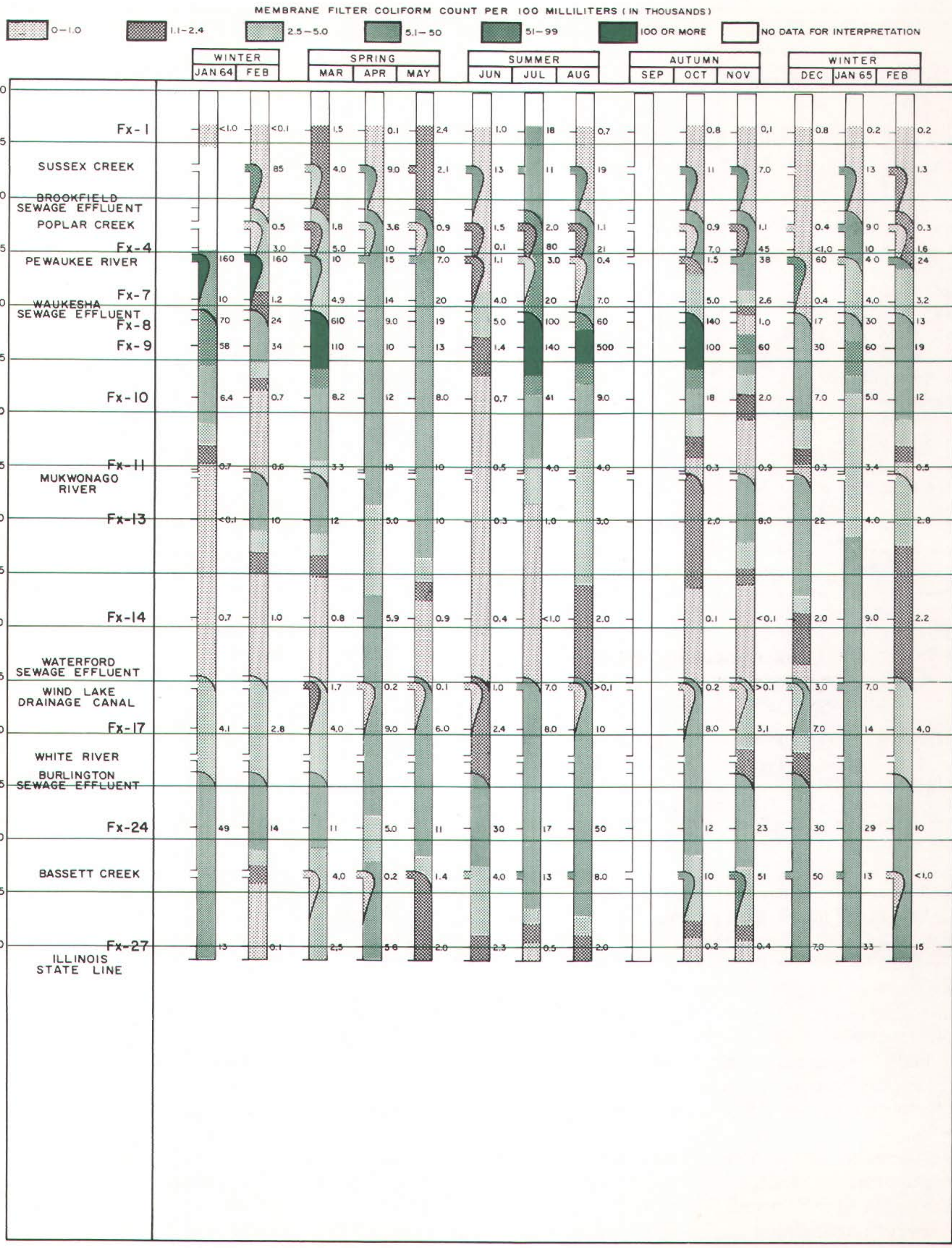


Table 54

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-8 ON THE FOX RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-22-64	7	10- 7-64
Iron	0.24	"	0.04	"
Manganese	--	--	0.01	"
Chromium	--	--	0.04	"
Hexavalent Chromium	--	--	<0.02	"
Calcium	89	4-22-64	93	"
Magnesium	48	"	42	"
Sodium (and Potassium)	25	"	95	"
Bicarbonate	275	"	335	"
Carbonate	0	"	5	"
Sulfate	186	"	150	"
Chloride	45	"	120	"
Fluoride	--	--	<1.0	"
Nitrite	0.0	4-22-64	0.2	"
Nitrate	--	--	6.7	"
Phosphorus	--	--	2.3	"
Cyanide	--	--	<0.01	12-28-64
Oil	--	--	<0.5	10- 7-64
Detergents	0.1	4-22-64	0.6	"
Dissolved Solids	530	"	685	"
Hardness	419	"	406	"
Noncarbonate Hardness	195	"	120	"
Calcium Hardness	222	"	232	"
Magnesium Hardness	197	"	174	"
Alkalinity P	0	"	2.5	"
Alkalinity M	225	"	280	"
Specific Conductance	800	"	1,050	"
pH	7.4	"	7.8	"
Color	30	"	5	"
Turbidity	6	"	5	"
Biochemical Oxygen Demand	4.1	"	3.8	"
Dissolved Oxygen	9.0	"	9.8	"
Coliform Count	9,000	"	140,000	"
Temperature (°F)	57	"	53	"

Source: SEWRPC.

Figure 11 shows the coliform count in the upper reaches of the Fox River at sampling stations Fx-1, Fx-4, Fx-7, and Fx-8, between a station 3.6 miles south of the source of the Fox River and a station 1.0 miles south of the Waukesha sewage treatment plant. The waste assimilation capacity of the Fox River with respect to coliform bacteria is greatly exceeded in the upper reaches of the river because of inferred discharges from the Brookfield and Waukesha sewage treatment plants. The coliform counts at Fx-1 may be taken as "background" level concentrations under the various climatic and streamflow conditions that prevailed during the 14-month period of study. Coliform counts at Fx-4 reflect a significant buildup of these counts from an average count at Fx-1 of 2,000 to an average count of 16,000 MFCC/100 ml at Fx-4. The inferred cause of this buildup is the effluent from the Brookfield sewage treatment plant. At Fx-7 the coliform counts are generally less than at Fx-4, the high coliform counts in the Pewaukee River apparently having little effect on the bacteriological quality of the Fox River at Fx-7, a station 3.3 miles downstream from where the Pewaukee River enters the Fox River. Downstream from the Waukesha sewage treatment plant at station Fx-8, coliform counts of the Fox River are further increased to an average of 84,000 MFCC/100 ml.

Table 55

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-27 ON THE FOX RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-23-64	2	10- 7-64
Iron	0.09	"	0.12	"
Manganese	--	--	0.00	"
Chromium	--	--	< 0.01	"
Hexavalent Chromium	--	--	0.00	"
Calcium	62	4-23-64	68	"
Magnesium	54	"	41	"
Sodium (and Potassium)	10	"	40	"
Bicarbonate	310	"	335	"
Carbonate	0	"	20	"
Sulfate	105	"	78	"
Chloride	20	"	30	"
Fluoride	--	--	< 0.9	"
Nitrite	0.0	4-23-64	0.0	"
Nitrate	--	--	1.3	"
Phosphorus	--	--	0.42	"
Cyanide	--	--	< 0.04	1-28-65
Oil	--	--	< 1	10- 7-64
Detergents	0.1	4-23-64	0.1	"
Dissolved Solids	415	"	445	"
Hardness	377	"	341	"
Noncarbonate Hardness	120	"	30	"
Calcium Hardness	154	"	170	"
Magnesium Hardness	223	"	171	"
Alkalinity P	0	"	10	"
Alkalinity M	255	"	295	"
Specific Conductance	656	"	664	"
pH	8.3	"	8.8	"
Color	60	"	15	"
Turbidity	8	"	9	"
Biochemical Oxygen Demand	6.8	"	9.4	"
Dissolved Oxygen	11.9	"	14.2	"
Coliform Count	5,800	"	200	"
Temperature (^{o}F)	55	"	51	"

Source: SEWRPC.

The variations in the temperature of the Fox River at three selected sampling stations are shown in Figure 12. Sampling stations Fx-1 and Fx-27 were chosen to show temperature differences between points at the extreme ends of the Fox River in southeastern Wisconsin. Fx-7 was chosen to indicate temperature conditions of the Fox River at the closest sampling station downstream from a known source of high temperature liquid industrial wastes.

The average temperature differential between sampling stations Fx-1 and Fx-27 from May through October 1964 was 9^{o}F and ranged from 6^{o} to 12^{o}F. During these months all stations on the Fox River were sampled on the same day, although sampling at station Fx-1 occurred from 20 to 60 minutes before sampling at station Fx-27, with the average time interval being 35 minutes. Despite this time differential, which could account for probably a maximum of one degree of the total temperature difference between these two sampling stations, it would appear that the volume of water involved affects the rate of water temperature change in response to changes in air temperature. Sampling station Fx-1 is only 3.6 miles downstream from the source of the Fox River and is located at a point where on April 29, 1964, for example, only 4.2 cubic feet of water was passing through the stream channel per second as compared to 466 cubic feet per second at sampling station Fx-27. The large difference in the volume of water passing by each of these

Figure 11

COLIFORM COUNT IN THE FOX RIVER

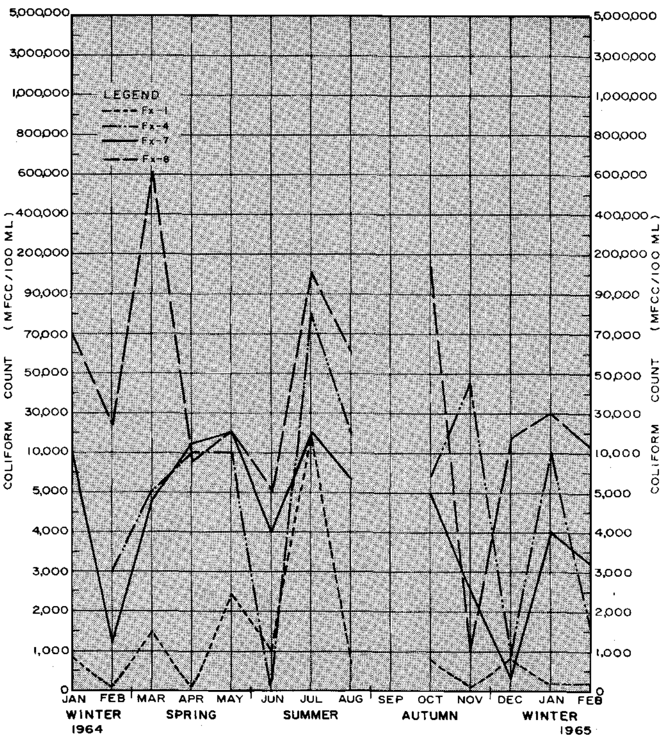
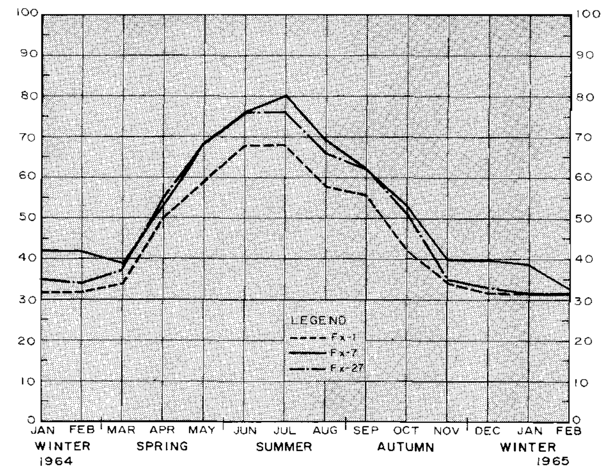


Figure 12

TEMPERATURE OF THE FOX RIVER



two sampling stations and the large difference in the time these volumes have been exposed to subaerial climatic conditions (following discharge from ground water aquifers) may account for a significant part of the stream temperature differential between the two stations.

A correlation between stream temperatures at sampling stations Fx-1 and Fx-27 and the mean daily air temperatures recorded at the U. S. Weather Bureau stations at Waukesha and at Burlington was made to determine whether stream temperatures reflected relatively short- or long-term changes in air temperature. Stream temperatures for the months from May through October 1964, at these two sampling stations, were correlated to the mean daily air temperature for periods of one through six consecutive days preceding the monthly dates of sampling. Stream temperatures at sampling station Fx-1 correlated most closely with the one-day period, indicating that stream temperatures at this station respond rapidly to changes in atmospheric temperature. Stream temperatures at Fx-27 frequently corresponded most closely with the five-day or six-day mean air temperature, indicating that the temperature of the Fox River at Fx-27 reflected the net effect of air temperatures that prevailed over the previous five to six days. However, rapid streamflow involving relatively large volumes of water or very low stream stage with correspondingly low-flow rates are conditions that promote heat exchange between stream and atmosphere. Under these conditions the Fox River at Fx-27 tended to reflect the net effect of air temperatures that prevailed over the previous 2 to 4 days. This correlation does not occur during seasons when stream temperatures are at or near 32°F (the freezing temperature of water), when the streams are partially or completely ice covered, and when mean daily air temperatures are slightly above, at, or below 32°F.

Streamflow and Precipitation: The flow of the Fox River is measured continuously by the U. S. Geological Survey at Waukesha (at sampling station Fx-7) by means of a water-stage recorder and at Wilmot (at sampling station Fx-27) by means of a wire-weight gage that is read twice daily. The records at the gaging stations at Waukesha and Wilmot start in January 1963 and in October 1939, respectively. During the present study, the SEWRPC made flow measurements in the spring and autumn of 1964. The measurements of both agencies provide flow data at Fx-1, Fx-4, Fx-7, Fx-8, Fx-17, and Fx-27 during periods of relatively high and low flow. These data are listed in Table 58. The U. S. Geological Survey streamflow measurements at Waukesha and Wilmot are listed in Tables 59 and 60, respectively.

Table 56

WATER QUALITY CONDITIONS OF THE FOX RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	445	50	5	23
Dissolved Solids (ppm)	1,210	510	295	23
Dissolved Oxygen (ppm)	19.0	9.6	0	66
Coliform Count (MFCC/100 ml)	610,000	12,600	<100	32
Temperature (^{o}F)	80	50	32	67

Source: SEWRPC.

Table 57

COLOR OF THE FOX RIVER: JUNE AND JULY 1964

Sampling Station	Color (in Units)		Sampling Station	Color (in Units)	
	June 1964	July 1964		June 1964	July 1964
Fx-1	40	170	Fx-11	40	190
Fx-4	40	270	Fx-13	35	175
Fx-7	50	235	Fx-14	--	170
Fx-8	30	240	Fx-17	--	85
Fx-9	--	195	Fx-24	30	70
Fx-10	--	180	Fx-27	25	60

Source: SEWRPC.

Table 58

STREAMFLOW MEASUREMENTS OF THE FOX RIVER: SPRING AND AUTUMN 1964

Sampling Station	Streamflow						Source of Measurement
	Spring of 1964			Autumn of 1964			
	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]	
Fx-1	4-29	4.1	.60	10-5	0	.01	SEWRPC
Fx-4	4-29	66	.60	10-5	4.6	.01	SEWRPC
Fx-7	4-29	97	.60	10-5	8.2	.01	USGS
	4-30	98	.67	--	--	--	USGS
	5- 1	96	.79	--	--	--	USGS
	5- 2	101	1.05	--	--	--	USGS
Fx-8	5- 2	91	1.05	10-5	21	.01	SEWRPC
Fx-17	4-30	267	.48	10-5	40	0	SEWRPC
Fx-27	4-29	466	.64	10-5	97	0	USGS
	4-30	455	.79	--	--	--	USGS
	5- 1	472	.98	--	--	--	USGS
	5- 2	466	1.11	--	--	--	USGS

[a] *Measured at U. S. Weather Bureau Stations at Waukesha and Burlington, Wisconsin, and at Antioch, Illinois.*

Source: U. S. Weather Bureau, USGS, and SEWRPC.

Table 59

DISCHARGE OF THE FOX RIVER AT WAUKESHA, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965[a]

Day	Streamflow[a] (in cfs)													
	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	3.2	6.6	6.6	28	96	18	15	40	9.5	9.5	12	20	14	8.5
2	3.5	6.2	8.2	41	101	18	14	29	10	9.5	17	18	41	8.0
3	3.8	7.0	10	85	98	18	12	23	10	7.8	16	15	38	8.0
4	3.7	7.4	12	85	95	17	11	20	10	7.8	14	14	36	8.0
5	3.7	7.8	11	86	90	16	16	16	9.5	8.2	13	12	28	8.0
6	3.6	8.2	11	170	83	16	14	14	9.5	9.0	13	11	21	15
7	3.7	7.8	15	237	106	15	11	11	9.0	9.0	13	12	20	80
8	3.8	6.6	14	286	159	14	10	10	10	10	12	12	24	76
9	3.9	6.2	16	216	157	14	9.5	10	9.5	9.0	13	12	18	89
10	3.7	6.0	15	159	121	15	9.0	10	11	7.4	14	12	20	130
11	3.5	6.0	15	132	91	18	8.2	15	10	7.4	13	15	16	127
12	3.5	6.0	19	111	74	19	7.4	12	9.5	9.5	14	15	14	153
13	3.5	5.8	50	101	76	18	10	12	10	12	13	16	12	173
14	3.5	5.6	124	82	71	16	10	12	12	11	11	16	10	180
15	3.5	5.8	120	86	70	16	9.0	10	12	12	18	14	10	159
16	3.5	5.8	103	68	90	13	10	12	11	12	15	12	9.5	136
17	3.6	6.2	78	70	150	13	28	12	10	10	15	12	9.5	118
18	3.7	6.6	64	70	130	13	97	11	19	9.5	14	10	10	101
19	4.0	6.6	78	62	94	14	82	10	10	10	14	8.6	10	73
20	7.8	6.4	34	60	78	14	116	10	12	11	14	7.8	10	90
21	6.2	6.2	18	104	66	14	201	45	14	12	12	8.6	10	100
22	8.2	6.0	35	116	54	44	292	25	13	12	11	9.5	19	90
23	8.6	5.8	37	109	46	80	314	24	14	11	12	10	14	70
24	30	5.6	36	96	40	26	280	21	10	11	12	10	12	58
25	18	5.4	33	85	34	19	237	17	12	10	13	9.5	12	46
26	11	5.4	26	77	30	17	180	15	12	11	12	9.5	11	40
27	8.4	5.4	24	80	27	15	165	15	10	12	19	9.0	10	36
28	6.8	5.4	23	90	25	14	133	12	10	13	44	10	9.5	40
29	7.4	5.6	23	97	19	13	87	10	10	12	30	10	9.0	--
30	7.8	--	23	98	18	12	61	12	9.5	12	26	12	8.5	--
31	7.8	--	24	--	19	--	53	10	--	12	--	10	8.5	--

[a] *Data from October through February based on unpublished records subject to revision.*

[b] *Underscored flow measurements indicate days when stream sampling occurred in the Fox River watershed.*

Source: U. S. Geological Survey discharge measurements.

The mean daily maximum and minimum flows of the Fox River at sampling stations Fx-7 and Fx-27 for the 14-month period of field investigation of the present study were 314 and 3.2 cfs and 1,510 and 65 cfs, respectively. Maximum and minimum daily flow conditions at the time of sampling on the Fox River were 116 cfs on April 22, 1964, and 7.8 cfs on January 20 and February 5, 1964, at sampling station Fx-7 and 598 cfs on March 18, 1964, and 88 cfs on December 28, 1964, at Fx-27.

Tables 61, 62, and 63 indicate the daily precipitation at Waukesha and Burlington, Wisconsin, and at Antioch, Illinois, respectively, from January 1964 through February 1965.

Forecast Quality of the Fox River for the Year 1990: SEWRPC population estimates for 1963 indicate that the 10 municipal sewage treatment plants in the Fox River watershed had a total connected population of 60,300 people (37 percent of the estimated total population of the watershed of 160,000 persons), representing an estimated total sewage flow rate of 9,700,000 gpd, or 15.0 cfs. By the year 1990, it is estimated that at least three new sewage treatment plants will be in operation in addition to the 10 presently located in the watershed.

Table 64 lists the estimated connected populations of these 13 sewage treatment plants under each of the proposed alternative regional land use plans. The estimated total 1990 population levels of the Fox River watershed are estimated under the Controlled Existing Trend Plan, the Corridor Plan, and the Satellite City Plan at 359,000, 377,000, and 334,000, respectively. The total connected populations of all existing

Table 60

DISCHARGE OF THE FOX RIVER AT WILMOT, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965[a]

Day	Streamflow[a] (in cfs)													
	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1. . .	70	160	106	293	472	162	141	280	99	97	96	233	205	80
2. . .	71	146	128	311	466	137	130	258	92	97	89	205	304	80
3. . .	72	134	155	505	487	158	137	241	85	97	110	180	393	78
4. . .	73	128	163	634	476	142	119	216	85	97	148	160	375	78
5. . .	74	124	151	680	466	138	104	204	85	97	164	145	324	80
6. . .	78	128	210	958	450	135	98	141	78	90	156	130	292	120
7. . .	84	126	370	1,170	424	135	98	106	78	97	140	120	261	260
8. . .	86	122	886	1,080	510	135	101	106	85	101	133	120	282	717
9. . .	88	116	728	1,030	597	135	108	103	92	104	125	121	271	1,270
10. . .	86	112	597	919	661	138	104	106	85	104	110	123	261	1,260
11. . .	82	110	539	834	478	138	104	132	92	104	103	123	228	1,430
12. . .	80	114	474	828	442	142	104	122	99	101	103	139	179	1,510
13. . .	78	112	473	783	450	138	108	113	85	87	103	155	147	1,400
14. . .	76	108	635	637	460	138	126	106	68	83	103	159	128	1,300
15. . .	74	106	741	644	387	138	130	99	71	83	110	163	110	1,120
16. . .	74	104	734	608	385	127	137	110	68	79	160	159	100	904
17. . .	76	104	673	556	441	124	134	112	68	79	189	147	94	813
18. . .	80	106	598	556	417	124	305	110	65	79	202	139	92	791
19. . .	84	108	484	491	373	124	709	106	65	83	198	124	90	755
20. . .	98	106	449	451	342	124	762	106	88	87	180	110	90	682
21. . .	130	102	433	476	285	131	590	240	105	87	160	100	92	783
22. . .	155	96	393	558	268	221	303	210	116	87	140	90	106	919
23. . .	180	94	370	583	246	410	360	185	120	87	125	94	124	813
24. . .	189	92	357	546	242	262	311	160	135	87	133	100	150	682
25. . .	189	90	383	510	202	262	298	143	127	97	140	105	128	540
26. . .	186	89	393	498	246	184	298	143	120	97	144	100	109	440
27. . .	182	88	383	476	226	168	311	121	112	97	156	96	102	360
28. . .	174	87	361	487	210	145	355	103	105	97	215	94	91	400
29. . .	170	88	329	466	184	137	340	103	98	90	202	90	88	--
30. . .	170	--	291	455	173	130	345	106	98	97	202	100	84	--
31. . .	166	--	293	--	165	--	321	103	--	97	--	143	82	--

[a] *Underscored flow measurements indicate days when stream sampling occurred in the Fox River watershed.*

Source: *U. S. Geological Survey discharge measurements.*

and proposed sewage treatment plants by the year 1990 under these three alternative plans are expected to be 258,600, 258,600, and 233,500, respectively. By the year 1990, the total connected populations will constitute 72, 68, and 70 percent of the total watershed population estimates according to these same three alternative land use plans.

Inspection of Table 64 indicates that, according to the three regional land use plan alternatives, a relatively heavy concentration of population can be expected in the upper reaches of the Fox River watershed. In 1963 approximately 6,500 people were connected to the three sewage treatment plants located in the watershed upstream from the City of Waukesha. The future estimated populations expected to be served by five plants in the same part of the watershed in 1990 are 98,600, 62,900, and 67,200 people according to the Controlled Existing Trend Plan, the Corridor Plan, and the Satellite City Plan, respectively. This heavy concentration of people will occur in the headwater area of the Fox River watershed, where the natural flow of the Fox River is least.

Table 65 indicates the estimated average daily sewage flow rates of existing and proposed sewage treatment plants in the Fox River watershed for the year 1990. As already noted, in 1963 the total discharge from all sewage treatment plants in the watershed was about 9,700,000 gpd, or 15 cfs. By the year 1990, the total flow rate is expected to be four to five times larger than the 1963 figures. Upstream from the City of Waukesha, 90 percent of the flow of the Fox River proper is expected, by the year 1990, to consist of water from sewage treatment plants.

Table 61

PRECIPITATION[a] AT WAUKESHA, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.12	--	0.18	--	--	--	0.04	0.05	0.32	0.03
2	--	--	--	0.58	0.26	0.18	--	--	0.07	0.01	0.69	0.03	0.21	--
3	--	--	--	--	--	--	--	--	--	--	--	0.01	--	--
4	--	--	0.60	--	--	--	--	--	--	--	0.03	0.16	--	--
5	--	--	0.69	0.82	--	--	--	--	--	--	--	--	--	--
6	--	--	0.05	1.26	--	--	0.03	--	--	--	0.01	--	--	--
7	--	--	--	0.03	1.66	--	0.25	--	--	--	--	--	0.01	0.08
8	--	--	0.50	--	0.14	--	0.02	--	0.07	0.13	--	--	--	0.07
9	--	--	--	--	--	--	--	--	--	--	--	--	--	0.12
10	--	--	--	--	--	--	--	0.09	0.09	--	--	0.06	--	0.01
11	0.07	--	--	--	--	--	0.02	0.54	--	--	--	0.02	--	0.26
12	0.03	0.18	--	--	--	0.02	--	--	--	--	0.10	0.23	--	0.04
13	--	--	--	0.08	0.60	--	0.43	--	--	--	--	--	--	--
14	--	--	0.07	--	--	0.02	0.01	--	0.15	--	--	--	0.04	--
15	--	0.05	--	--	--	0.27	--	--	--	--	0.46	--	0.05	--
16	--	--	--	--	0.66	--	--	0.19	--	--	--	--	0.02	--
17	--	--	--	0.30	--	0.04	0.85	--	--	--	--	--	--	--
18	--	--	--	--	0.11	--	1.58	--	0.59	--	--	--	--	--
19	0.12	0.01	--	--	--	0.14	--	--	0.03	--	--	0.06	--	--
20	0.18	--	0.04	0.01	--	--	0.60	0.07	0.14	--	0.15	--	--	--
21	--	--	--	1.06	--	0.45	--	1.36	0.13	--	--	--	--	--
22	--	--	--	--	--	1.62	--	0.02	--	--	--	--	0.76	--
23	--	0.02	--	--	--	--	--	0.02	0.23	--	--	0.01	1.11	0.17
24	0.91	--	--	--	0.23	--	--	--	0.03	--	--	--	0.14	0.10
25	0.02	--	0.25	--	--	--	0.51	--	0.09	--	--	0.06	0.01	--
26	--	--	0.13	0.07	--	--	--	--	0.29	--	--	--	0.27	--
27	--	--	0.07	0.19	--	--	0.26	--	--	0.03	1.23	--	--	--
28	--	--	--	0.20	--	--	--	--	--	--	0.23	0.02	--	--
29	--	--	0.01	0.14	--	--	--	--	--	--	--	0.02	--	--
30	--	--	--	0.17	--	--	--	0.14	--	--	--	--	--	--
31	--	--	--	--	0.04	--	--	--	--	--	--	--	0.20	--
Total	1.31	0.26	2.41	4.81	3.82	2.74	4.74	2.43	1.91	0.17	2.74	0.73	3.14	0.88

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Table 66 indicates the estimated quality of the Fox River for the year 1990. The most conspicuous deterioration of river quality will occur in the upper reaches because of low base flow and the aggregate effect of the proposed and existing sewage treatment plants at Lannon, Sussex, Brookfield, near the mouth of Poplar Creek, and Pewaukee. This impact will extend to several miles south of sampling station Fx-8. The water quality of the entire Fox River, however, may be expected to deteriorate to a level impairing all uses.

The proposed expansion of the sewage treatment facilities at the City of Waukesha include plans for post-chlorination to disinfect the effluent. It is assumed that this process will be carefully applied to the treated liquid wastes to avoid excessive kill of the saprophytic bacteria which will continue to reduce the wastes to more stable substances in the stream. The non-chlorinated wastes discharged into the Fox River upstream from the City of Waukesha sewage outfall will, under the above assumption, blend with the wastes from the outfall at Waukesha and tend to be reduced in coliform count. Estimates of the coliform counts for 1990 at stations Fx-8 and Fx-11 reflect the possible effects of carefully controlled post-chlorination at Waukesha.

Sussex Creek

Present Stream Quality: One sampling station, Fx-2, was established on Sussex Creek and is located 4.7 miles downstream from the river source and 1.3 miles upstream from the mouth. Sussex Creek enters the Fox River 7.5 miles downstream from the source of the Fox River, 3.4 miles upstream from the Brookfield sewage treatment plant, and 7.0 miles upstream from sampling station Fx-4, the nearest station downstream on the Fox River. The effluent from the sewage treatment plant at Sussex is discharged into Sussex Creek approximately four miles upstream from sampling station Fx-2.

Table 62

PRECIPITATION[a] AT BURLINGTON, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul.	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.15	--	--	--	--	--	--	--	--	0.19
2	--	--	--	--	0.16	--	0.15	--	--	--	0.13	0.01	0.60	--
3	--	--	0.03	0.85	--	0.23	--	--	--	--	0.30	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	0.14	--	--
5	--	--	0.73	--	--	--	--	--	--	--	0.03	0.01	--	--
6	--	--	--	1.03	--	--	--	--	--	--	--	--	--	--
7	--	--	--	0.10	0.12	--	0.02	--	--	--	--	--	--	0.13
8	--	--	--	--	0.22	--	0.16	--	--	0.13	--	--	--	0.15
9	--	--	0.43	--	--	--	--	--	--	0.05	--	--	0.07	--
10	--	0.01	--	--	--	--	--	0.47	--	--	--	--	--	0.07
11	--	--	--	--	--	--	--	0.27	0.16	--	--	0.13	--	0.24
12	--	--	--	--	--	--	--	--	--	--	0.11	--	--	--
13	--	0.35	--	0.03	0.30	0.02	0.02	--	--	--	--	0.15	--	--
14	--	--	0.15	--	0.40	--	0.33	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	0.04	--
16	--	--	--	--	0.70	0.84	--	--	--	--	1.05	--	0.03	--
17	--	0.01	--	--	--	0.06	0.40	--	--	--	--	--	--	--
18	--	--	--	0.08	0.01	--	2.00	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	0.57	--	--	--	--	--
20	0.05	--	--	0.13	--	--	--	--	--	--	--	0.01	--	--
21	--	--	0.12	0.73	--	0.25	--	1.25	0.53	--	0.02	--	--	--
22	--	--	--	--	--	0.20	--	--	0.32	--	--	--	0.09	--
23	--	--	--	--	--	0.99	--	0.14	0.61	--	--	--	1.02	--
24	0.10	0.10	--	--	0.24	--	--	--	--	--	--	0.01	0.57	0.17
25	0.50	--	0.27	--	--	--	0.95	--	--	--	--	--	--	0.02
26	--	--	0.12	--	0.10	--	--	--	--	--	--	0.05	0.24	--
27	--	--	--	0.08	--	--	--	--	0.51	--	--	--	0.10	--
28	--	--	--	0.07	--	--	0.26	--	--	0.03	1.25	--	--	--
29	--	--	--	0.15	--	--	0.17	--	--	--	--	--	--	--
30	--	--	--	0.15	--	--	--	0.33	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	0.65	0.47	1.85	3.40	2.40	2.59	4.46	2.46	2.70	0.21	2.89	0.51	2.76	0.87

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Sussex Creek is a calcium bicarbonate stream of relatively constant total mineralization. Of three complete chemical analyses of water sampled from Sussex Creek in February, April, and October 1964, calcium (ranging from 95 to 80 ppm) was the predominant cation; and bicarbonate (ranging from 395 to 295 ppm) exceeded all other anion concentrations. Sulfate concentrations were relatively high and ranged from 220 to 116 ppm. The maximum nitrate concentration was 3.6 ppm. On October 7, 1964, total phosphorus was 0.26 ppm. Selected water analyses of Sussex Creek at sampling station Fx-2 are indicated in Table 67. Water quality conditions of Sussex Creek are indicated in Table 68.

The chloride concentrations in Sussex Creek indicate a probable chloride impact upon the stream from human sources. If the "background" chloride concentration of the stream were assumed to be 10 ppm, this concentration was exceeded by as much as 60 ppm during the three samplings. The effluent of the Sussex sewage treatment plant may be the source of a greater part of this impact concentration, although local sources near sampling station Fx-2, such as the effluents from private septic tanks, may contribute to this impact. None of the present or potential uses listed in Table 4 are adversely affected.

The variations in the dissolved solids concentrations of Sussex Creek are affected principally by variations in bicarbonate, chloride, sulfate, and sodium concentrations. No present or potential uses are adversely affected by the concentrations of dissolved solids. The principal part of the dissolved solids concentration (possibly 425) is derived from ground water seepage.

The dissolved oxygen concentration of Sussex Creek was determined 12 times during the 14-month period of field study. A minimum concentration of 4.3 ppm occurred in February 1965 under ice cover. Waste assimilation loading of Sussex Creek does not suppress the dissolved oxygen concentrations to critical levels (3.0 ppm or less) during daylight hours.

Table 63

PRECIPITATION[a] AT ANTIOCH, ILLINOIS: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.19	--	0.07	--	--	--	--	--	0.43	0.05
2	--	--	--	0.46	0.13	0.19	0.40	--	--	--	0.32	0.29	0.65	--
3	--	--	0.01	0.25	--	--	--	--	--	--	0.45	0.02	--	--
4	--	--	0.02	--	--	--	--	--	--	--	0.04	0.39	--	--
5	--	--	0.64	0.92	--	--	--	--	--	--	--	--	--	--
6	--	--	--	0.10	0.06	--	--	--	0.02	0.04	--	--	--	--
7	--	--	--	--	--	--	0.54	--	--	--	0.03	--	0.31	0.08
8	--	--	0.06	--	1.55	--	--	--	--	0.06	--	--	--	--
9	0.03	--	--	--	0.07	--	--	--	--	--	--	--	--	0.23
10	--	--	--	--	--	--	--	0.80	0.86	--	--	--	--	0.05
11	--	--	--	--	--	--	--	0.11	--	--	--	0.05	--	--
12	--	0.30	--	--	--	0.10	--	--	--	0.02	0.37	--	--	--
13	--	--	--	0.10	0.57	--	0.27	--	--	--	--	0.06	--	--
14	--	--	0.20	--	--	--	0.20	--	--	--	--	--	--	--
15	--	0.10	--	--	--	2.06	--	--	--	--	0.99	--	0.30	--
16	0.05	0.20	--	--	0.61	--	--	--	--	--	0.03	--	--	0.50
17	--	--	--	0.04	--	--	--	--	--	--	--	--	--	--
18	--	--	--	0.17	--	--	3.00	--	0.59	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	0.64	--	0.55	0.34	--	0.11	--	--	0.54	--	0.08	--	--	--
21	--	0.05	--	0.33	--	0.08	0.05	0.89	--	--	--	--	--	--
22	--	--	--	--	--	1.02	0.31	0.17	1.46	--	--	--	1.19	--
23	--	--	--	--	--	--	--	--	--	--	--	--	0.90	--
24	0.14	--	0.30	--	0.35	--	--	--	--	--	--	0.02	0.22	0.50
25	--	--	0.65	--	--	--	0.30	0.04	--	--	--	--	--	--
26	--	--	0.10	--	--	--	--	--	--	--	--	0.06	0.51	--
27	--	--	0.02	0.20	--	--	--	--	0.37	--	--	--	--	--
28	--	--	--	0.17	--	--	1.55	--	--	--	1.75	--	--	--
29	--	--	0.16	0.27	--	--	0.83	--	--	0.05	--	0.02	--	--
30	--	--	--	0.15	--	--	--	0.22	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	0.10	--
Total	0.86	0.65	2.71	3.50	3.53	3.56	7.52	2.23	3.84	0.17	4.06	0.91	4.61	1.41

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Table 64

ESTIMATED POPULATION CONNECTED TO EXISTING AND PROPOSED SEWAGE TREATMENT PLANTS IN THE FOX RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Lannon	0[a]	18,600	300	2,100
Village of Sussex	1,400	8,800	2,000	5,300
City of Brookfield	2,200	27,800	31,700	27,000
Near Mouth of Poplar Creek	0[a]	37,000	17,100	27,400
Village of Pewaukee	2,900	6,400	11,800	5,400
City of Waukesha	35,000	82,100	71,600	66,800
Village of Mukwonago	1,900	6,800	10,600	13,200
Village of Waterford	1,600	5,800	14,400	5,600
Village of Muskego	0[a]	31,600	44,000	9,500
City of Burlington	6,200	14,200	19,400	43,200
Village of East Troy	1,500	3,600	5,200	4,400
City of Lake Geneva	4,500	11,000	24,800	17,700
Village of Twin Lakes	3,100	4,900	5,700	5,900
Total Connected Population	60,300	258,600	258,600	233,500

[a] *Sewage treatment plant not in existence in 1963.*

Source: SEWRPC.

Table 65

ESTIMATED AVERAGE DAILY SEWAGE FLOW RATES OF EXISTING AND PROPOSED SEWAGE TREATMENT PLANTS IN THE FOX RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Average Daily Sewage Flow Rate			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Lannon	0[a] 0[a]	3,300,000 5.1	30,000 0.05	300,000 0.5
Village of Sussex	200,000[b] 0.3[c]	1,600,000 2.5	200,000 0.3	900,000 1.4
City of Brookfield	300,000[b] 0.5[c]	5,000,000 7.7	5,700,000 8.8	4,900,000 7.6
Near Mouth of Poplar Creek	0[a] 0[a]	6,700,000 10.4	3,100,000 4.8	4,900,000 7.6
Village of Pewaukee	300,000[b] 0.5[c]	1,200,000 1.9	2,100,000 3.2	1,000,000 1.5
City of Waukesha	6,300,000[b] 9.7[c]	14,700,000 22.7	12,900,000 20.0	12,000,000 18.6
Village of Mukwonago	200,000[b] 0.3[c]	1,200,000 1.9	1,900,000 2.9	2,400,000 3.7
Village of Waterford	0[a] 0[a]	5,700,000 8.8	7,900,000 12.2	1,700,000 2.6
Village of Muskego	200,000[b] 0.3[c]	1,000,000 1.5	2,600,000 4.0	1,000,000 1.5
City of Burlington	1,100,000[b] 1.7[c]	2,600,000 4.0	3,500,000 5.4	7,800,000 12.1
Village of East Troy	200,000[b] 0.3[c]	400,000 0.6	1,000,000 1.5	500,000 0.8
City of Lake Geneva	500,000[b] 0.8[c]	2,000,000 3.1	4,500,000 7.0	3,200,000 4.9
Village of Twin Lakes	400,000[b] 0.6[c]	600,000 0.9	1,000,000 1.5	1,000,000 1.5
Total Average Daily Sewage Flow Rate	9,700,000[b] 15.0[c]	46,000,000 71.1	46,400,000 71.8	41,600,000 64.3

[a] *Sewage treatment plant not in existence in 1963.*

[b] *Gallons per day.*

[c] *Cubic feet per second.*

Source: SEWRPC.

Coliform counts in Sussex Creek were relatively high and exceeded 10,000 MFCC/100 ml during the months of June through September. This stream has coliform counts probably indicative of human sources of pollution, which probably include the Sussex sewage treatment plant and the more local effluent from septic tanks.

The maximum temperature of Sussex Creek was 70°F in July 1964. The average temperature for the period of June through September 1964 was 62°F. The temperature condition of Sussex Creek is suitable for fish life.

Table 66

FORECAST QUALITY OF THE FOX RIVER: 1990 ALTERNATIVE LAND USE PLANS

Stream	Parameter	Sampling Station	Stream Quality in 1964	Forecast Quality for 1990: Controlled Existing Trend Plan	Forecast Quality for 1990: Corridor Plan	Forecast Quality for 1990: Satellite City Plan
Fox River	Chloride (in ppm)	Fx-1	30[a]	150	40	120
		Fx-4	120	170	170	170
		Fx-7	65	170	170	170
		Fx-8	120	170	170	170
		Fx-11	65	From 100 to 150		
		Fx-13	55			
		Fx-14	55			
		Fx-17	50	From 50 to 100		
		Fx-24	45			
		Fx-27	30			
	Dissolved Solids (in ppm)	Fx-1	460[a]	650	500	600
		Fx-4	765	850	850	850
		Fx-7	600	800	800	800
		Fx-8	685	750	750	750
		Fx-11	575	From 600 to 700		
		Fx-13	520			
		Fx-14	520			
		Fx-17	500	From 500 to 600		
		Fx-24	485			
		Fx-27	445			
	Dissolved Oxygen (in ppm)	Fx-1	2.2[b]	Concentrations of less than 3.0 may be expected to occur most frequently.		
		Fx-4	3.2			
		Fx-7	5.1			
		Fx-8	4.0			
		Fx-11	6.4	Concentrations between 3.0 and 5.0 may be expected to occur most frequently.		
		Fx-13	7.3			
		Fx-14	8.4			
		Fx-17	10.0	More than 6.0		More than 6.0
		Fx-24	8.0			More than 4.0
		Fx-27	11.8			More than 6.0
	Coliform Count (in MFCC/ 100 ml)	Fx-1	5,100[c]	From 40,000 to more than 100,000		
		Fx-4	27,000	More than 100,000		
		Fx-7	9,000	More than 100,000		
		Fx-8	76,000	Less than 50,000		
		Fx-11	2,200	Less than 5,000		
		Fx-13	1,600	More than 15,000		
		Fx-14	900	More than 5,000		
		Fx-17	7,100	More than 20,000		
		Fx-24	27,200	More than 50,000		
		Fx-27	1,200	More than 3,000		

[a] *All chloride and dissolved solids concentrations in this column are based on water analyses for October 1964.*

[b] *All dissolved oxygen concentrations in this column are based on average for period June through September.*

[c] *All coliform counts in this column are based on average for period June through October 1964. No data for September 1964.*

Source: SEWRPC.

Table 67

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-2 ON SUSSEX CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	3	4-22-64	4	10-7-64
Iron	0.02	"	0.07	"
Manganese	--	--	0.01	"
Chromium	--	--	< 0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	95	4-22-64	80	"
Magnesium	50	"	47	"
Sodium (and Potassium)	35	"	50	"
Bicarbonate	295	"	330	"
Carbonate	0	"	10	"
Sulfate	220	"	116	"
Chloride	40	"	65	"
Fluoride	--	--	< 0.35	"
Nitrite	0.0	4-22-64	0.0	"
Nitrate	--	--	3.6	"
Phosphorus	--	--	.66	"
Cyanide	--	--	--	--
Oil	--	--	< 1	10-7-64
Detergents	0.2	4-22-64	0.4	"
Dissolved Solids	590	"	535	"
Hardness	443	"	392	"
Noncarbonate Hardness	205	"	105	"
Calcium Hardness	236	"	199	"
Magnesium Hardness	207	"	193	"
Alkalinity P	0	"	5	"
Alkalinity M	240	"	280	"
Specific Conductance	836	"	828	"
pH	7.7	"	8.0	"
Color	60	"	20	"
Turbidity	2	"	5	"
Biochemical Oxygen Demand	2.8	"	2.0	"
Dissolved Oxygen	8.9	"	12.2	"
Coliform Count	9,000	"	11,000	"
Temperature (°F)	50	"	41	"

Source: SEWRPC.

Table 68

WATER QUALITY CONDITIONS OF SUSSEX CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	70	60	40	3
Dissolved Solids (ppm)	650	590	535	3
Dissolved Oxygen (ppm)	12.2	7.7	4.3	12
Coliform Count (MFCC/100 ml)	85,000	16,000	1,300	11
Temperature (°F)	70	48	32	11

Source: SEWRPC.

Streamflow and Precipitation: Sussex Creek is a shallow meandering stream occupying a very narrow channel. At sampling station Fx-2, a distance of 4.7 miles from the source, this stream had a maximum depth of 0.4 feet and was six feet wide when measured under low-flow conditions in October 1964. The small size and low flow of Sussex Creek preclude its use for all but three of the ten major uses listed in Table 4. These three uses are waste assimilation, preservation of aquatic life, and aesthetic use.

The waste assimilation capacity of Sussex Creek at sampling station Fx-2 was exceeded, with respect to dissolved oxygen, in that the waste loading was sufficient to occasionally lower the dissolved oxygen concentrations to substandard levels (between 5.0 and 3.1 ppm) for the preservation of fish life. Farther upstream toward the Sussex sewage treatment plant, where waste loading can be presumed to be heavier (because of less dilution by the stream), the dissolved oxygen concentrations of the creek may be depressed to critical levels (3.0 ppm or less). The generally shallow depth of Sussex Creek imposes natural limitations on the size of the fish that can inhabit the stream. Regardless of how favorable the quality of Sussex Creek may be for the preservation of fish life, the shallow depth of the stream limits its habitation by fish to small species, such as minnows.

The flow of Sussex Creek was measured by the SEWRPC at station Fx-2 in April and October 1964, as listed in Table 69. Table 61 indicates the daily precipitation at Waukesha, Wisconsin, from January 1964 through February 1965.

Forecast Quality of Sussex Creek for the Year 1990: Population studies by the SEWRPC indicate that the Village of Sussex sewage treatment plant had a connected population in 1963 of about 1,400 people. The connected population of this sewage treatment plant by the year 1990, according to the SEWRPC alternative land use plans, is listed in Table 70. Based on procedures discussed at the beginning of this chapter, estimates of the quality of Sussex Creek at sampling station Fx-2 are listed in Table 71.

Alternative regional land use plans prepared by the SEWRPC indicate that, under the Controlled Existing Trend and Satellite City Land Use Plans, large increases are anticipated in the population served by the Sussex sewage treatment plant. The estimates of future water quality in Table 71 indicate that the most serious effects that this human impact can have on the quality of Sussex Creek are the lowering of the dissolved oxygen concentrations to levels that are frequently less than 3.0 ppm and the buildup of nutrients. Although marked increases in the concentrations of chloride, dissolved solids, and coliform bacterial counts can be expected, these concentrations should not interfere with the preservation of fish and wildlife and the aesthetic use of the stream. However, buildup of BOD and of nutrients in the stream, such as nitrates and phosphates, may result in very critical oxygen levels and in algae blooms that impair the aesthetic value of the stream through unsightliness and foul odors and make the stream unsuitable for the preservation of fish and wildlife. To what extent Sussex Creek may contribute to the contamination of wells in the shallow aquifers is not considered in this study.

Poplar Creek

Present Stream Quality: One sampling station, Fx-3, was established on Poplar Creek and is located 5.3 miles downstream from its source and 0.8 miles from its confluence with the Fox River. Poplar

Table 69

STREAMFLOW MEASUREMENTS OF SUSSEX CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-2	4-29 10- 6	4.4 0.5	0.60 0.01

[a] *Measured at U. S. Weather Bureau Station at Waukesha, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 70

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE VILLAGE OF SUSSEX SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend plan	Corridor Plan	Satellite City Plan
Village of Sussex	1,400	8,800	2,000	5,300
	Estimated Average Daily Sewage Flow Rate			
	200,000[a] 0.3[b]	1,600,000 2.5	200,000 0.3	1,000,000 1.5
	Estimated Low Flow of Sussex Creek at Station Fx-2			
	Less than 0.5[b]	2	Less than 0.5	1

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 71

FORECAST QUALITY OF SUSSEX CREEK AT SAMPLING STATION FX-2: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sussex Creek	Fx-2	Chloride (in ppm)	50[a]	170	65	150
		Dissolved Solids (in ppm)	520[a]	850	535	690
		Dissolved Oxygen (in ppm)	6.7[b]	Less than 3.0 ppm can be expected to occur frequently.	5.0	Less than 3.0 ppm can be expected to occur frequently.
		Coliform Count (in MFCC/ 100 ml)	14,300[b]	85,000	20,000	50,000

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Creek joins the Fox River at a point 12.8 miles downstream from the source of the Fox River and 1.7 miles upstream from sampling station Fx-4.

Poplar Creek is a calcium bicarbonate stream of relatively constant total mineralization. Of three complete chemical analyses of water sampled from Poplar Creek in February, April, and October 1964, calcium (ranging from 117 to 85 ppm) was the predominant cation; and bicarbonate (ranging from 440 to 220 ppm) exceeded all other anion concentrations. Sulfate concentrations were relatively high and ranged from 323 to 155 ppm. The maximum nitrate concentration was 1.6 ppm. On October 7, 1964, total phosphorus was 0.20 ppm. Selected water analyses of Poplar Creek at sampling station Fx-3 are indicated in Table 72. Water quality conditions of Poplar Creek are indicated in Table 73.

The chloride concentrations in Poplar Creek are relatively low and reflect a low chloride impact upon the stream from human sources. No sewage treatment plants discharge treated wastes into the area drained by Poplar Creek. The prime source of the chlorides is presumably the effluent from the many private septic tanks in the housing developments that are scattered throughout the area. No present or potential uses listed in Table 4 are adversely affected by the present chloride concentrations of Poplar Creek.

Table 72

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-3 ON POPLAR CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	4	4-22-64	8	10-7-64
Iron	0.10	"	0.08	"
Manganese	--	--	0.07	"
Chromium	--	--	<0.005	"
Hexavalent chromium	--	--	0.00	"
Calcium	85	4-22-64	109	"
Magnesium	41	"	48	"
Sodium (and potassium)	20	"	40	"
Bicarbonate	220	"	440	"
Carbonate	0	"	0	"
Sulfate	172	"	155	"
Chloride	50	"	20	"
Fluoride	--	--	<0.60	"
Nitrite	0.0	4-22-64	0.0	"
Nitrate	--	--	1.6	"
Phosphorus	--	--	0.20	"
Cyanide	--	--	--	--
Oil	--	--	<2	10-7-64
Detergents	0.0	4-22-64	0.1	"
Dissolved solids	480	"	595	"
Hardness	382	"	469	"
Noncarbonate hardness	200	"	110	"
Calcium hardness	212	"	272	"
Magnesium hardness	170	"	197	"
Alkalinity P	0	"	0	"
Alkalinity M	180	"	360	"
Specific conductance	744	"	832	"
pH	7.6	"	7.6	"
Color	90	"	30	"
Turbidity	5	"	8	"
Biochemical oxygen demand	2.7	"	2.4	"
Dissolved oxygen	6.4	"	8.2	"
Coliform count	3,600	"	900	"
Temperature (°F)	51	"	42	"

Source: SEWRPC

Table 73

WATER QUALITY CONDITIONS OF POPLAR CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	50	35	20	3
Dissolved Solids (ppm)	765	615	480	3
Dissolved Oxygen (ppm)	12.1	5.9	0.1	13
Coliform Count (MFCC/100 ml) .	9,000	1,900	300	12
Temperature (^{o}F)	73	47	32	12

Source: SEWRPC.

The variations of dissolved solids concentrations in Poplar Creek are affected principally by variations in bicarbonate, sulfate, calcium, chloride, and sodium concentrations. The principal part of the dissolved solids concentration (possibly 550 ppm) is derived from ground water seepage. No present or potential uses of the stream water are adversely affected by dissolved solids concentrations.

The dissolved oxygen concentration of Poplar Creek was determined on 13 samples collected over the period of field study. During June, July, August, and September, the minimum concentration was 0.1 ppm following the heavy rains of July 1964. With the exception of that month, a minimum of 3.2 ppm occurred under ice cover in February 1966. This concentration is substandard for the preservation of fish life but is not considered to be critical. Waste assimilation loading of Poplar Creek is sufficient to suppress the dissolved oxygen concentration for the preservation of fish life to near critical levels during daylight hours.

The coliform counts in Poplar Creek are very low as compared to those of the 42 other streams and watercourses studied by the SEWRPC. The counts exceeded 2,400 MFCC/100 ml only during January 1965. Human sources did not appear necessarily to be contributory to the coliform counts in this stream except possibly in January 1965.

The maximum temperature of Poplar Creek was 73^{o}F in July 1964. The average temperature for the period of June through September 1964 was 63^{o}F. The temperature condition of Poplar Creek is suitable for the maintenance of fish life.

Streamflow and Precipitation: Poplar Creek is a relatively deep meandering stream. At sampling station Fx-3, a distance 5.3 miles from the source, this stream was 1.5 feet deep and 22 1/2 feet wide when measured under low-flow conditions in October 1964. The flow conditions make this stream suitable for waste assimilation, preservation of fish and wildlife, partial-body contact recreation, and aesthetic use. Although potentially suited for whole-body contact recreation, such as swimming, this use is problematic because the stream has a muck bottom in its lower reaches.

The flow of Poplar Creek was measured by the SEWRPC at sampling station Fx-3 in April and October 1964, as listed in Table 74. Table 61 indicates the daily precipitation at Waukesha from January 1964 through February 1965.

Table 74

STREAMFLOW MEASUREMENTS OF POPLAR CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-3	4-29 10- 6	28 0	0.60 0.01

[a] *Measured at U. S. Weather Bureau Station at Waukesha, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Forecast Quality of Poplar Creek for the Year 1990: A new sewage treatment plant is presently under construction near the mouth of Poplar Creek. This plant will service parts of the Town of Brookfield and the northwest part of the City of New Berlin, which are estimated by the SEWRPC to have had a combined population of 7,500 in 1963. Present development in the area to be serviced depends upon septic tank systems for waste disposal. The connected population of the new sewage treatment plant by the year 1990 according to the SEWRPC alternative regional land use plans is listed in Table 75. Based on procedures discussed at the beginning of this chapter, estimates of the quality of Poplar Creek at sampling station Fx-3 and downstream from the proposed sewage treatment plant are listed in Table 76 and 77, respectively. The effect of the Poplar Creek sewage treatment plant upon the quality of the Fox River is discussed under the section of this chapter pertaining to the Fox River.

Pewaukee River

Present Stream Quality: Two sampling stations, Fx-5 and Fx-6, were established on the Pewaukee River. Sampling station Fx-5 is located 1.3 miles downstream from the outlet of Pewaukee Lake and 0.8 miles downstream from the Pewaukee sewage treatment plant. Sampling station Fx-6 is located 4.9 miles downstream from station Fx-5 and 0.2 miles upstream from where the Pewaukee River enters the Fox River. The confluence of these two rivers is 1.4 miles downstream from sampling station Fx-4 and 3.3 miles upstream from station Fx-7.

The Pewaukee River is predominantly a calcium bicarbonate stream that is subject to moderate changes in total mineralization. Of 17 complete chemical analyses, calcium (ranging from 98 to 53 ppm) was the most abundant cation in 11 analyses; and bicarbonate (ranging from 535 to 245 ppm) exceeded all other anion concentrations in the 17 analyses. Sodium occurred as the most abundant cation in six analyses at concentrations ranging from 120 to 80 ppm. Sodium concentrations tended to be higher at sampling station Fx-5 than at sampling station Fx-6. Maximum nitrate concentrations at stations Fx-5 and Fx-6 were 18.2 and 4.5 ppm, respectively, with 18.2 ppm being the highest nitrate concentration encountered at any sampling station in the Region. On October 7, 1964, total phosphorus was 3.2 ppm at station Fx-5 and 0.96 ppm at station Fx-6. Selected water analyses of the Pewaukee River at sampling station Fx-6 are indicated in Table 78. Water quality conditions of the Pewaukee River are indicated in Table 79. The average numerical values are weighted averages.

Table 75

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE POPLAR CREEK SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Poplar Creek	0	37,000	17,100	27,000
	Estimated Average Daily Sewage Flow Rate			
	0	6,700,000[a]	3,100,000	4,900,000
	0	10.4[b]	4.8	7.6
	Estimated Low Flow of Poplar Creek at Station Fx-3			
	0	8[b]	4	6

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 76

FORECAST QUALITY OF POPLAR CREEK AT SAMPLING STATION FX-3: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Poplar Creek	Fx-3	Chloride (in ppm)	20[a]	10	10	10
		Dissolved Solids (in ppm)	600[a]	550	550	550
		Dissolved Oxygen (in ppm)	4.8[b]	More than 5.0		
		Coliform Count (in MFCC/ 100 ml)	1,500[c]	Less than 1,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964 with data for July excluded.*

[c] *Based on average for the period June through October 1964.*

Source: SEWRPC.

The chloride concentrations of the Pewaukee River indicate a strong chloride impact upon the stream from human sources. If the "background" chloride concentration of the stream were assumed to be 10 ppm, this concentration was exceeded by as much as 110 ppm in the 17 complete chemical analyses run on water samples collected from the Pewaukee River during the study. The effluent of the Pewaukee sewage treatment plant is the probable source of this impact concentration. None of the present or potential uses of this stream are adversely affected by these chloride concentrations.

The variations in dissolved solids concentrations of the Pewaukee River result principally from variations in the concentrations of bicarbonate, sodium, chloride, sulfate, and calcium. The principal part of the dissolved solids concentration (possibly 425 ppm) is derived from ground water seepage.

The dissolved oxygen concentrations of the Pewaukee River were determined on 13 samples collected at sampling station Fx-5 and on 14 samples collected at station Fx-6. A minimum concentration of 0.7 ppm occurred at station Fx-5 under ice cover during December 1964. The minimum concentration of dissolved oxygen from June through September 1964 was 3.0 ppm. Waste loading of the Pewaukee River suppressed the dissolved oxygen concentrations to critical levels (3.0 ppm or less) during daylight hours, with the lowest concentrations occurring from December 1964 through February 1965.

Table 77

FORECAST QUALITY OF POPLAR CREEK DOWNSTREAM FROM THE PROPOSED SEWAGE TREATMENT PLANT:[a] 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Poplar Creek	Hypothetical station downstream from proposed sewage treatment plant	Chloride (in ppm)	20[b]	170	170	170
		Dissolved Solids (in ppm)	600[b]	850	850	850
		Dissolved Oxygen (in ppm)	4.8[c]	Between 2.5 and 5.0		
		Coliform Count (in MFCC/100 ml)	1,500[d]	More than 100,000		

[a] *A new sewage treatment plant is presently under construction near the mouth of Poplar Creek.*

[b] *Based on water analysis for October 1964 at sampling station Fx-3.*

[c] *Based on average for the period June through September 1964 with data for July excluded.*

[d] *Based on average for the period June through October 1964.*

Source: SEWRPC.

Coliform counts in the Pewaukee River were exceptionally high, reaching a maximum of 3,000,000 MFCC/100 ml and averaging 197,000 MFCC/100 ml. The highest counts occurred during the autumn and winter months at sampling station Fx-5. Relatively low counts occurred from July through October 1964 (no data for September). These counts ranged from 3,000 to 8,000 MFCC/100 ml and averaged 5,700 MFCC/100 ml. At sampling station Fx-6, the maximum coliform count was 160,000 MFCC/100 ml and occurred under ice cover in January and February 1964. Relatively low counts occurred from May through October 1964 (no data for September). These counts ranged from 400 to 7,000 MFCC/100 ml and averaged 2,600 MFCC/100 ml.

The maximum temperature of the Pewaukee River was 74°F at sampling station Fx-5 in July 1964. The average temperatures for the period of June through September 1964 were 65°F at station Fx-5 and 63°F at station Fx-6. The average temperature difference between these two stations of two degrees may have been due in part to the higher heating effect of the sun upon waters of generally higher turbidity downstream from the outfall of the Pewaukee sewage treatment plant. Pewaukee Lake may have discharged warmer water into the upper reach of the Pewaukee River which then blended with cooler ground water seeping into the stream channel. The temperature of the treated sewage from the Pewaukee sewage treatment plant may also have contributed to the slightly higher stream temperature at station Fx-5.

Table 78

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-6 ON THE PEWAUKEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-22-64	2	10- 7-64
Iron	0.00	"	0.03	"
Manganese	--	--	0.01	"
Chromium	--	--	<0.02	"
Hexavalent Chromium	--	--	0.00	"
Calcium	73	4-22-64	77	"
Magnesium	44	"	46	"
Sodium (and Potassium)	25	"	55	"
Bicarbonate	270	"	385	"
Carbonate	0	"	5	"
Sulfate	142	"	87	"
Chloride	35	"	65	"
Fluoride	--	--	<0.6	"
Nitrite	0.0	4-22-64	0.0	"
Nitrate	--	--	0.8	"
Phosphorus	--	--	.96	"
Cyanide	--	--	< .01	12-28-64
Oil	--	--	<0.5	10- 7-64
Detergents	0.2	4-22-64	0.5	"
Dissolved Solids	450	"	530	"
Hardness	363	"	382	"
Noncarbonate Hardness	145	"	60	"
Calcium Hardness	182	"	192	"
Magnesium Hardness	181	"	190	"
Alkalinity P	0	"	2.5	"
Alkalinity M	220	"	320	"
Specific Conductance	700	"	840	"
pH	7.8	"	8.0	"
Color	20	"	20	"
Turbidity	5	"	2	"
Biochemical Oxygen Demand	4.0	"	2.3	"
Dissolved Oxygen	10.9	"	12.6	"
Coliform Count	15,000	"	1,500	"
Temperature (^{o}F)	53	"	44	"

Source: SEWRPC.

Streamflow and Precipitation: The Pewaukee River is a shallow stream occupying a relatively narrow channel. At sampling station Fx-6, a distance 6.3 miles from the outlet of Pewaukee Lake, this stream was 0.7 feet deep and 16 feet wide when measured during low flow in October 1964. The flow conditions make this stream potentially suitable for waste assimilation, preservation of fish and wildlife, and aesthetic use. The flow of the Pewaukee River was measured by the SEWRPC at sampling station Fx-6 in January, February, March, April, and October 1964, as indicated in Table 80. The daily precipitation at Waukesha from January 1964 through February 1965 is listed in Table 61.

Forecast Quality of the Pewaukee River for the Year 1990: Population studies by the SEWRPC indicate that the Village of Pewaukee sewage treatment plant had an estimated connected population in 1963 of about 2,900 people. The estimated future connected populations and average daily sewage flow rates by 1990 are listed in Table 81 for each of the alternative regional land use plans. The forecast quality of the Pewaukee River which may be expected in 1990 at sampling station Fx-6 under the various land use alternatives is indicated in Table 82. It should be noted that the forecast quality does not differ between the three plans, although the estimated populations and sewage flow rates differ greatly between the plans. This is because the anticipated sewage flow rates far exceed the assumed base flow of the stream.

Table 79

WATER QUALITY CONDITIONS OF PEWAUKEE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	120	65	30	17
Dissolved Solids (ppm)	755	520	350	14
Dissolved Oxygen (ppm)	12.6	7.3	0.7	27
Coliform Count (MFCC/100 ml) .	3,000,000	197,000	400	25
Temperature (°F)	74	48	32	25

Source: SEWRPC.

Table 80

STREAMFLOW MEASUREMENTS OF THE PEWAUKEE RIVER: 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-6	1-21-64	1.2	0.30
	2- 4-64	0.9	0
	3-20-64	7.3	0.11
	4-29-64	25	0.60
	10- 6-64	0.3	0.01

[a] *Measured at U. S. Weather Bureau Station at Waukesha, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 81

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES
FOR THE VILLAGE OF PEWAUKEE SEWAGE TREATMENT PLANT
1963 AND 1990 ALTERNATIVE LAND USE PLANS

<table>
<tr><th rowspan="3">Location of Sewage Treatment Plant</th><th colspan="4">Estimated Connected Population</th></tr>
<tr><th rowspan="2">Existing 1963</th><th colspan="3">1990</th></tr>
<tr><th>Controlled Existing Trend Plan</th><th>Corridor Plan</th><th>Satellite City Plan</th></tr>
<tr><td rowspan="6">Village of Pewaukee</td><td>2,900</td><td>6,400</td><td>11,800</td><td>5,400</td></tr>
<tr><td colspan="4">Estimated Average Daily Sewage Flow Rate</td></tr>
<tr><td>300,000[a]</td><td>1,200,000</td><td>2,100,000</td><td>1,000,000</td></tr>
<tr><td>0.5[b]</td><td>1.9</td><td>3.2</td><td>1.5</td></tr>
<tr><td colspan="4">Estimated Low Flow of the Pewaukee River at Station Fx-6</td></tr>
<tr><td>Less than 0.5[b]</td><td>1</td><td>3</td><td>1</td></tr>
</table>

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 82

FORECAST QUALITY OF THE PEWAUKEE RIVER AT SAMPLING STATION FX-6: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Pewaukee River	Fx-6	Chloride (in ppm)	65[a]	170	170	170
		Dissolved Solids (in ppm)	530[a]	750	750	750
		Dissolved Oxygen (in ppm)	8.2[b]	Less than 5.0 but generally more than 3.0 can be expected to occur frequently at Station Fx-6.		
		Coliform Count (in MFCC/ 100 ml)	1,500[c]	More than 5,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for period June through September 1964.*

[c] *Based on average for period June through October 1964. No data available for September 1964.*

Source: SEWRPC.

Mukwonago River

Present Stream Quality: One sampling station, Fx-12, was established on the Mukwonago River and is located 9.1 miles downstream from the source of the river, 0.3 miles upstream from the Mukwonago sewage treatment plant, and 2.1 miles upstream from the confluence of the Mukwonago River and the Fox River. The Mukwonago River joins the Fox River 35.7 miles from the source of the Fox River, 0.6 miles downstream from station Fx-11, and 4.3 miles upstream from station Fx-13.

The Mukwonago River is a calcium bicarbonate stream of relatively constant total mineralization. In all 13 complete chemical analyses, calcium (ranging from 58 to 36 ppm) was the predominant cation; and bicarbonate (ranging from 385 to 230 ppm) exceeded all other anion concentrations. Maximum nitrate concentration was 0.9 ppm. No analysis for total phosphorus was made. Selected water analyses of the Mukwonago River at sampling station Fx-12 are indicated in Table 83. Water quality conditions of the Mukwonago River are indicated in Table 84.

The chloride concentrations of the Mukwonago River are exceptionally low both in terms of the encountered maximum of 15 ppm and the average concentration of 5 ppm. The assumed "background" concentration of the stream is 5 ppm. The maximum concentrations of 15 ppm occurred in three consecutive months from November 1964 through January 1965. The Mukwonago River shows very slight effects of chloride buildup. This buildup to possibly 10 ppm above the "background" level of concentration is temporary and appears to be seasonal. The condition described applies to that part of the Mukwonago River below the outlet of Lower Phantom Lake and above the Mukwonago sewage treatment plant, a distance of 0.5 miles.

Table 83

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-12 ON THE MUKWONAGO RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	1	4-22-64	15	10-7-64
Iron	0.17	"	0.03	"
Manganese	--	--	0.01	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	47	4-22-64	50	10-7-64
Magnesium	33	"	36	"
Sodium (and Potassium)	10	"	15	"
Bicarbonate	295	"	295	"
Carbonate	0	"	20	"
Sulfate	20	"	28	"
Chloride	5	"	5	"
Fluoride	--	--	--	--
Nitrite	0.0	4-22-64	0.0	10-7-64
Nitrate	--	--	0.4	"
Phosphorus	--	--	--	--
Cyanide	--	--	<0.4	1-27-65
Oil	--	--	--	--
Detergents	0.1	4-22-64	0.0	10-7-64
Dissolved Solids	260	"	315	"
Hardness	253	"	276	"
Noncarbonate Hardness	15	"	0	"
Calcium Hardness	116	"	126	"
Magnesium Hardness	137	"	150	"
Alkalinity P	0	"	10	"
Alkalinity M	240	"	260	"
Specific Conductance	440	"	462	"
pH	7.9	"	8.6	"
Color	15	"	5	"
Turbidity	10	"	2	"
Biochemical Oxygen Demand	2.9	"	1.8	"
Dissolved Oxygen	10.1	"	11.9	"
Coliform Count	100	"	100	"
Temperature (°F)	55	"	51	"

Source: SEWRPC.

Table 84

WATER QUALITY CONDITIONS OF THE MUKWONAGO RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	15	5	0	13
Dissolved Solids (ppm)	400	285	240	13
Dissolved Oxygen (ppm)	16.5	11.6	9.3	13
Coliform Count (MFCC/100 ml)	1,000	250	100	12
Temperature (°F)	77	49	35	12

Source: SEWRPC.

The dissolved solids concentrations of the Mukwonago River are relatively low as compared to the other streams and watercourses of the Region. The "background" dissolved solids concentration of the stream may be approximately 285 ppm. The maximum of 400 ppm dissolved solids concentration occurred in December 1964 and involved increases in the bicarbonate, calcium, sodium, sulfate, and chloride concentrations.

The dissolved oxygen concentrations of the Mukwonago River are adequate for the preservation of fish life. The minimum concentration was 9.2 ppm. The maximum, average, and minimum dissolved oxygen concentrations for the four months of June through September were 9.8, 9.6, and 9.3 ppm. A dam spillway near the outlet of Lower Phantom Lake is located about 750 feet upstream from sampling station Fx-12. This spillway and the very minor waste loading that occurs on the stream, together with the broad, flat, and shallow depth of the stream bed and the rapid flow of the stream over a gravel and boulder channel bottom, are the principal factors in aerating the river.

The coliform counts in the Mukwonago River were exceptionally low, the maximum being less than 1,000 MFCC/100 ml and the average less than 250 MFCC/100 ml. These counts are thought to be of "background" concentrations derived from local surface runoff rather than originating from sources of human body wastes.

The temperature of the Mukwonago River at sampling station Fx-12 was three to four degrees warmer during the winter months of December, January, and February than the Fox River at stations Fx-11 and Fx-13 during the same period. The stream did not freeze over during the 14-month period of the SEWRPC study, indicating a constant rather than an intermittent source of relatively warm water in sufficient quantity to sustain the stream temperature at no less than three degrees above freezing temperature from bank to bank and for a distance of possibly 2.1 miles to the confluence of the Mukwonago River and the Fox River. This temperature condition is presumably caused by the relatively rapid local seepage of ground water into the stream channel. The volume of ground water seeping at normal ground water temperature (about 51^{o}F) into the channel is sufficient to sustain above freezing temperatures as the river water moves to the Fox River.

Streamflow and Precipitation: The Mukwonago River is shallow and wide downstream from the Phantom Lake outlet. At sampling station Fx-12, a distance 9.6 miles from the source, this stream was 0.6 feet deep and 60 feet wide when measured during low flow in October 1964. The flow conditions make this stream suitable for waste assimilation, preservation of aquatic life, whole- and partial-body contact recreation, and aesthetic use.

The flow of the Mukwonago River was measured by the SEWRPC at sampling station Fx-12 in February, March, April, and October 1964, as indicated in Table 85. Daily precipitation at Waukesha from January 1964 through February 1965 is listed in Table 61.

Forecast Quality of the Mukwonago River for the Year 1990: Population studies by the SEWRPC indicate that the Village of Mukwonago sewage treatment plant had an estimated connected population in 1963 of about 1,900 people. The estimated future connected populations and average daily sewage flow rates for 1990 are listed in Table 86 for each of the alternative regional land use plans. The forecast quality of the Mukwonago River which may be expected in 1990 at sampling station Fx-12 under the three land use alternatives is indicated in Table 87.

Table 85

STREAMFLOW MEASUREMENTS OF THE MUKWONAGO RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-12	2- 7-64	32	0
	3-20-64	28	0.11
	4-29-64	37	0.60
	10- 5-64	13	0.01

[a] *Measured at U. S. Weather Bureau Station at Waukesha, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 86

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE VILLAGE OF MUKWONAGO SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Mukwonago	1,900	6,800	10,600	13,200
	Estimated Average Daily Sewage Flow Rate			
	200,000[a] 0.3[b]	1,200,000 1.9	1,900,000 2.9	2,400,000 3.7
	Estimated Low Flow of Mukwonago River Downstream from the Village of Mukwonago Sewage Treatment Plant			
	13	14	15	16

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

It should be noted that the forecast quality of the Mukwonago River applies only to the reach of this stream that extends from the outlet of Lower Phantom Lake to immediately upstream from the Village of Mukwonago sewage treatment plant. Under the three alternative land use plans, the future quality of this reach of stream should be subject to little impact from the increasing population. The forecast quality of the Mukwonago River at its confluence with the Fox River is discussed under the section of this chapter dealing with the Fox River.

Muskego Canal

Present Stream Quality: One sampling station, Fx-15, was established on the Muskego Canal. This station is located 1.1 miles below the Muskego Lake spillway and 0.2 miles above Wind Lake.

Two complete chemical analyses were run on water samples collected in April and October 1964 from the Muskego Canal at sampling station Fx-15. The stream is subject to small changes in total mineralization. It shifted from a calcium sulfate water in April to a calcium bicarbonate water in October. The calcium, sulfate, and bicarbonate concentrations of the two samples for April and October were 213 and 115 ppm, 910 and 252 ppm, and 150 and 295 ppm, respectively. The maximum calcium (213 ppm) and magnesium (97 ppm) concentrations in this watercourse in April 1964 account for the fact that the hardness (928 ppm) at this station was the maximum encountered at any of the 87 sampling stations in the Region. The maximum nitrate determination was 2.1 ppm. No analysis for total phosphorus was made. Selected water analyses of the Muskego Canal at station Fx-15 are indicated in Table 88. Water quality conditions of the Muskego Canal are indicated in Table 89.

The chloride concentration of the Muskego Canal at station Fx-15 was 35 ppm. This concentration is higher than would be expected as the "background" concentration of the stream. With quality data consisting of only two identical analyses, no estimate can be made of the "background" chloride concentration. If it were assumed that the "background" chloride concentration was as much as 15 ppm, the Muskego Canal had a chloride impact of at least 20 ppm from human sources.

The variations in dissolved solids concentrations of the Muskego Canal result principally from variations in sulfate, bicarbonate, calcium, magnesium, and sodium concentrations. Muskego Lake, which is the

Table 87

FORECAST QUALITY OF THE MUKWONAGO RIVER AT SAMPLING STATION FX-12: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964[a]	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Mukwonago River	Fx-12	Chloride (in ppm)	5[b]	5	5	5
		Dissolved Solids (in ppm)	315[b]	300	300	300
		Dissolved Oxygen (in ppm)	9.6[c]	More than 5.0		
		Coliform Count (in MFCC/100 ml)	< 450[d]	Less than 2,400		

[a] *Sampling station Fx-12 is upstream from the Village of Mukwonago sewage treatment plant, and the quality of the Mukwonago River at this station does not represent the quality of this river downstream from the sewage treatment plant.*

[b] *Based on water analysis for October 1964.*

[c] *Based on average for months of June through September 1964.*

[d] *Based on average count for June, July, August, and October 1964. No data available for September 1964.*

Source: SEWRPC.

source of the Muskego Canal, is bordered by extensive swamp areas. Analyses of streams having swampy headwaters or flowing through large swamps indicate that such streams tend to be relatively high in sulfate concentration. The high concentration of this parameter in April 1964 may be due to a spring flushing effect upon the lake and its swamps caused by the large amount of precipitation that occurred in April prior to sampling.

The dissolved oxygen concentrations of the Muskego Canal during the period from June through September 1964 ranged from 8.5 to 0.8 ppm and averaged 3.6 ppm. These concentrations were on the average 6.1 ppm less than the solubility of oxygen in water at the prevailing temperatures at the time of sampling. The dissolved oxygen concentration of the Muskego Canal was suppressed to critical levels (3.0 ppm or less) in the months of August and September 1964 and again in January 1965. Concentrations in the range of 5.0 to 3.1 ppm occurred in May, July, and October 1964.

Coliform counts in the Muskego Canal were relatively high and reached a maximum of 70,000 MFCC/100 ml in June 1964. During the period June through September 1964, the counts ranged from 13,000 to 70,000 MFCC/100 ml and averaged 44,000 MFCC/100 ml. These concentrations make the Muskego Canal unsuitable for partial- or whole-body recreational use.

Table 88

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-15 ON THE MUSKEGO CANAL: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	1	4-23-64	8	10-8-64
Iron	0.00	"	0.10	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	213	4-23-64	114	10-8-64
Magnesium	97	"	54	"
Sodium (and Potassium)	90	"	25	"
Bicarbonate	150	"	295	"
Carbonate	0	"	0	"
Sulfate	910	"	252	"
Chloride	35	"	35	"
Fluoride	--	--	--	--
Nitrite	0.0	4-23-64	0.0	10-8-64
Nitrate	--	--	2.1	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.0	4-23-64	0.1	10-8-64
Dissolved Solids	1,420	"	635	"
Hardness	928	"	505	"
Noncarbonate Hardness	805	"	265	"
Calcium Hardness	531	"	284	"
Magnesium Hardness	397	"	221	"
Alkalinity P	0	"	0	"
Alkalinity M	125	"	240	"
Specific Conductance	1,560	"	884	"
pH	7.4	"	7.4	"
Color	15	"	130	"
Turbidity	2	"	4	"
Biochemical Oxygen Demand	2.4	"	3.5	"
Dissolved Oxygen	7.9	"	4.8	"
Coliform Count	66,000	"	17,000	"
Temperature (^{o}F)	52	"	48	"

Source: SEWRPC.

Table 89

WATER QUALITY CONDITIONS OF MUSKEGO CANAL (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	35	35	35	2
Dissolved Solids (ppm)	1,420	1,030	635	2
Dissolved Oxygen (ppm)	14.3	6.2	0.8	10
Coliform Count (MFCC/100 ml)	70,000	33,000	400	10
Temperature (^{o}F)	72	52	32	10

Source: SEWRPC

The temperature of the Muskego Canal at sampling station Fx-15 reached a maximum of 72°F in July 1964. The average temperature for the period of June through September 1964 was 66°F. Temperature conditions of the Muskego Canal are favorable for the preservation of fish life.

Streamflow and Precipitation: Muskego Canal is a relatively deep and wide rectilinear watercourse connecting Muskego Lake with Wind Lake. At sampling station Fx-15, the water in this canal was approximately 3.8 feet deep and extended 35 feet from bank to bank during low-flow conditions in October 1964. The flow and channel characteristics make the watercourse potentially suitable for partial-body contact recreation and aesthetic use.

The flow of the Muskego Canal was not measured by the SEWRPC during this study. As with a number of streams and watercourses in southeastern Wisconsin, the flow of water through the Muskego Canal is regulated by a water control structure and is, therefore, not necessarily related to rainfall or ice and snowmelt.

Forecast Quality of the Muskego Canal for the Year 1990: The location of a sewage treatment plant serving the expected future populations indicated in Table 90 will have a profound adverse effect upon the water quality of Muskego Lake. It is the considered opinion of the SEWRPC that high coliform counts, eutrophication, and algae bloom may convert Muskego Lake into an undesirable body of water, an aesthetic problem to local residents, unsuited for abundant fish life and useless for all forms of whole- or partial-body contact recreation. The future stream quality conditions which may be expected in the Muskego Canal in 1990 at sampling station Fx-15 is indicated in Table 91 for the various alternative regional land use plans. The forecast quality of the Muskego Canal is meant to reflect the quality of Muskego Lake at a time when it has reached a relatively stabilized condition in relation to the impact from the sewage wastes discharged from the treatment plant. It should be noted that the forecast stream quality does not differ between the three plans, although the forecast populations and sewage flow rates differ greatly between the plans. The similarity in quality in the canal is due to the water quality of Muskego Lake, which, during periods of relatively little or no rainfall, will tend to approach the quality of the treated sewage being discharged into the lake from the proposed City of Muskego sewage treatment plant.

Wind Lake Drainage Canal

Present Stream Quality: One sampling station, Fx-16, was established on the Wind Lake Drainage Canal

Table 90

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE CITY OF MUSKEGO SEWAGE TREATMENT PLANT:[a] 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
City of Muskego	0	31,600	44,000	9,500
	Estimated Average Daily Sewage Flow Rate			
	0	5,700,000[b]	7,900,000	1,700,000
	0	8.8[c]	12.2	2.6
	Estimated Low Flow of the Muskego Canal at Station Fx-15			
	0	7[c]	10	2

[a] This proposed plant is to be located near the mouth of an unnamed watercourse connecting Little Muskego Lake with Muskego Lake.

[b] Gallons per day.

[c] Cubic feet per second.

Source: SEWRPC.

Table 91

FORECAST QUALITY OF THE MUSKEGO CANAL AT SAMPLING STATION FX-15: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Water Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Muskego Canal	Fx-15	Chloride (in ppm)	35[a]	170	170	170
		Dissolved Solids (in ppm)	635[a]	850	850	850
		Dissolved Oxygen (in ppm)	3.6[b]	Less than 3.0 probably will occur most frequently		
		Coliform Count (in MFCC/ 100 ml)	44,000[b]	More than 50,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

and is located 6.1 miles downstream from the Wind Lake outlet and 1.1 miles upstream from where the canal joins the Fox River. This confluence is 55.8 miles from the source of the Fox River and 6.6 miles downstream from sampling station Fx-14, the nearest upstream station on the Fox River.

Two complete chemical analyses were run on samples collected from the Wind Lake Drainage Canal. The watercourse has relatively constant total mineralization. The quality of water in this canal shifted from a calcium sulfate water in April to a calcium bicarbonate water in October 1964. The calcium, sulfate, and bicarbonate concentrations of the two samples for April and October were 110 and 71 ppm, 300 and 132 ppm, and 220 and 315 ppm, respectively. Maximum nitrate concentration was 3.6 ppm. On October 8, 1964, total phosphorus was 0.38 at station Fx-16. Selected water analyses of the Wind Lake Drainage Canal at sampling station Fx-16 are indicated in Table 92. Water quality conditions of the Wind Lake Drainage Canal are indicated in Table 93.

The chloride concentrations of the Wind Lake Drainage Canal at sampling station Fx-16 were low, varying from 30 ppm in April to 35 ppm in October. If it were assumed that the "background" chloride concentration was as much as 15 ppm, the Wind Lake Drainage Canal had a chloride impact of 15 to 20 ppm from human sources.

The variations in the dissolved solids concentrations of the Wind Lake Drainage Canal result principally from variations in sulfate, bicarbonate, calcium, magnesium, and sodium concentrations. This condition

Table 92

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-16 ON THE WIND LAKE DRAINAGE CANAL: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	1	4-23-64	2	10-8-64
Iron	0.05	"	0.11	"
Manganese.	--	--	0.01	"
Chromium	--	--	< 0.005	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	110	4-23-64	71	"
Magnesium.	86	"	45	"
Sodium (and Potassium)	0	"	45	"
Bicarbonate.	220	"	315	"
Carbonate.	0	"	10	"
Sulfate.	300	"	132	"
Chloride	30	"	35	"
Fluoride	--	--	< 0.65	"
Nitrite.	0.0	4-23-65	0.0	"
Nitrate.	--	--	1.3	"
Phosphorus	--	--	0.38	"
Cyanide.	--	--	--	--
Oil.	--	--	< 1	10-8-64
Detergents	0.0	4-23-64	0.1	"
Dissolved Solids	635	"	495	"
Hardness	627	"	363	"
Noncarbonate Hardness.	445	"	85	"
Calcium Hardness	274	"	178	"
Magnesium Hardness	353	"	185	"
Alkalinity P	0	"	5	"
Alkalinity M	180	"	270	"
Specific Conductance	1,120	"	700	"
pH	7.5	"	8.4	"
Color.	100	"	30	"
Turbidity.	10	"	10	"
Biochemical Oxygen Demand. . . .	3.8	"	3.4	"
Dissolved Oxygen	9.2	"	10.1	"
Coliform Count	200	"	200	"
Temperature (°F)	54	"	50	"

Source: SEWRPC.

Table 93

WATER QUALITY CONDITIONS OF WIND LAKE DRAINAGE CANAL (1964-1965)

Parameter	Numerical Value Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	35	35	30	2
Dissolved Solids (ppm)	635	565	495	2
Dissolved Oxygen (ppm)	16.0	10.2	4.1	11
Coliform Count (MFCC/100 ml) .	7,000	1,800	100	11
Temperature (°F)	76	53	32	11

Source: SEWRPC.

is similar to the shift in water quality that was found occurring in Muskego Canal at sampling station Fx-15 and may be imposed by seasonal quality changes occurring in Muskego Lake and in Wind Lake.

The dissolved oxygen concentrations of the Wind Lake Drainage Canal during the period from June through September 1964 ranged from 9.8 to 4.1 ppm and averaged 7.5 ppm. These concentrations were on the average 3.4 ppm less than the solubility of oxygen in water at the prevailing temperature at the time of sampling. The dissolved oxygen concentrations of the Wind Lake Drainage Canal were lowered to a minimum of 4.1 ppm in July 1964, which is substandard but normally adequate for the preservation of fish life.

Coliform counts in the Wind Lake Drainage Canal were relatively low, reaching a maximum of 7,000 MFCC/100 ml in July 1964 and in February 1965. During the period of June through September 1964, the counts ranged from less than 100 MFCC/100 ml to 7,000 MFCC/100 ml and averaged 2,500 MFCC/100 ml or less than 1,000 MFCC/100 ml, if the July determination is excluded. These concentrations make the lower reaches of the Wind Lake Drainage Canal suitable for partial- or whole-body contact recreation.

The temperature of the Wind Lake Drainage Canal at sampling station Fx-16 reached a maximum of 76°F in June 1964. The average temperature for the period of June through September was 69°F. Temperature conditions of the Wind Lake Drainage Canal are favorable for the preservation of fish life.

Streamflow and Precipitation: The Wind Lake Drainage Canal is a relatively deep and wide rectilinear watercourse. At sampling station Fx-16, a distance 6.1 miles from the Wind Lake outlet, the canal was 55 1/2 feet wide and had a maximum depth of 5.9 feet when measured in October 1964. The characteristically sluggish flow of this watercourse probably precludes its use for all but four of the ten major uses listed in Table 4. The four uses are waste assimilation, preservation of aquatic life, recreation, and aesthetic use.

The waste assimilation capacity of the Wind Lake Drainage Canal at sampling station Fx-16 is presently being only occasionally exceeded with respect to coliform count. Following the period of heavy rainfall in July 1964, the coliform count reached a high of 7,000 MFCC/100 ml. During the same month, the dissolved oxygen concentration was lowered to a level of 4.1 ppm, which is substandard for the preservation of fish life. Excluding the July measurement, the minimum dissolved oxygen concentration was 7.0 ppm; and the average was 10.8 ppm. Swimming in the Wind Lake Drainage Canal may be dangerous because of the steep banks that afford poor foothold.

The flow of the Wind Lake Drainage Canal was measured by the SEWRPC in May and October 1964, as listed in Table 94. Table 62 indicates the daily precipitation at Burlington, Wisconsin, from January 1964 through February 1965.

Forecast Quality of the Wind Lake Drainage Canal for the Year 1990: Population studies by the SEWRPC indicate that the population in the watershed area tributary to the Wind Lake Drainage Canal at station Fx-16 totaled approximately 2,500 in 1963. This area is presently served by septic tank systems. There are no sewage treatment plants proposed to serve any part of this area by the year 1990. The estimated future population levels by 1990 are listed in Table 95 for each of the alternative regional land use plans. Because

Table 94

STREAMFLOW MEASUREMENTS OF THE WIND LAKE DRAINAGE CANAL: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-16	5-2-64	0	0.68
	10-6-64	0	0

[a] *Measured at U. S. Weather Bureau Station at Burlington, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 95

ESTIMATED POPULATION OF THE WIND LAKE DRAINAGE AREA: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
		1990		
	Existing 1963	Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Wind Lake Drainage Area	2,500	5,800	8,800	2,900

Source: SEWRPC.

this population is not served by sewage treatment plants, no sewage flow rates are indicated. The future water quality of the canal which may be expected in 1990 at sampling station Fx-16 under the various land use alternatives is indicated in Table 96. In estimating future water quality conditions at Fx-16, consideration was taken of the estimated future water quality conditions of the Muskego Canal.

White River

Present Stream Quality: Two sampling stations, Fx-18 and Fx-20, were established on the White River. Station Fx-18 is 4.4 miles from the source and 0.8 miles upstream from where Como Creek joins the White River. Station Fx-20 is 13.4 miles downstream from station Fx-18 and 2.2 miles upstream from the

Table 96

FORECAST QUALITY OF THE WIND LAKE DRAINAGE CANAL AT SAMPLING STATION FX-16: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Wind Lake Drainage Canal	Fx-16	Chloride (in ppm)	35[a]	150	150	125
		Dissolved Solids (in ppm)	495[a]	700	700	650
		Dissolved Oxygen (in ppm)	7.5[b]	More than 8.0		
		Coliform Count (in MFCC/ 100 ml)	2,500[b]	More than 3,000		

[a] Based on water analysis for October 1964.

[b] Based on average for period June through September 1964.

Source: SEWRPC.

confluence of the White River and the Fox River. The Lake Geneva sewage treatment plant discharges its treated wastes into the White River at a point 2.8 miles upstream from station Fx-18.

Six complete chemical analyses were run on water samples collected from the White River. Two of these were collected at Fx-18 in April and October 1964; and four were collected in February, April, May, and October at Fx-20. One sample was collected at station Fx-20 for special chemical analysis.

The White River is a calcium bicarbonate stream subject to small changes in total mineralization. In the six complete chemical analyses, calcium (ranging from 80 to 45 ppm) was the predominant cation; and bicarbonate (ranging from 400 to 270 ppm) exceeded all other anion concentrations. Maximum nitrate concentration was 6.8 ppm. On October 8, 1964, total phosphorus was 0.36 ppm. Selected water analyses of the White River at sampling stations Fx-18 and Fx-20 are indicated in Table 97 and Table 98, respectively. Water quality conditions of the White River are indicated in Table 99. The average numerical values are weighted averages.

Table 97

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-18 ON THE WHITE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-23-64	12	10-8-64
Iron	0.03	"	0.03	"
Manganese	--	--	0.02	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	45	4-23-64	80	10-8-64
Magnesium	36	"	43	"
Sodium (and Potassium)	5	"	70	"
Bicarbonate	270	"	360	"
Carbonate	0	"	50	"
Sulfate	43	"	65	"
Chloride	5	"	55	"
Fluoride	--	--	--	--
Nitrite	0.0	4-23-64	0.3	10-8-64
Nitrate	--	--	6.8	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.0	4-23-64	0.4	10-8-64
Dissolved Solids	265	"	560	"
Hardness	260	"	378	"
Noncarbonate Hardness	40	"	0	"
Calcium Hardness	113	"	200	"
Magnesium Hardness	147	"	178	"
Alkalinity P	0	"	25	"
Alkalinity M	220	"	345	"
Specific Conductance	486	"	766	"
pH	8.3	"	8.0	"
Color	5	"	0	"
Turbidity	3	"	10	"
Biochemical Oxygen Demand	2.7	"	2.8	"
Dissolved Oxygen	12.6	"	11.8	"
Coliform Count	21,000	"	83,000	"
Temperature (°F)	50	"	50	"

Source: SEWRPC.

Table 98

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-20 ON THE WHITE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-23-64	4	10-8-64
Iron	0.16	"	0.07	"
Manganese	--	--	0.00	"
Chromium	--	--	< 0.01	"
Hexavalent Chromium	--	--	0.00	"
Calcium	66	4-23-64	67	"
Magnesium	37	"	48	"
Sodium (and Potassium)	5	"	45	"
Bicarbonate	310	"	400	"
Carbonate	0	"	10	"
Sulfate	52	"	62	"
Chloride	15	"	35	"
Fluoride	--	--	< 0.55	"
Nitrite	0.0	4-23-64	0.0	"
Nitrate	--	--	0.9	"
Phosphorus	--	--	0.36	"
Cyanide	--	--	--	--
Oil	--	--	< 1	10-8-64
Detergents	0.0	4-23-64	0.1	"
Dissolved Solids	340	"	470	"
Hardness	318	"	365	"
Noncarbonate Hardness	65	"	20	"
Calcium Hardness	164	"	168	"
Magnesium Hardness	154	"	197	"
Alkalinity P	0	"	5	"
Alkalinity M	255	"	340	"
Specific Conductance	564	"	640	"
pH	8.0	"	8.8	"
Color	30	"	0	"
Turbidity	10	"	8	"
Biochemical Oxygen Demand	2.0	"	2.4	"
Dissolved Oxygen	9.5	"	12.5	"
Coliform Count	4,100	"	2,000	"
Temperature (°F)	51	"	50	"

Source: SEWRPC.

Table 99

WATER QUALITY CONDITIONS OF THE WHITE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	55	25	5	6
Dissolved Solids (ppm)	560	390	265	6
Dissolved Oxygen (ppm)	14.1	10.1	5.6	23
Coliform Count (MFCC/100 ml)	570,000	28,000	400	23
Temperature (°F)	77	51	32	23

Source: SEWRPC.

The chloride concentrations of the White River were relatively low, varying at sampling station Fx-18 from 5 ppm in April to 55 ppm in October 1964, and at station Fx-20 from 15 ppm in April to 35 ppm in October 1964. Assuming a "background" concentration of 10 ppm, the White River had a chloride impact of 5 to 45 ppm from human sources. None of the present or potential uses of the White River are adversely affected by these chloride concentrations.

The average dissolved solids concentration of the White River is comparatively low. At sampling station Fx-18, the dissolved solids in April was 265 as compared to 560 in October. This increase in mineralization was due largely to the increases in sodium, carbonate, chloride, bicarbonate, calcium, and silica concentrations. At sampling station Fx-20, the dissolved solids concentrations were 340 ppm in April and 305 ppm in May 1964. This decrease was due largely to decreased calcium, bicarbonate, and silica concentrations. In October the dissolved solids level was 470 ppm, an increase of 130 ppm since April. This increase was due largely to increases in the bicarbonate, sodium, chloride, magnesium, sulfate, and carbonate concentrations.

The minimum dissolved oxygen concentration in the White River was 5.6 ppm at station Fx-20 in June 1964. During the months of June through September, the maximum, average, and minimum dissolved oxygen concentrations at station Fx-18 were 10.3, 8.8, and 5.9 ppm, respectively. During the same period, the corresponding figures at station Fx-20 were 10.6, 7.6, and 5.6 ppm, respectively. The dissolved oxygen concentrations in the White River are favorable for the preservation of fish life.

Coliform counts in the White River were comparatively high, being as much as 570,000 MFCC/100 ml in February 1965 at station Fx-18 and 20,000 MFCC/100 ml in June at station Fx-20. During the period from June through September, the maximum, average, and minimum concentrations at station Fx-18 were 61,000, 19,000, and 2,000 MFCC/100 ml, respectively. During the same period, the corresponding figures at station Fx-20 were 20,000, 10,500, and 3,000 MFCC/100 ml. The White River is consequently presently unsuited for partial- or whole-body contact recreation.

The maximum temperature of the White River was $77^{\circ}F$ in June 1964. The average temperature for the period of June through September 1964 was $68^{\circ}F$ at stations Fx-18 and Fx-20. The temperature condition of the river is suitable for fish life.

Streamflow and Precipitation: The White River is a relatively shallow, meandering stream. At sampling stations Fx-18 and Fx-20, 4.4 miles and 17.8 miles from the source, respectively, the maximum depths of this stream were 1.0 and 1.4 feet, respectively, when measured during low flow in October 1964. The corresponding widths were 21 and 60 feet. The flow of the White River was measured by the SEWRPC at sampling station Fx-18 and Fx-20 in May and October 1964 as indicated in Table 100. The flow conditions make this stream suitable for waste assimilation, preservation of aquatic life, recreation, and aesthetic use. Daily precipitation at Burlington, Wisconsin, from January 1964 through February 1965 is listed in Table 62.

Forecast Quality of the White River for the Year 1990: Population studies by the SEWRPC indicate that the population of the City of Lake Geneva totaled approximately 4,500 in 1963. The equivalent estimated population and average daily sewage flow rates for 1990 are listed in Table 101 for each of the alternative regional land use plans. Included with the data pertaining to the City of Lake Geneva are equivalent data pertaining to the villages of Williams Bay, Fontana, and Walworth, although the treated wastes from these villages apparently do not discharge into the White River or into Lake Geneva and, therefore, may have no direct bearing on the present or future water quality which may be expected in 1990 at sampling station Fx-20 under the three alternative land use plans, as indicated in Table 102. Considered in this forecast are the effects that Como Creek may have upon the quality of the White River at station Fx-20.

Como Creek

Present Stream Quality: One sampling station, Fx-19, was established on Como Creek. Station Fx-19 is 0.9 miles from the outlet of Lake Como and 2.9 miles from where Como Creek enters the White River. No sewage treatment plants are presently located on Como Creek.

Table 100

STREAMFLOW MEASUREMENTS OF THE WHITE RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-18	5-1-64	48	0.45
Fx-18	10-9-64	3.4	0.13
Fx-20	5-1-64	105	0.45
Fx-20	10-9-64	4.8	0.13

[a] *Measured at U. S. Weather Bureau Station at Burlington, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 101

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR SEWAGE TREATMENT PLANTS NEAR LAKE GENEVA: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
City of Lake Geneva	4,500	11,000	24,800	17,700
Village of Williams Bay	1,500	3,500	3,700	3,500
Village of Fontana	1,500	3,400	1,500	3,200
Village of Walworth	0	500	0	900
	Estimated Average Daily Sewage Flow Rate			
City of Lake Geneva	540,000[a] 0.8[b]	1,980,000 3.1	4,460,000 6.9	3,190,000 4.9
Village of Williams Bay	180,000[a] 0.3[b]	420,000 0.6	440,000 0.7	420,000 0.6
Village of Fontana	180,000[a] 0.3[b]	410,000 0.6	180,000 0.3	380,000 0.6
Village of Walworth	0[a] 0[b]	50,000 0.1	0 0	90,000 0.1
	Estimated Low Flow of the White River at Station Fx-18			
	3[b]	5	9	7

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 102

FORECAST QUALITY OF THE WHITE RIVER AT SAMPLING STATION FX-20: 1990 ALTERNATIVE LAND USE PLANS

Stream	Parameter	Sampling Station	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
White River	Fx-20	Chloride (in ppm)	35[a]	75	165	115
		Dissolved Solids (in ppm)	470[a]	550	700	625
		Dissolved Oxygen (in ppm)	7.6[b]	More than 7.5		
		Coliform Count	10,500[b]	More than 25,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Como Creek is a calcium bicarbonate stream of relatively constant total mineralization. In the two complete chemical analyses that were run on water samples collected from Como Creek in April and October 1964, calcium (ranging from 73 to 53 ppm) was the predominant cation; and bicarbonate (ranging from 425 to 340 ppm) exceeded all other anion concentrations. Maximum nitrate concentration was 2.4 ppm. On October 8, 1964, total phosphorus was 0.24 ppm. Selected water analyses of Como Creek at sampling station Fx-19 are indicated in Table 103. Water quality conditions of Como Creek are indicated in Table 104.

The chloride concentrations of Como Creek were very low, varying from 5 ppm in April to 15 ppm in October 1964. Assuming a background chloride concentration of 5 ppm, Como Creek had a chloride impact of 0 to 10 ppm from human sources.

The maximum dissolved solids concentration of Como Creek is very low compared to that of other streams and watercourses in southeastern Wisconsin. The concentration of this parameter varied within narrow limits, being 390 ppm in April and 430 ppm in October 1964. The increase in dissolved solids resulted principally from increases in bicarbonate, calcium, silica, and chloride concentrations offset by a decrease in sulfate concentration.

The minimum dissolved oxygen concentration in Como Creek was 4.8 ppm in August 1964. During the months of June through September, the maximum, average, and minimum concentrations were 7.2, 6.1, and 4.8 ppm. Dissolved oxygen conditions on Como Creek were substandard for the preservation of fish life in August 1964.

Table 103

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-19 ON COMO CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-23-64	14	10-8-64
Iron	0.03	"	0.10	"
Manganese	--	--	0.04	"
Chromium	--	--	<0.01	"
Hexavalent Chromium	--	--	0.00	"
Calcium	53	4-23-64	73	"
Magnesium	47	"	45	"
Sodium (and Potassium)	25	"	25	"
Bicarbonate	340	"	425	"
Carbonate	0	"	0	"
Sulfate	89	"	47	"
Chloride	5	"	15	"
Fluoride	--	--	<0.4	"
Nitrite	0.0	4-23-64	0.0	"
Nitrate	--	--	1.8	"
Phosphorus	--	--	0.24	"
Cyanide	--	--	--	--
Oil	--	--	2	10-8-64
Detergents	0.0	4-23-64	0.0	"
Dissolved Solids	390	"	430	"
Hardness	329	"	368	"
Noncarbonate Hardness	50	"	20	"
Calcium Hardness	134	"	181	"
Magnesium Hardness	195	"	187	"
Alkalinity P	0	"	0	"
Alkalinity M	280	"	350	"
Specific Conductance	616	"	654	"
pH	7.9	"	7.4	"
Color	15	"	10	"
Turbidity	5	"	25	"
Biochemical Oxygen Demand	1.8	"	6.6	"
Dissolved Oxygen	11.3	"	5.3	"
Coliform Count	6,700	"	16,000	"
Temperature (^{o}F)	51	"	50	"

Source: SEWRPC.

Table 104

WATER QUALITY CONDITIONS OF COMO CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	15	10	5	2
Dissolved Solids (ppm)	430	410	390	2
Dissolved Oxygen (ppm)	12.3	8.3	4.8	11
Coliform Count (MFCC/100 ml)	21,000	7,200	300	11
Temperature (^{o}F)	77	51	32	11

Source: SEWRPC.

Coliform counts in Como Creek, although relatively low with respect to certain other streams in the Region, were high with respect to standards for recreational water use, having a maximum concentration of 21,000 MFCC/100 ml in June 1964. During the period from June through September, the maximum, average, and minimum concentrations were 21,000, 11,800, and 2,000 MFCC/100 ml. Como Creek is not suited for partial- or whole-body contact recreation.

The maximum temperature of Como Creek was 77^{o}F in June 1964. The average temperature for the period of June through September 1964 was 67^{o}F. The temperature condition of Como Creek is suitable for fish life.

Streamflow and Precipitation: Como Creek is a shallow stream with few meander bends. At sampling station Fx-19, a distance 0.9 miles from the Lake Como outlet, this stream was 0.3 feet deep and 0.4 feet wide when measured during low flow in October 1964. The flow conditions make this stream suitable for waste assimilation and aesthetic use. The flow of Como Creek was measured by the SEWRPC at sampling station Fx-19 in April and October 1964, as indicated in Table 105. Daily precipitation at Burlington, Wisconsin, from January 1964 through February 1965 is listed in Table 62.

Forecast Quality of Como Creek for the Year 1990: Population studies by the SEWRPC indicate that the estimated population of the drainage area tributary to Como Creek at station Fx-19 in 1963 was about 1,800 people. The sanitary waste disposal needs of these people are presently served exclusively by septic tank systems. No municipal sewage treatment plant has been proposed at this time for this area. The estimated present and future population under each of the alternative regional land use plans is listed in Table 106. The future water quality of Como Creek which may be expected in 1990 at sampling station Fx-19 under the three land use alternatives is indicated in Table 107.

Honey Creek

Present Stream Quality: Two sampling stations, Fx-21 and Fx-23, were established on Honey Creek. Station Fx-21 is 11.4 miles from its source, approximately 2.3 miles downstream from the East Troy

Table 105

STREAMFLOW MEASUREMENTS OF COMO CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-19	4-30-64 10- 9-64	12 0.1	0.45 0.13

[a] *Measured at U. S. Weather Bureau Station at Burlington, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 106

ESTIMATED POPULATION OF THE LAKE COMO DRAINAGE AREA: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
		1990		
	Existing 1963	Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Lake Como Drainage Area	1,800	3,100	2,700	2,700

Source: SEWRPC.

Table 107

FORECAST QUALITY OF COMO CREEK AT SAMPLING STATION FX-19: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Como Creek	Fx-19	Chloride (in ppm)	15[a]	25	20	20
		Dissolved Solids (in ppm)	430[a]	450	440	440
		Dissolved Oxygen (in ppm)	6.1[b]	More than 6.0		
		Coliform Count (in MFCC / 100 ml)	11,800[b]	More than 15,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

sewage treatment plant and 14.3 miles upstream from station Fx-23. Sampling station Fx-23 is 1.1 miles upstream from where Honey Creek enters the White River.

Honey Creek is a calcium bicarbonate stream of relatively constant total mineralization. In six complete analyses run on water samples collected from Honey Creek at stations Fx-21 and Fx-23, calcium (ranging from 104 to 56 ppm) was the predominant cation; and bicarbonate (ranging from 380 to 275 ppm) exceeded all other anion concentrations. Maximum nitrate was 5.8 ppm. On October 8, 1964, total phosphorus was 0.14 ppm at station Fx-23. Selected water analyses of Honey Creek at sampling stations Fx-21 and Fx-23 are indicated in Table 108 and Table 109, respectively. Water quality conditions of Honey Creek are indicated in Table 110. The average numerical values in this table are weighted averages.

The chloride concentrations of Honey Creek were unusually stable in that all six analyses of samples taken at stations Fx-21 and Fx-23 in February, April, May, and October 1964 indicated a concentration of 15 ppm. None of the present or potential uses of Honey Creek are adversely affected by these chloride concentrations.

Dissolved solids concentrations of Honey Creek were relatively low compared to that of other streams and watercourses in the Region. At station Fx-21 the total dissolved solids was 455 ppm in April and 435 ppm in October 1964. At station Fx-23 the concentration of this parameter varied from 440 to 340 ppm. From April to October, decreases at both stations in calcium, magnesium, and sulfate concentrations were

Table 108

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-21 ON HONEY CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	9	4-24-64	10	10-8-64
Iron	0.02	"	0.07	"
Manganese	--	--	0.01	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	104	4-24-64	71	10-8-64
Magnesium	48	"	40	"
Sodium (and Potassium)	0	"	35	"
Bicarbonate	275	"	340	"
Carbonate	0	"	30	"
Sulfate	145	"	58	"
Chloride	15	"	15	"
Fluoride	--	--	--	--
Nitrite	0.0	4-24-64	0.0	10-8-64
Nitrate	--	--	4.2	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.1	4-24-64	0.1	10-8-64
Dissolved Solids	455	"	435	"
Hardness	459	"	342	"
Noncarbonate Hardness	235	"	10	"
Calcium Hardness	260	"	177	"
Magnesium Hardness	199	"	165	"
Alkalinity P	0	"	15	"
Alkalinity M	225	"	310	"
Specific Conductance	784	"	630	"
pH	8.0	"	8.0	"
Color	55	"	0	"
Turbidity	7	"	3	"
Biochemical Oxygen Demand	1.8	"	2.8	"
Dissolved Oxygen	10.4	"	10.3	"
Coliform Count	34,000	"	3,200	"
Temperature (^{o}F)	50	"	50	"

Source: SEWRPC.

largely offset by increased sodium and bicarbonate concentrations, resulting in little change in the dissolved solids of the water sampled in April and in October.

The minimum dissolved oxygen concentration in Honey Creek at sampling station Fx-21 was 5.2 ppm in June 1964. During the months of June through September, the maximum, average, and minimum concentrations were 12.9, 8.5, and 5.2 ppm, respectively. The minimum dissolved oxygen concentration in Honey Creek at sampling station Fx-23 was 4.8 ppm in June 1964. During the months of June through September, the maximum, average, and minimum concentrations were 10.2, 7.0, and 4.8 ppm, respectively. The dissolved oxygen concentration in Honey Creek was substandard for the preservation of fish life at Fx-23 at the time of sampling in June 1964.

Coliform counts in Honey Creek were relatively low compared to other streams in the Region but were high with respect to standards for recreational water use, having a maximum concentration of 40,000 MFCC/100 ml at station Fx-21 in January 1965 and a maximum of 7,000 MFCC/100 ml at Fx-23 in July 1964. During the period from June through September, the maximum, average, and minimum concentrations

Table 109

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-23 ON HONEY CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-23-64	7	10-8-64
Iron	0.05	"	0.10	"
Manganese	--	--	--	--
Chromium	--	--	< 0.01	10-8-64
Hexavalent Chromium	--	--	0.00	"
Calcium	74	4-23-64	63	"
Magnesium	45	"	38	"
Sodium (and Potassium)	10	"	35	"
Bicarbonate	345	"	380	"
Carbonate	0	"	0	"
Sulfate	78	"	53	"
Chloride	15	"	15	"
Fluoride	--	--	< 0.85	"
Nitrite	0.0	4-23-64	0.0	"
Nitrate	--	--	1.8	"
Phosphorus	--	--	0.14	"
Cyanide	--	--	--	--
Oil	--	--	1	10-8-64
Detergents	0.0	4-23-64	0.1	"
Dissolved Solids	400	"	400	"
Hardness	370	"	315	"
Noncarbonate Hardness	85	"	5	"
Calcium Hardness	185	"	157	"
Magnesium Hardness	185	"	158	"
Alkalinity P	0	"	0	"
Alkalinity M	285	"	310	"
Specific Conductance	656	"	542	"
pH	8.0	"	8.0	"
Color	55	"	0	"
Turbidity	15	"	9	"
Biochemical Oxygen Demand	2.6	"	2.2	"
Dissolved Oxygen	8.6	"	12.1	"
Coliform Count	400	"	3,000	"
Temperature (^{o}F)	53	"	51	"

Source: SEWRPC.

Table 110

WATER QUALITY CONDITIONS OF HONEY CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	15	15	15	6
Dissolved Solids (ppm)	455	420	340	6
Dissolved Oxygen (ppm)	14.5	10.2	4.8	23
Coliform Count (MFCC/100 ml)	40,000	9,400	100	23
Temperature (^{o}F)	77	51	32	23

Source: SEWRPC.

at station Fx-21 were 23,000, 11,800, and less than 1,000 MFCC/100 ml, respectively. Corresponding concentrations at station Fx-23 were 7,000, 3,800, and 2,000 MFCC/100 ml. Honey Creek is unsuited for partial- or full-body contact recreation at Fx-21 and unsuited for full-body contact recreation at station Fx-23.

The maximum temperature of Honey Creek was 77°F in June 1964. The average temperature for the period of June through September 1964 was 68°F at station Fx-21 and 69°F at station Fx-23. The temperature condition of the creek is suitable for fish life.

Streamflow and Precipitation: Honey Creek, a second rank tributary of the Fox River, is a relatively deep meandering stream. At sampling station Fx-23, a distance of 17.5 miles from the source, the stream had a depth of 2.2 feet and extended 45 feet from bank to bank during low-flow conditions in October 1964. The flow and channel characteristics make Honey Creek suitable for waste assimilation, preservation of aquatic life, partial-body contact recreation, and aesthetic use.

The flow of Honey Creek was measured by the SEWRPC at sampling station Fx-23 in May and October 1964, as indicated in Table 111. Daily precipitation at Burlington, Wisconsin, from January 1964 through February 1965 is listed in Table 62.

Forecast Quality of Honey Creek for the Year 1990: Population studies by the SEWRPC indicate that the Village of East Troy sewage treatment plant had a connected population in 1963 of about 1,600 people. The estimated future connected populations and average daily sewage flow rates for 1990 are listed in Table 112 for each of the alternative regional land use plans. The future water quality conditions of Honey Creek which may be expected in 1990 at sampling stations Fx-21 and Fx-23 under the three land use alternatives are indicated in Table 113.

Sugar Creek

Present Stream Quality: One sampling station, Fx-22, was established on Sugar Creek. Station Fx-22 is 6.7 miles downstream from the source of Sugar Creek and 21.5 miles upstream from the point where Sugar Creek joins Honey Creek. No sewage treatment plants are presently located within the area drained by Sugar Creek.

Sugar Creek is a calcium bicarbonate stream of relatively constant total mineralization. In the two complete chemical analyses run on water samples collected in April and October 1964, calcium (ranging from 80 to 72 ppm) was the predominant cation; and bicarbonate (ranging from 415 to 365 ppm) exceeded all other anion concentrations. Maximum nitrate was 3.6 ppm. No analysis for total phosphorus was made. Selected water analyses of Sugar Creek at sampling station Fx-22 are indicated in Table 114. Water quality conditions of Sugar Creek are indicated in Table 115.

The chloride concentrations of Sugar Creek were relatively low, varying from 30 ppm in April to 20 ppm in October. Assuming a background chloride concentration of 10 ppm, Sugar Creek had a chloride impact of 10 to 20 ppm from human sources.

Table 111

STREAMFLOW MEASUREMENTS OF HONEY CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-23	5-1-64 10-6-64	80 13	0.45 0

[a] *Measured at U. S. Weather Bureau Station at Burlington, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 112

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES OF THE VILLAGE OF EAST TROY SEWAGE TREATMENT PLANT: 1990

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
East Troy	1,600	3,600	5,200	4,400
	Estimated Average Daily Sewage Flow Rate			
	192,000[a] 0.4[b]	432,000 0.81	936,000 1.45	528,000 1.03
	Estimated Low Flow of Honey Creek at Station Fx-23			
	13[a]	13	14	14

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 113

FORECAST QUALITY OF HONEY CREEK AT SAMPLING STATIONS FX-21 AND FX-23: 1990

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Honey Creek	Fx-21 Fx-23	Chloride (in ppm)	15[a] 15[a]	20 20	25 25	25 25
		Dissolved Solids (in ppm)	435[a] 400[a]	445 410	450 420	450 420
		Dissolved Oxygen (in ppm)	8.5[b] 7.0[b]	Between 8.5 to 9.5 Between 5.0 and 7.0		
		Coliform Count (in MFCC/ 100 ml)	11,800[b] 3,800[b]	More than 20,000 More than 5,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Table 114

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-22 ON SUGAR CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-24-64	15	10-8-64
Iron	0.03	"	0.05	"
Manganese	--	--	0.01	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	80	4-24-64	72	10-8-64
Magnesium	40	"	35	"
Sodium (and Potassium)	30	"	45	"
Bicarbonate	365	"	415	"
Carbonate	10	"	0	"
Sulfate	70	"	46	"
Chloride	30	"	20	"
Fluoride	--	--	--	--
Nitrite	0.0	4-24-64	0.0	10-8-64
Nitrate	--	--	1.8	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.1	4-24-64	0.1	10-8-64
Dissolved Solids	450	"	440	"
Hardness	363	"	325	"
Noncarbonate Hardness	45	"	0	"
Calcium Hardness	199	"	180	"
Magnesium Hardness	164	"	145	"
Alkalinity P	5	"	0	"
Alkalinity M	310	"	340	"
Specific Conductance	694	"	636	"
pH	8.4	"	8.0	"
Color	40	"	5	"
Turbidity	5	"	3	"
Biochemical Oxygen Demand	< 0.5	"	1.4	"
Dissolved Oxygen	12.1	"	10.4	"
Coliform Count	1,800	"	1,800	"
Temperature ($^{\circ}$F)	50	"	50	"

Source: SEWRPC.

The maximum dissolved solids concentration of Sugar Creek was very low as compared to that of other streams and watercourses in southeastern Wisconsin. In the two complete chemical analyses, this parameter varied within narrow limits, being 450 ppm in April and 440 in October 1964. The principal part of the dissolved solids concentration (possibly 425 ppm) is derived from ground water seepage into the stream channel.

The minimum dissolved oxygen concentration in Sugar Creek at sampling station Fx-22 was 8.5 ppm. During the months of June through September 1964, the maximum, average, and minimum concentrations were 11.8, 9.9, and 8.5 ppm, respectively. The dissolved oxygen concentration of Sugar Creek is suitable for the maintenance of fish life.

Coliform counts in Sugar Creek were relatively low at station Fx-22. The maximum count of 13,000 MFCC/100 ml occurred in June 1964, and the minimum of less than 100 MFCC/100 ml occurred in December 1964. During the period from June through September 1964, the maximum, average, and minimum concentrations at station Fx-22 were 13,000, 6,400, and 1,400 MFCC/100 ml, respectively. Nevertheless, Sugar Creek is unsuited for partial- and whole-body contact recreation in its upper reaches.

Table 115

WATER QUALITY CONDITIONS OF SUGAR CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	30	25	20	2
Dissolved Solids (ppm)	450	445	440	2
Dissolved Oxygen (ppm)	13.9	10.9	8.5	10
Coliform Count (MFCC/100 ml) .	13,000	3,100	100	10
Temperature (^{O}F)	71	52	32	10

Source: SEWRPC.

The maximum temperature of Sugar Creek was 71^{O}F in June 1964. Average temperature for the period of June through September 1964 was 65^{O}F. The temperature condition of the creek is suitable for the maintenance of fish life.

Streamflow and Precipitation: Sugar Creek is a relatively deep meandering stream. When measured at sampling station Fx-22, a distance 6.7 miles from the source, the creek had a maximum depth of 2.2 feet and a width of approximately 24 feet during low-flow conditions in October 1964. The stream is potentially suitable for waste assimilation, preservation of aquatic life, partial-body contact, recreation, and aesthetic use.

The waste assimilation capacity of Sugar Creek was exceeded by the coliform counts, which rendered the stream unsuitable for full- or partial-body contact recreation at sampling station Fx-22. However, it is thought that this condition was local and applied to a reach of the creek near the small community of Abells Corners from about one mile upstream from station Fx-22 to approximately three miles downstream from the station.

The flow of Sugar Creek was not measured during this study.

Forecast Quality of Sugar Creek for the Year 1990: Population studies by the SEWRPC indicate that the Sugar Creek sub-watershed had an estimated population of 2,000 people in 1963. The population is presently served by domestic septic tank systems. In the alternative regional land use plans, the Sugar Creek sub-watershed is retained principally as an agricultural and recreational area of low-density population. No sewage treatment plants are proposed. The estimated populations of the Sugar Creek sub-watershed for the year 1990 are listed in Table 116.

Table 116

ESTIMATED POPULATION OF THE SUGAR CREEK SUB-WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
		1990		
	Existing 1963	Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sugar Creek Sub-watershed	2,000	2,100	3,400	8,500

Source: SEWRPC.

The quality of the stream in its middle and lower reaches should not be affected significantly by urban development under any of the three alternative regional land use plans nor impaired for recreational use nor for the preservation of fish and wildlife. Table 117 provides a general estimate of the water quality of the middle and lower reaches of Sugar Creek.

Bassett Creek

Present Stream Quality: Two sampling stations, Fx-25 and Fx-26, were established on Bassett Creek. Station Fx-25 is 1.3 miles from the source of Bassett Creek and about 350 feet downstream from the confluence with an unnamed watercourse that receives the treated wastes from the Twin Lakes sewage treatment plant. This plant is located 0.7 miles upstream from the confluence. Sampling station Fx-26 is located about 400 feet from where Bassett Creek joins the Fox River. The distance between the stations is 3.6 miles.

Bassett Creek is predominantly a calcium bicarbonate stream of relatively constant total mineralization. Complete chemical analyses were run on four water samples collected at the two stations on Bassett Creek. At station Fx-25 the analyses indicate that the quality of the stream changed from a calcium bicarbonate water in April 1964 to a sodium bicarbonate water in October 1964. This change resulted from a marked increase in the concentrations of sodium (from 15 to 100 ppm), bicarbonate (from 360 to 420 ppm), and chloride (from 20 to 90 ppm) between the times of sampling in April and in October 1964. Calcium concentrations decreased from 80 to 76 ppm between April and October 1964. In the two complete chemical analyses run on water samples collected at station Fx-26, calcium (ranging from 86 to 75 ppm) was the predominant cation; and bicarbonate (ranging from 440 to 310 ppm) exceeded all other anion concentra-

Table 117

FORECAST QUALITY OF THE MIDDLE AND LOWER REACHES OF SUGAR CREEK: 1990

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sugar Creek	Fx-22	Chloride (in ppm)	20[a]	20	20	30
		Dissolved Solids (in ppm)	440[a]	450	450	500
		Dissolved Oxygen (in ppm)	9.9[b]	Between 8.0 and 12.0		
		Coliform Count (in MFCC/ 100 ml)	2,000[b]	2,000	2,500	4,000

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

tions. The maximum nitrate concentrations at stations Fx-25 and Fx-26 were 7.0 and 2.9 ppm, respectively. Selected water analyses of Bassett Creek at sampling station Fx-26 are indicated in Table 118. Water quality conditions of Bassett Creek are indicated in Table 119.

The chloride concentrations of Bassett Creek at sampling stations Fx-25 and Fx-26 were 20 and 90 ppm, respectively, in April and 30 and 55 ppm, respectively, in October 1964. With an assumed "background" chloride concentration of 10 ppm, Bassett Creek had a chloride impact of 10 to 80 ppm from human sources.

The variations in the dissolved solids concentrations of Bassett Creek resulted principally from changes in the concentrations of sulfate, bicarbonate, sodium, chloride, and magnesium. No present or potential water uses are adversely affected by the concentrations of dissolved solids. The principal part of the dissolved solids concentration (possibly 400 ppm) is derived from ground water seepage.

The dissolved oxygen concentrations of Bassett Creek reached a minimum of 3.3 ppm at sampling station Fx-25 and 8.2 ppm at station Fx-26 in August 1964. For the period from June through September, the

Table 118

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-26 ON BASSETT CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-23-64	15	10-8-64
Iron	0.02	"	0.16	"
Manganese	--	--	0.03	"
Chromium	--	--	<0.01	"
Hexavalent Chromium	--	--	0.00	"
Calcium	86	4-23-64	75	"
Magnesium	77	"	41	"
Sodium (and Potassium)	25	"	65	"
Bicarbonate	310	"	440	"
Carbonate	0	"	0	"
Sulfate	280	"	58	"
Chloride	30	"	55	"
Fluoride	--	--	<0.6	"
Nitrite	0	4-23-64	0.1	"
Nitrate	--	--	2.9	"
Phosphorus	--	--	1.9	"
Cyanide	--	--	--	--
Oil	--	--	1	10-8-64
Detergents	0.1	4-23-64	0.4	"
Dissolved Solids	655	"	530	"
Hardness	534	"	356	"
Noncarbonate Hardness	280	"	0	"
Calcium Hardness	216	"	188	"
Magnesium Hardness	318	"	168	"
Alkalinity P	0	"	0	"
Alkalinity M	255	"	360	"
Specific Conductance	908	"	762	"
pH	8.0	"	8.0	"
Color	70	"	0	"
Turbidity	2	"	8	"
Biochemical Oxygen Demand	1.1	"	2.7	"
Dissolved Oxygen	9.2	"	10.8	"
Coliform Count	200	"	10,000	"
Temperature (°F)	52	"	50	"

Source: SEWRPC.

Table 119

WATER QUALITY CONDITIONS OF BASSETT CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	90	50	20	4
Dissolved Solids (ppm)	655	575	530	4
Dissolved Oxygen (ppm)	19.5	9.2	3.3	23
Coliform Count (MFCC/100 ml) .	250,000	32,000	200	23
Temperature (^{O}F)	73	50	32	23

Source: SEWRPC.

maximum, average, and minimum concentrations of dissolved oxygen at sampling stations Fx-25 and Fx-26 were 7.6, 4.9, and 3.3 ppm, and 10.8, 8.3, and 5.6 ppm, respectively. Concentrations of dissolved oxygen between 5.0 and 3.1 ppm occurred in July, August, and September 1964 at station Fx-25. The dissolved oxygen concentration at station Fx-26 is not substandard for the preservation of fish life.

Coliform counts in Bassett Creek were relatively high, reaching a maximum of 250,000 MFCC/100 ml at sampling station Fx-25 in June 1964 and a maximum of 51,000 MFCC/100 ml at sampling station Fx-26 in November 1964. During the period from June through September 1964, the maximum, average, and minimum counts at stations Fx-25 and Fx-26 were 250,000, 97,000, and 22,000 MFCC/100 ml and 13,000, 9,300, and 4,000 MFCC/100 ml, respectively. Bassett Creek is not suited for partial- or whole-body contact recreation.

The temperature of Bassett Creek reached a maximum of 73^{O}F in June 1964. The average temperature for the period of June through September was 64^{O}F at sampling station Fx-25 and 65^{O}F at sampling station Fx-26. Temperature conditions of Bassett Creek are favorable for the preservation of fish life.

Streamflow and Precipitation: Bassett Creek is a shallow meandering stream occupying a narrow channel. At sampling station Fx-26, a distance 5.0 miles from the source, this stream had a maximum depth of 0.6 feet and a width of 11 feet when measured under low-flow conditions in October 1964. The small size of this stream precludes its use for all but three of the ten major uses listed in Table 4. These three uses are waste assimilation, preservation of aquatic life, and aesthetic use.

The waste assimilation capacity of Bassett Creek is presently being exceeded by coliform count and by organic wastes that result in the depression of the dissolved oxygen in the upper reaches of the stream to substandard concentrations (5.0 to 3.1 ppm). The aesthetic value of Bassett Creek is diminished in the lower reaches of the stream by thick muck bottom conditions.

The flow of Bassett Creek was measured by the SEWRPC at station Fx-26 in April and October 1964, as indicated in Table 120. The daily precipitation at Burlington, Wisconsin, from January 1964 through February 1965 is listed in Table 62.

Table 120

STREAMFLOW MEASUREMENTS OF BASSETT CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-26	4-30 10- 9	4.7 0.4	0.30 0.13

[a] Measured at U. S. Weather Bureau Station at Burlington, Wisconsin.

Source: SEWRPC.

Forecast Quality of Bassett Creek for the Year 1990: Population studies by the SEWRPC indicate that the Village of Twin Lakes sewage treatment plant had an estimated connected population of 3,100 in 1963. The estimated future connected populations and average daily sewage flow rates for 1990 are listed in Table 121 for each of the alternative regional land use plans. The forecast quality of Bassett Creek which may be expected in 1990 at sampling stations Fx-25 and Fx-26 under the three land use alternatives is indicated in Table 122.

Nippersink Creek

Present Stream Quality: One sampling station, Fx-28, was established on Nippersink Creek. Station Fx-28 is 0.4 miles downstream from where the East Branch and North Branch join to form Nippersink Creek and 1.7 miles upstream from where it crosses the state line. Nippersink Creek does not join the Fox River in Wisconsin.

Nippersink Creek is a calcium bicarbonate stream of relatively constant total mineralization. Complete chemical analyses were run on two water samples collected from Nippersink Creek in April and October 1964. Calcium (ranging from 81 to 73 ppm) was the predominant cation; and bicarbonate (ranging from 365 to 355 ppm) exceeded all other anion concentrations. The maximum nitrate concentration was 2.4 ppm. On October 8, 1964, total phosphorus was 0.24 ppm. Selected water analyses of Nippersink Creek at sampling station Fx-28 are indicated in Table 123. Water quality conditions of Nippersink Creek are indicated in Table 124.

The chloride concentrations of Nippersink Creek were low, varying from 20 ppm in April to 30 ppm in October 1964. Assuming a "background" chloride concentration of 10 ppm, Nippersink Creek had a chloride impact of 10 to 20 ppm from human sources.

The dissolved solids concentrations of Nippersink Creek were relatively low, varying within the narrow limits of 450 to 455 ppm from April to October 1964, respectively. Slight changes in the concentrations of principal cations and anions offset each other, and the dissolved solids remained almost unchanged.

The minimum dissolved oxygen concentration encountered on Nippersink Creek was 8.8 ppm in February 1965. During the months of June through September 1964, the maximum, average, and minimum con-

Table 121

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE VILLAGE OF TWIN LAKES SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Twin Lakes	3,100	4,900	5,700	5,900
	Estimated Average Daily Sewage Flow Rate			
	400,000[a] 0.6[b]	600,000 0.9	1,000,000 1.5	1,100,000 1.7
	Estimated Low Flow of Bassett Creek at Station Fx-26			
	Less than 0.5[b]	Less than 0.7	1	1

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 122

FORECAST QUALITY OF BASSETT CREEK: 1990

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990: Controlled Existing Trend Plan	Forecast Quality for 1990: Corridor Plan	Forecast Quality for 1990: Satellite City Plan
Bassett Creek	Fx-25 Fx-26	Chloride (in ppm)	90[a] 55[a]	120 75	140 90	140 90
		Dissolved Solids (in ppm)	645[a] 530[a]	725 580	750 605	750 605
		Dissolved Oxygen (in ppm)	4.9[b] 8.2[b]	Less than 3.0 can be expected to occur frequently at Fx-25. Less than 5.0 but generally more than 3.0 can be expected at Fx-26		
		Coliform Count (in MFCC/ 100 ml)	97,000[b] 9,300[b]	More than 100,000 More than 12,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

centrations at sampling station Fx-28 were 12.8, 11.1, and 9.5 ppm, respectively. A marked condition of supersaturation (21.6 ppm) occurred in October during conditions of low flow. How far upstream and downstream this condition prevailed and to what extent fish life may have been adversely affected by such high dissolved oxygen concentrations are not known. No dead fish were observed at the sampling station at the time of sampling in October 1964.

Coliform counts in Nippersink Creek were relatively low. The maximum of 10,000 MFCC/100 ml occurred in September 1964. During the period from June through September, the maximum, average, and minimum concentrations were 10,000, 5,300, and 3,000 MFCC/100 ml. Nippersink Creek is suitable for partial-body contact recreation in the area near station Fx-28.

The maximum temperature of Nippersink Creek was 77°F in June 1964. The average temperature for the period June through September 1964 was 69°F. The temperature condition of the creek is suitable for fish life.

Streamflow and Precipitation: Nippersink Creek is a shallow meandering stream occupying a relatively wide channel at sampling station Fx-28. This station is 0.4 miles from the point of origin; and, when the streamflow was measured in October 1964 under low-flow conditions, the creek had a maximum depth of 1.3 feet and a width of 28 feet. As a preliminary evaluation based upon the size, flow, and quality of Nippersink Creek, it would appear that the stream is potentially suitable for waste assimilation, preservation of aquatic life, and aesthetic use.

The waste assimilation capacity of Nippersink Creek is presently being exceeded by the coliform counts which render the stream unsuitable for full-body contact recreation, and for partial-body contact recrea-

Table 123

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION FX-28 ON NIPPERSINK CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-23-64	12	10-8-64
Iron	0.10	"	0.03	"
Manganese.	--	--	0.03	"
Chromium	--	--	0.005	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	81	4-23-64	73	"
Magnesium.	47	"	43	"
Sodium (and Potassium)	15	"	35	"
Bicarbonate.	355	"	365	"
Carbonate.	10	"	10	"
Sulfate.	93	"	72	"
Chloride	20	"	30	"
Fluoride	--	--	0.35	"
Nitrite.	0.0	4-23-64	0.1	"
Nitrate.	--	--	1.7	"
Phosphorus	--	--	0.24	"
Cyanide.	--	--	--	--
Oil.	--	--	2	10-8-64
Detergents	0.1	4-23-64	0.1	"
Dissolved Solids	450	"	455	"
Hardness	397	"	360	"
Noncarbonate Hardness.	90	"	45	"
Calcium Hardness	202	"	183	"
Magnesium Hardness	195	"	177	"
Alkalinity P	5	"	5	"
Alkalinity M	300	"	310	"
Specific Conductance	690	"	620	"
pH	8.4	"	8.0	"
Color.	30	"	10	"
Turbidity.	6	"	4	"
Biochemical Oxygen Demand. . . .	0.6	"	2.0	"
Dissolved Oxygen	12.8	"	21.6	"
Coliform Count	100	"	1,000	"
Temperature (^{o}F)	52	"	50	"

Source: SEWRPC.

tion during part of the summer and autumn. The dissolved oxygen concentrations and stream depth are adequate for the preservation of fish life. The aesthetic value of the stream is occasionally diminished by heavy growth of floating microscopic and macroscopic plant life.

The flow of Nippersink Creek was measured by the SEWRPC at station Fx-28 in April and October 1964, as listed in Table 125. The daily precipitation at Antioch, Illinois, from January 1964 through February 1965 is indicated in Table 63.

Forecast Quality of Nippersink Creek for the Year 1990: Population studies by the SEWRPC indicate that the Nippersink Creek sub-watershed had a population of 1,500 persons in 1963. The future population levels under each of the three alternative regional land use plans are listed in Table 126. The existing population in 1963 of an estimated 1,500 people was served by domestic septic tank systems. In the alternative plans, the populations outside the service area of the existing City of Genoa sewerage system and its proposed expansion will continue to be served by septic tank systems.

The forecast quality of Nippersink Creek which may be expected in 1990 at sampling station Fx-28 under the three regional land use alternatives is indicated in Table 127.

Table 124

WATER QUALITY CONDITIONS OF NIPPERSINK CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	30	25	20	2
Dissolved Solids (ppm)	455	455	450	2
Dissolved Oxygen (ppm)	21.6	12.3	8.8	11
Coliform Count (MFCC/100 ml) .	10,000	2,700	100	11
Temperature (°F)	77	52	32	11

Source: SEWRPC.

Table 125

STREAMFLOW MEASUREMENTS OF NIPPERSINK CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Fx-28	4-30	30	0.64
	10- 9	5.8	0.10

[a] *Measured at U. S. Weather Bureau Station at Antioch, Illinois.*

Source: SEWRPC.

Table 126

ESTIMATED POPULATION OF THE NIPPERSINK CREEK SUB-WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
		1990		
	Existing 1963	Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Nippersink Creek Sub-watershed	1,500	2,300	3,200	2,300

Source: SEWRPC.

Table 127

FORECAST QUALITY OF NIPPERSINK CREEK AT SAMPLING STATION FX-28: 1990

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Nippersink Creek	Fx-28	Chloride (in ppm)	30[a]	40	50	40
		Dissolved Solids (in ppm)	450[a]	450	500	450
		Dissolved Oxygen (in ppm)	11.1[b]	More than 8.0		
		Coliform Count (in MFCC/ 100 ml)	5,300[b]	More than 6,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

KINNICKINNIC RIVER WATERSHED

The Kinnickinnic River watershed ranks fourth in population and eleventh in size as compared to the other 11 watersheds of the Region. An estimated 186,900 persons reside within this small, highly urbanized watershed, which has a total area of 25.7 square miles and an average population density of 7,270 people per square mile. Principal land uses include residential and transportation-communication, which together comprise 63.5 percent of the area of the watershed. The areas within the watershed devoted to each of eight major land use categories are listed in Table 128.

One stream was studied by the SEWRPC in the Kinnickinnic River watershed—the Kinnickinnic River proper. This stream rises near Lyons Park in the southwestern part of the City of Milwaukee and flows generally easterly and northerly approximately 9.6 miles to the Milwaukee harbor.

The northern boundary of the Kinnickinnic River watershed extends westward from the mouth of the river to halfway across the end-moraine system that parallels Lake Michigan. At this point the western boundary trends abruptly southeasterly, roughly along the western margin of a prominent moraine in the end-moraine system. Thence the southern boundary trends abruptly eastward across the moraine, down upon ground moraine, and up onto another broad end-moraine. Here the eastern boundary trends northwesterly along the eastern edge of the moraine and ends at the mouth of the Kinnickinnic River.

Kinnickinnic River

Present Stream Quality: One sampling station, Kk-1, was established on the Kinnickinnic River. This station is located 4.4 miles from the source and 5.4 miles upstream from the Milwaukee harbor entrance.

Based on SEWRPC estimate for 1963.

Table 128

EXISTING LAND USE IN THE KINNICKINNIC RIVER WATERSHED - 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Transportation-Communication.	8.2	5,271	32.07
Residential	8.0	5,165	31.42
Woodland, Wetland, and Unused Land.	4.0	2,548	15.50
Governmental-Institutional.	1.5	977	5.94
Industrial.	1.3	829	5.04
Park and Recreational	1.4	812	4.94
Agricultural.	0.7	453	2.76
Commercial.	0.6	383	2.33
Total	25.7	16,438	100.00

Source: SEWRPC.

The Kinnickinnic River watershed is served by the Milwaukee metropolitan sewerage system. Industrial and domestic waste water in combined storm and sanitary sewers serving 14 percent of the basin may discharge temporarily into the lower reaches of the Kinnickinnic River during periods of heavy rainfall. Seepage from springs reportedly also enters the stream channel and thus contributes, probably in a minor way, to the flow of the river. In an effort to improve the stream quality, dilution water is pumped during the summer months from Lake Michigan into the stream by a Milwaukee Metropolitan Sewerage Commission pumping station at E. Chase Avenue and S. First Street, which is located 2.7 miles downstream from sampling station Kk-1.

The Kinnickinnic River is a calcium bicarbonate stream subject to small changes in total mineralization. Complete chemical analyses were run on two water samples collected from the Kinnickinnic River in April and September 1964. Calcium (ranging from 93 to 51 ppm) was the predominant cation; and bicarbonate (ranging from 275 to 195 ppm) exceeded all other anion concentrations. The maximum nitrate concentration was 1.8 ppm. On September 23, 1964, total phosphorus was 0.72 ppm. Selected water analyses of the Kinnickinnic River at sampling station Kk-1 are indicated in Table 129. Water quality conditions of the Kinnickinnic River are indicated in Table 130.

The chloride concentrations of the Kinnickinnic River varied from 115 ppm in April to 20 ppm in September 1964. Assuming a "background" chloride concentration of 10 ppm, the river had a chloride impact of 10 to 105 ppm from human sources.

The dissolved solids concentrations varied from 680 ppm in April to 290 ppm in September 1964. No "background" concentration of dissolved solids can be assumed from the two complete water analyses of this watercourse.

The minimum dissolved oxygen content of the stream at sampling station Kk-1 was 7.3 ppm. During the months of June through September 1964, the maximum, average, and minimum concentrations were 11.6, 9.4, and 7.3 ppm, respectively. Figure 13 shows the variations in dissolved oxygen concentrations for the period May 1964 through February 1965 at sampling station Kk-1.

Coliform counts in the Kinnickinnic River were found to vary from a maximum of 340,000 to a minimum of 4,000 MFCC/100 ml. During the period June through September 1964, the maximum, average, and minimum concentrations at station Kk-1 were 340,000, 102,000, and 8,000 MFCC/100 ml, respectively. Figure 14 shows the variations of coliform counts for the period April 1964 through February 1965 at station Kk-1.

The maximum temperature of the Kinnickinnic River was 82°F in July 1964 and averaged 73°F for the period June through September 1964. Figure 15 shows the variations in stream temperature during the period May 1964 through February 1965.

Table 129

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION KK-1 ON THE KINNICKINNIC RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-9-64	4	9-23-64
Iron	0.06	"	0.17	"
Manganese	--	--	0.04	"
Chromium	--	--	0.06	"
Hexavalent Chromium	--	--	0.00	"
Calcium	93	4-9-64	51	9-23-64
Magnesium	49	"	24	"
Sodium (and Potassium)	80	"	20	"
Bicarbonate	275	"	195	"
Carbonate	30	"	0	"
Sulfate	168	"	75	"
Chloride	115	"	20	"
Fluoride	--	--	0.7	"
Nitrite	0.0	4-9-64	0.0	9-23-64
Nitrate	--	--	1.4	"
Phosphorus	--	--	0.72	"
Cyanide	--	--	0.03	10- 4-64
Oil	--	--	2	9-23-64
Detergents	0.2	4-9-64	0.1	"
Dissolved Solids	680	"	290	"
Hardness	435	"	226	"
Noncarbonate Hardness	160	"	65	"
Calcium Hardness	233	"	127	"
Magnesium Hardness	202	"	99	"
Alkalinity P	15	"	0.0	"
Alkalinity M	255	"	160	"
Specific Conductance	1,040	"	426	"
pH	8.0	"	7.3	"
Color	20	"	35	"
Turbidity	15	"	65	"
Biochemical Oxygen Demand	5.7	"	9.1	"
Dissolved Oxygen	11.8	"	8.3	"
Coliform Count	75,000	"	340,000	"
Temperature (^{o}F)	41	"	64	"

Source: SEWRPC.

Table 130

WATER QUALITY CONDITIONS OF THE KINNICKINNIC RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	115	65	20	2
Dissolved Solids (ppm)	680	485	290	2
Dissolved Oxygen (ppm)	13.3	10.6	7.3	11
Coliform Count (MFCC/100 ml)	340,000	77,000	4,000	11
Temperature (^{o}F)	82	57	32	11

Source: SEWRPC.

Figure 13

DISSOLVED OXYGEN CONCENTRATIONS IN THE KINNICKINNIC RIVER

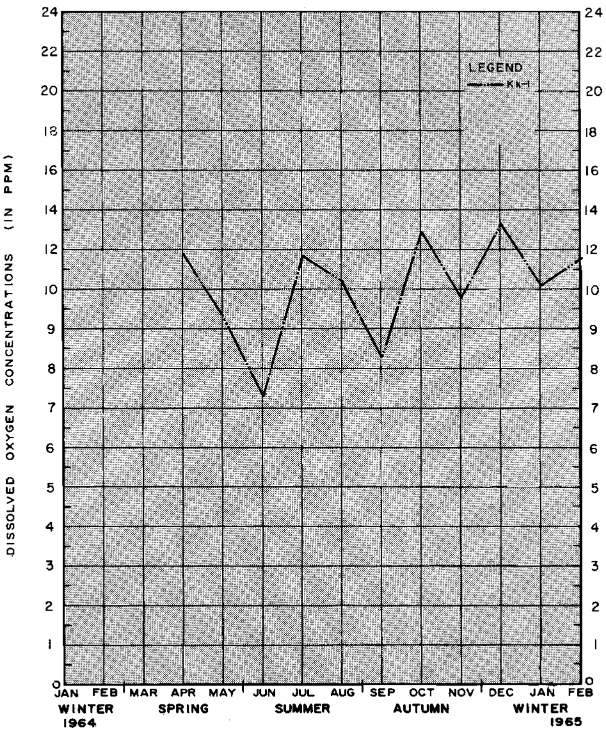


Figure 14

COLIFORM COUNT IN THE KINNICKINNIC RIVER

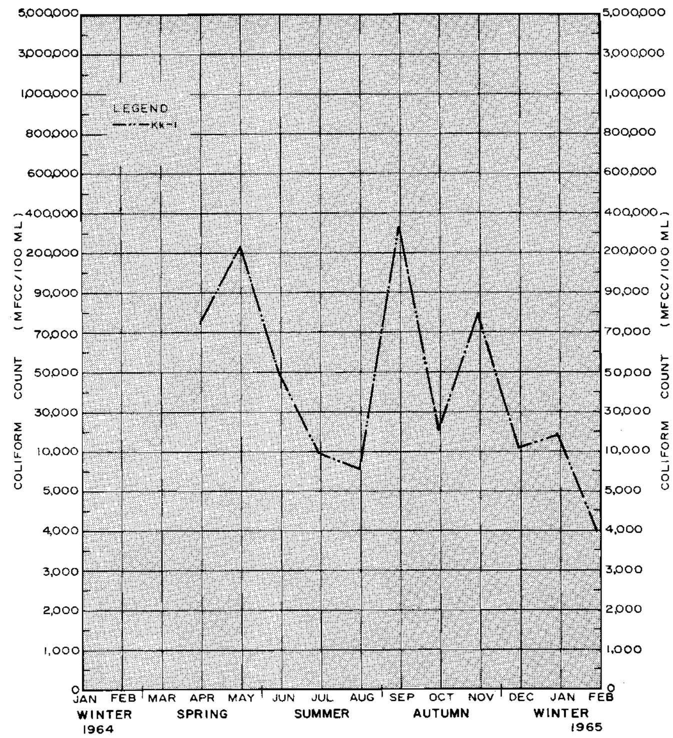
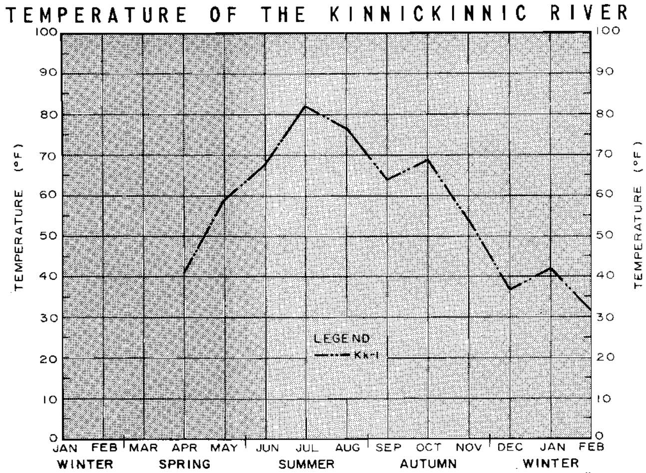


Figure 15

TEMPERATURE OF THE KINNICKINNIC RIVER



Streamflow and Precipitation: The Kinnickinnic River is a shallow watercourse occupying a channel which has been artificially straightened, deepened, and extensively lined with concrete. At sampling station Kk-1, a distance 4.4 miles from the source, this watercourse had a maximum depth of 0.7 feet and a width of 12 feet when measured under low-flow conditions in September 1964. It appears that the use of the Kinnickinnic River has become limited to navigation in its very lowest reach and to waste assimilation upstream from its navigable portion. The stream is generally very shallow and is, consequently, not being controlled for the preservation of fish life. Its aesthetic values are those of a stream artificially channeled, concreted, and converted to a functional drainageway for urban waste waters.

The flow of the Kinnickinnic River was measured by the SEWRPC at station Kk-1 in April and September 1964, as indicated in Table 131. The daily precipitation at West Allis, Wisconsin, from January 1964 through February 1965 is listed in Table 132.

Table 131

STREAMFLOW MEASUREMENTS OF THE KINNICKINNIC RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Kk-1	4-11-64 9-22-64	2.5 16	0 0.15

[a] *Measured at U. S. Weather Bureau Station at West Allis, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 132

PRECIPITATION[a] AT WEST ALLIS, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.14	--	0.27	--	--	--	0.03	0.05	0.35	0.02
2	--	--	--	0.73	0.21	0.14	--	--	0.10	0.01	0.48	0.02	0.20	--
3	--	--	--	--	--	--	--	--	--	--	--	0.01	--	--
4	--	--	0.61	--	--	--	--	--	--	--	0.05	0.13	--	--
5	--	--	0.47	0.87	--	--	--	--	--	--	--	--	--	--
6	--	--	--	0.47	.13	--	0.11	--	--	--	--	--	--	--
7	--	--	--	--	1.27	--	0.13	--	--	--	--	0.02	--	0.13
8	0.02	--	0.42	--	0.07	--	0.03	--	--	0.17	--	--	--	0.05
9	--	0.02	--	--	--	--	--	--	--	--	--	--	--	0.11
10	--	--	--	--	--	--	--	0.06	0.01	--	--	0.07	--	--
11	--	--	--	--	--	--	--	0.93	--	--	--	--	--	0.31
12	--	0.16	--	--	--	0.02	--	--	--	--	0.13	0.35	0.01	--
13	--	--	--	--	0.36	--	0.44	--	--	--	--	--	--	--
14	--	--	0.11	--	--	0.07	0.03	--	0.17	--	--	--	0.02	--
15	--	0.03	--	--	--	0.40	--	--	--	--	0.62	--	0.03	--
16	0.01	--	--	--	0.77	--	--	0.23	--	--	--	--	--	0.01
17	--	--	--	0.17	--	--	1.76	--	--	--	--	--	--	--
18	--	--	--	--	0.10	--	2.43	--	0.65	--	--	--	--	0.02
19	0.28	--	--	--	--	0.03	--	--	0.04	--	--	0.09	--	--
20	0.08	--	0.08	0.10	--	--	0.07	0.06	0.05	--	0.10	--	--	--
21	--	--	--	1.26	--	0.40	--	1.74	0.06	--	--	--	--	--
22	--	--	--	--	--	0.79	0.05	--	0.10	--	--	--	0.75	--
23	--	0.01	--	--	--	--	--	--	0.13	--	--	--	0.77	0.23
24	1.08	--	0.02	--	0.15	--	--	--	--	--	--	--	0.14	0.11
25	0.10	--	0.28	--	--	--	1.79	--	0.13	--	--	0.05	0.04	--
26	--	--	--	0.20	--	--	--	--	0.21	--	--	--	0.28	--
27	--	--	0.06	0.35	--	--	--	--	--	--	1.11	0.02	--	--
28	--	--	--	0.19	--	--	--	--	--	--	0.19	0.01	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	0.11	--	--	0.01	0.13	--	--	--	--	--	--
31	--	--	--	--	0.04	--	--	--	--	--	--	--	0.22	--
Total	1.57	0.22	2.05	4.45	3.24	1.85	7.12	3.15	1.65	0.18	2.71	0.82	2.81	0.99

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Forecast Quality of the Kinnickinnic River for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were 186,900 people living in the Kinnickinnic River watershed. All of this population is connected to the Milwaukee metropolitan sewerage system. Table 133 indicates the estimated populations for the year 1990 under the three alternative regional land use plans. No estimated sewage flow rates are indicated in the table because the sewage is not discharged into the river except during periods of storm water runoff that causes overflow from combined sewers. Table 134 indicates the stream quality of the Kinnickinnic River in 1964 with respect to four selected parameters. The forecast quality of the river by 1990 is indeterminate because the flow consists largely of industrial wastes and storm sewer discharges.

Table 133

ESTIMATED POPULATION OF THE KINNICKINNIC RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Kinnickinnic River Watershed	186,900	219,000	228,000	222,000

Source: SEWRPC.

Table 134

FORECAST QUALITY OF THE KINNICKINNIC RIVER AT SAMPLING STATION KK-1: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Kinnickinnic River	Kk-1	Chloride (in ppm)	115[a]	Present stream quality determined by industrial wastes and storm sewer discharges. Water quality by the year 1990 indeterminate.		
		Dissolved Solids (in ppm)	680[a]			
		Dissolved Oxygen (in ppm)	9.4[b]			
		Coliform Count (in MFCC/100 ml)	102,000[b]			

[a] *Based on water analysis for April 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

MENOMONEE RIVER WATERSHED

The Menomonee River watershed ranks second in population and fifth in size as compared to the other 11 watersheds of the Region. An estimated 338,600 persons reside in this watershed, which has a total area of 134.5 square miles and an average population density of 2,520 people per square mile. Principal

Based on SEWRPC estimate for 1963.

land uses include agriculture and residential, which together comprise over 60 percent of the total area of the watershed. The areal extent of the eight major land use categories is listed below in Table 135.

Four streams were studied by the SEWRPC in the Menomonee River watershed: the Menomonee River proper and three first-rank tributaries, the Little Menomonee River, Underwood Creek, and Honey Creek. The Menomonee River rises within the Region in swampy areas immediately north and northeast of the Village of Germantown in the southeastern corner of Washington County. From this area the Menomonee River flows approximately 28.7 miles in a general southeasterly direction to where it joins the Milwaukee River 0.9 miles upstream from the mouth of the Milwaukee River. For the purposes of this study, the Menomonee River watershed is treated separately from the Milwaukee River watershed, although the Menomonee River and its tributaries are first- and second-rank tributaries of the Milwaukee River.

The Menomonee River occupies a relatively narrow basin of irregular topography. The eastern boundary of the watershed coincides generally with a north-south oriented morainal ridge within the end-moraine system that roughly parallels Lake Michigan. The southeastern boundary trends southeastward across the moraine and onto ground-moraine to the confluence with the Milwaukee River. The northern boundary is oriented generally east-west and extends from within the end-moraine system across a belt of ground-moraine and marsh into the eastern hills of the interlobate moraine that was formed along the contact between the Green Bay and Lake Michigan ice lobes. From this area the watershed boundary trends southerly along the eastern slopes of interlobate moraine and abruptly trends easterly back across the belt of ground-moraine separating the end-moraine system from the interlobate moraine of the Lake Michigan glaciers. The western watershed boundary follows roughly along the western margin of the end-moraine system and then trends abruptly eastward across several morainal ridges. From this area the southern watershed boundary trends southward and then northward enclosing much of an inter-morainal valley occupied by Honey Creek. Thence the boundary trends east across the moraine system to the point of confluence of the Menomonee River with the Milwaukee River.

Menomonee River

Present Stream Quality: Nine sampling stations, Mn-1 through Mn-6, Mn-7A, Mn-7B, and Mn-10 were established on the Menomonee River proper at points upstream and downstream from the Germantown, Menomonee Falls, and Butler sewage treatment plant outfalls and upstream and downstream from the confluence of the Menomonee River with the Little Menomonee River, Underwood Creek, and Honey Creek. The nine sampling stations, the three treatment plant outfalls, and the confluences with the three tributaries are significant selected points of reference on the Menomonee River and are listed in Table 136 in terms of their distances downstream from the river source and the distances between consecutive points of reference.

The Menomonee River is predominantly a calcium bicarbonate stream that is subject to medium changes in total mineralization. Of 51 complete chemical analyses run on water samples of the Menomonee River, calcium (ranging from 197 to 78 ppm) was the most abundant cation in 31 analyses; and bicarbonate

Table 135

EXISTING LAND USE IN THE MENOMONEE RIVER WATERSHED: 1963

Land Use	Area: Square Miles	Area: Acres	Percent of Total Watershed
Agricultural	51.7	33,112	38.46
Residential	30.4	19,477	22.63
Transportation-Communication	19.9	12,765	14.83
Woodland, Wetland, and Unused Land	19.1	12,230	14.21
Park and Recreational	4.4	2,848	3.31
Governmental-Institutional	3.9	2,511	2.92
Industrial	3.3	2,127	2.47
Commercial	1.6	1,007	1.17
Total	134.2	86,077	100.00

Source: SEWRPC.

(ranging from 470 to 250 ppm) exceeded all other anion concentrations in 44 analyses. Sodium (ranging from 310 to 90 ppm) occurred as the most abundant cation in 20 analyses. At sampling station Mn-1, sulfate (ranging from 620 to 282 ppm) was the predominant cation in 6 of 13 complete chemical analyses. Maximum nitrate concentration was 8.4 ppm. On October 14, 1964, maximum total phosphorus was 4.6 ppm. Selected water analyses of the Menomonee River at sampling stations Mn-1, Mn-6, and Mn-10 are indicated in Tables 137, 138, and 139. Water quality conditions of the Menomonee River are indicated in Table 140.

The variations of the chloride concentrations in the Menomonee River are shown by a series of 14 interpretive stream quality graphs in Figure 16. A conspicuous interpretive feature of these graphs are the marked increase in the chloride concentrations downstream from where the effluent from the Village of Menomonee Falls sewage treatment plant enters the Menomonee River. The chloride concentrations of the upper reaches of this river were low with a maximum of 20 ppm at station Mn-1 as compared to the maximum of 105 ppm at station Mn-4. The flow of the Menomonee River is normally sluggish, and the average discharge of approximately 3.6 cfs from the Village of Menomonee Falls sewage treatment plant has, as inferred from the relatively high concentrations at station Mn-4, a noticeable impact upon the chloride concentration in the river. During periods of relatively high streamflow, such as in July 1964, sufficient dilution occurs so that the chloride concentrations decrease to less than 50 ppm throughout the entire mapped reach of the river.

The general levels of chloride concentration in the Menomonee River are indicative of heavy chloride impact upon the river from human sources. This impact is occasionally very heavy near sampling station Mn-10, where chloride concentrations reach as much as 425 ppm. These high chloride concentrations in the Menomonee River at station Mn-10 are probably due to the occasional high chloride concentrations of Honey Creek, which enters the Menomonee River 0.1 miles upstream from the station.

The variations of the dissolved solids concentrations in the Menomonee River are shown by a series of 14 interpretive stream quality graphs in Figure 17. As shown in these graphs, the dissolved solids concentrations upstream from the Village of Germantown were found to vary from 1,200 ppm to 435 ppm. The

Table 136

DISTANCES OF SELECTED POINTS OF REFERENCE ON THE MENOMONEE RIVER FROM THE RIVER SOURCE AND BETWEEN CONSECUTIVE POINTS OF REFERENCE

Point of Reference	Distance From River Source (in miles)	Distance Between Points of Reference (in miles)
River Source	0	--
Mn-1	0.8	0.8
Germantown STPO[a]	1.5	0.7
Mn-2	2.2	0.7
Mn-3	4.6	2.4
Menomonee Falls STPO	7.2	2.6
Mn-4	8.6	1.4
Mn-5	11.0	2.4
Mn-6	13.6	2.6
Butler STPO	15.2	1.6
Little Menomonee River	16.0	0.8
Mn-7A	17.4	1.4
Mn-7B	20.1	2.7
Underwood Creek	20.2	0.1
Honey Creek	22.4	2.2
Mn-10	22.5	0.1
Milwaukee River	28.7	6.2

[a] STPO--Sewage treatment plant outfall.

Source: SEWRPC.

Figure 16

CHLORIDE CONCENTRATION IN THE MENOMONEE RIVER

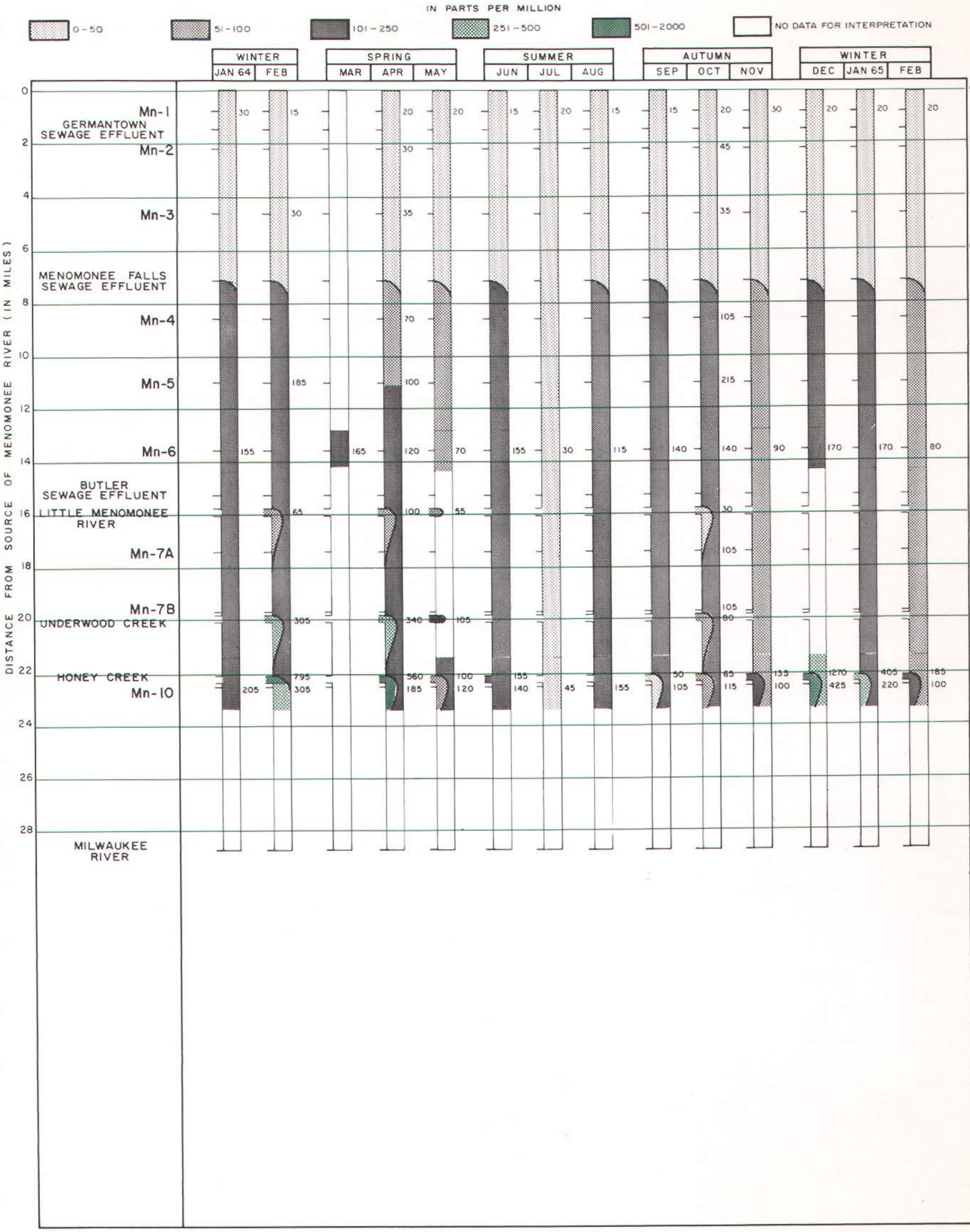


Figure 17

DISSOLVED SOLIDS CONCENTRATION IN THE MENOMONEE RIVER

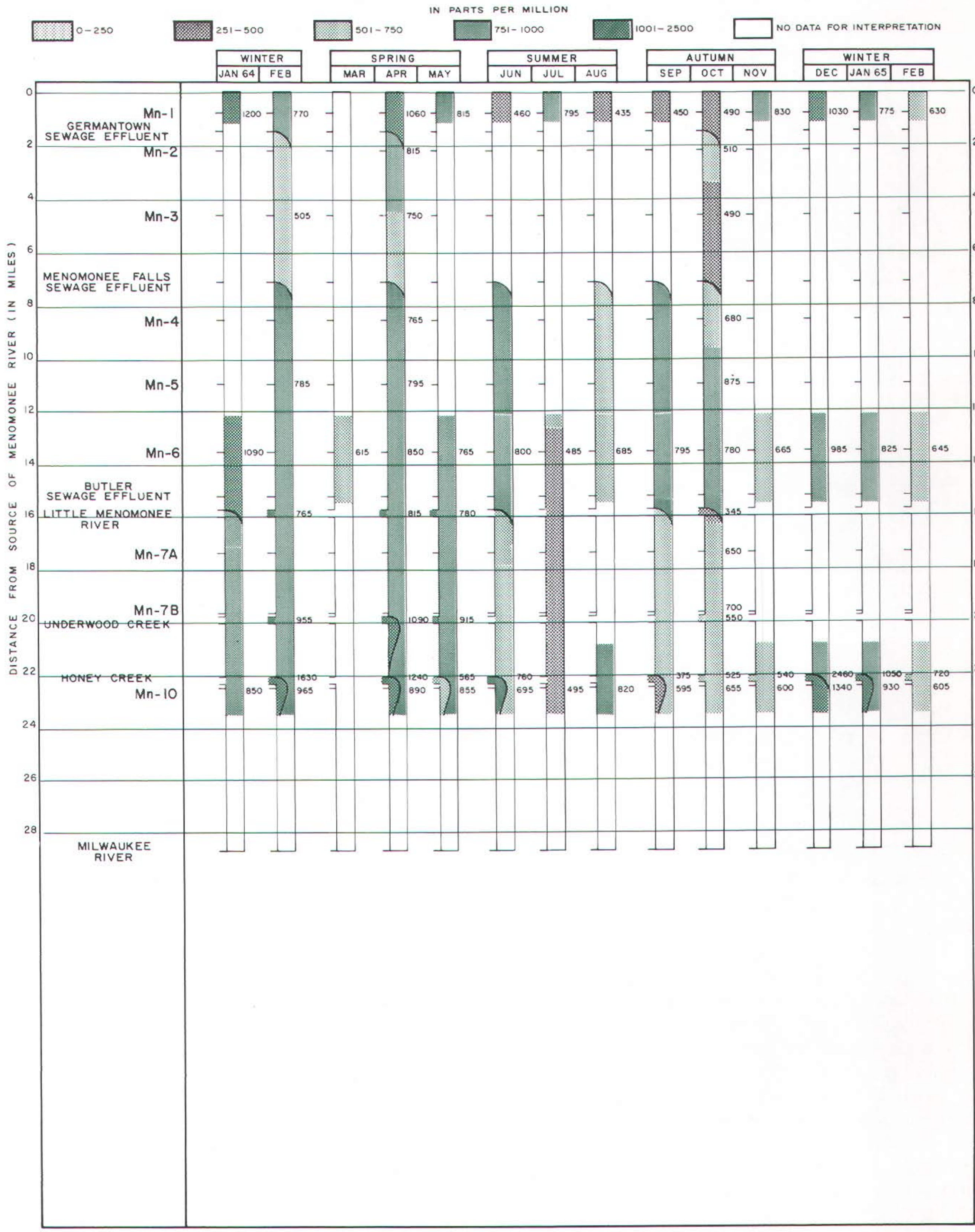


Table 137

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MN-1 ON THE MENOMONEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	5	4-1-64	6	10-14-64
Iron	0.20	"	0.05	"
Manganese.	--	--	0.01	"
Chromium	--	--	< 0.004	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	197	4-1-64	83	"
Magnesium.	91	"	43	"
Sodium (and Potassium)	10	"	40	"
Bicarbonate.	295	"	365	"
Carbonate.	0	"	30	"
Sulfate.	590	"	87	"
Chloride	20	"	20	"
Fluoride	--	--	< 0.45	"
Nitrite.	0.0	4-1-64	0.0	"
Nitrate.	--	--	1.8	"
Phosphorus	--	--	0.06	"
Cyanide.	--	--	< 0.01	12-17-64
Oil.	--	--	3	10-14-64
Detergents	0.0	4-1-64	0.0	"
Dissolved Solids	1,060	"	490	"
Hardness	866	"	385	"
Noncarbonate Hardness.	625	"	35	"
Calcium Hardness	493	"	206	"
Magnesium Hardness	373	"	179	"
Alkalinity P	0	"	15	"
Alkalinity M	240	"	330	"
Specific Conductance	1,350	"	678	"
pH	8.3	"	7.6	"
Color.	100	"	5	"
Turbidity.	6	"	7	"
Biochemical Oxygen Demand. . . .	4.5	"	3.3	"
Dissolved Oxygen	9.6	"	5.8	"
Coliform Count	900	"	800	"
Temperature (^{o}F)	36	"	47	"

Source: SEWRPC.

principal ions involved in the higher concentrations of dissolved solids are sulfate, sodium, and calcium. It is thought that these variations in the quality of the Menomonee River upstream from the Village of Germantown are principally the result of natural processes occurring in the marshy headwater area of the river.

Effluent from the sewage treatment plants at the villages of Germantown and Menomonee Falls and the flow from the Little Menomonee River presumably reduce the natural dissolved solids concentration in the upper reaches of the Menomonee River. An exception to this occurs when the dissolved solids concentration of the headwater area of the river is relatively low, as in September 1964. Under this condition the effluent from the sewage treatment plant at the Village of Germantown may increase the concentration. Honey Creek frequently increases the dissolved solids concentration of the lower reaches of the Menomonee River at and near station Mn-10.

The variations in the dissolved oxygen concentrations in the Menomonee River are shown by a series of 14 interpretive stream quality graphs in Figure 18. Critical dissolved oxygen concentrations (3.0 ppm or

Table 138

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MN-6 ON THE MENOMONEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-1-64	4	10-14-64
Iron	0.01	"	0.03	"
Manganese	--	--	0.01	"
Chromium	--	--	< 0.004	"
Hexavalent Chromium	--	--	0.00	"
Calcium	133	4-1-64	93	"
Magnesium	58	"	45	"
Sodium (and Potassium)	85	"	130	"
Bicarbonate	310	"	390	"
Carbonate	40	"	0	"
Sulfate	253	"	168	"
Chloride	120	"	140	"
Fluoride	--	--	< 1.1	"
Nitrite	0.0	4-1-64	0.4	"
Nitrate	--	--	6.7	"
Phosphorus	--	--	3.68	"
Cyanide	--	--	<0.01	12-17-64
Oil	--	--	3	10-14-64
Detergents	0.3	4-1-64	0.7	"
Dissolved Solids	850	"	780	"
Hardness	572	"	416	"
Noncarbonate Hardness	250	"	95	"
Calcium Hardness	332	"	232	"
Magnesium Hardness	240	"	184	"
Alkalinity P	20	"	0	"
Alkalinity M	295	"	320	"
Specific Conductance	1,240	"	1,210	"
pH	8.4	"	8.0	"
Color	50	"	10	"
Turbidity	4	"	4	"
Biochemical Oxygen Demand	4.4	"	3.0	"
Dissolved Oxygen	10.2	"	13.4	"
Coliform Count	50,000	"	2,300	"
Temperature (°F)	37	"	52	"

Source: SEWRPC.

less) occurred frequently during the period of sampling in June, July, and August 1964 in the upper reaches of the stream. In July 1964 the dissolved oxygen concentration of the Menomonee River was critical for the preservation of fish life from station Mn-1 to Mn-7, a distance of approximately 19 miles. Within this distance the maximum concentrations were 2.1 and 2.9 ppm at stations Mn-4 and Mn-7B, respectively. At the eight stations along this reach of stream, the maximum, average, and minimum concentrations were 2.9, 1.3, and 0 ppm, respectively. The Menomonee River upstream from the Village of Germantown was apparently very low in dissolved oxygen content during the summer months; and the heavy rainfall that occurred in the upper reaches of the watershed on July 18, 1964, four days prior to the monthly SEWRPC sampling of the river, may have flushed large quantities of vegetal material out of marshy areas into the Menomonee River where this material was carried downstream. This vegetal loading from marshy areas, together with the possible waste loading from overland runoff across septic tank filter fields and from wet weather effects upon sewage treatment plant operations, probably caused the critical decline in the dissolved oxygen concentration of the river much in the same manner as occurred in the Fox River during the same month.

Figure 18

DISSOLVED OXYGEN CONCENTRATION IN THE MENOMONEE RIVER

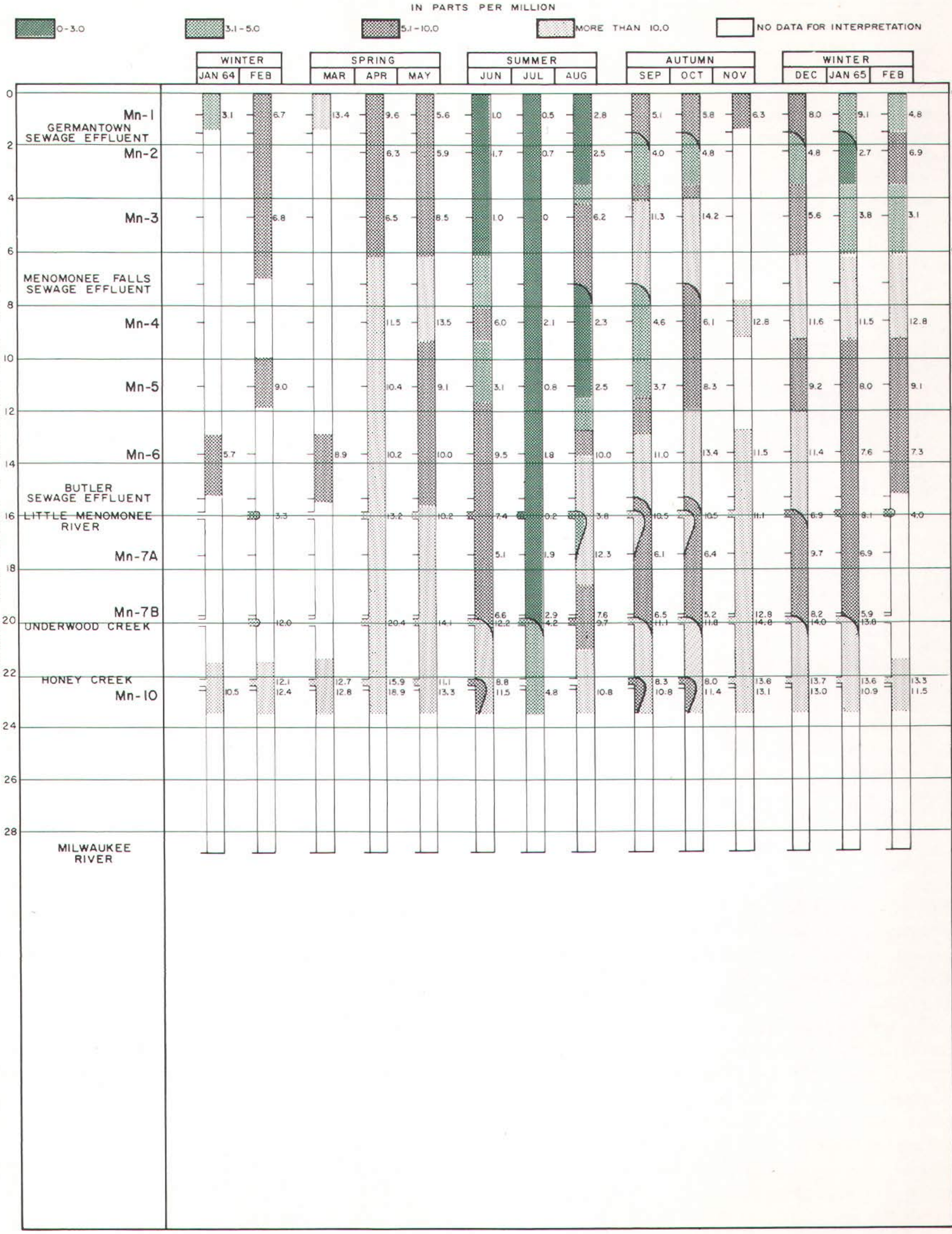


Table 139

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MN-10 ON THE MENOMONEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	7	4-1-64	2	10-14-64
Iron	0.09	"	0.04	"
Manganese	--	--	0.01	"
Chromium	--	--	< 0.01	"
Hexavalent Chromium	--	--	< 0.01	"
Calcium	122	4-1-64	87	"
Magnesium	53	"	42	"
Sodium (and Potassium)	120	"	90	"
Bicarbonate	280	"	315	"
Carbonate	30	"	0	"
Sulfate	233	"	160	"
Chloride	185	"	115	"
Fluoride	--	--	< 0.9	"
Nitrite	0.0	4-1-64	0.1	"
Nitrate	--	--	2.6	"
Phosphorus	--	--	1.32	"
Cyanide	--	--	< 0.01	12-17-64
Oil	--	--	3	10-14-64
Detergents	0.2	4-1-64	0.3	"
Dissolved Solids	890	"	655	"
Hardness	524	"	389	"
Noncarbonate Hardness	245	"	130	"
Calcium Hardness	305	"	218	"
Magnesium Hardness	219	"	171	"
Alkalinity P	15	"	0	"
Alkalinity M	260	"	260	"
Specific Conductance	1,340	"	1,020	"
pH	8.7	"	8.0	"
Color	45	"	10	"
Turbidity	7	"	20	"
Biochemical Oxygen Demand	3.3	"	1.8	"
Dissolved Oxygen	18.9	"	11.4	"
Coliform Count	400	"	2,000	"
Temperature (^{o}F)	41	"	50	"

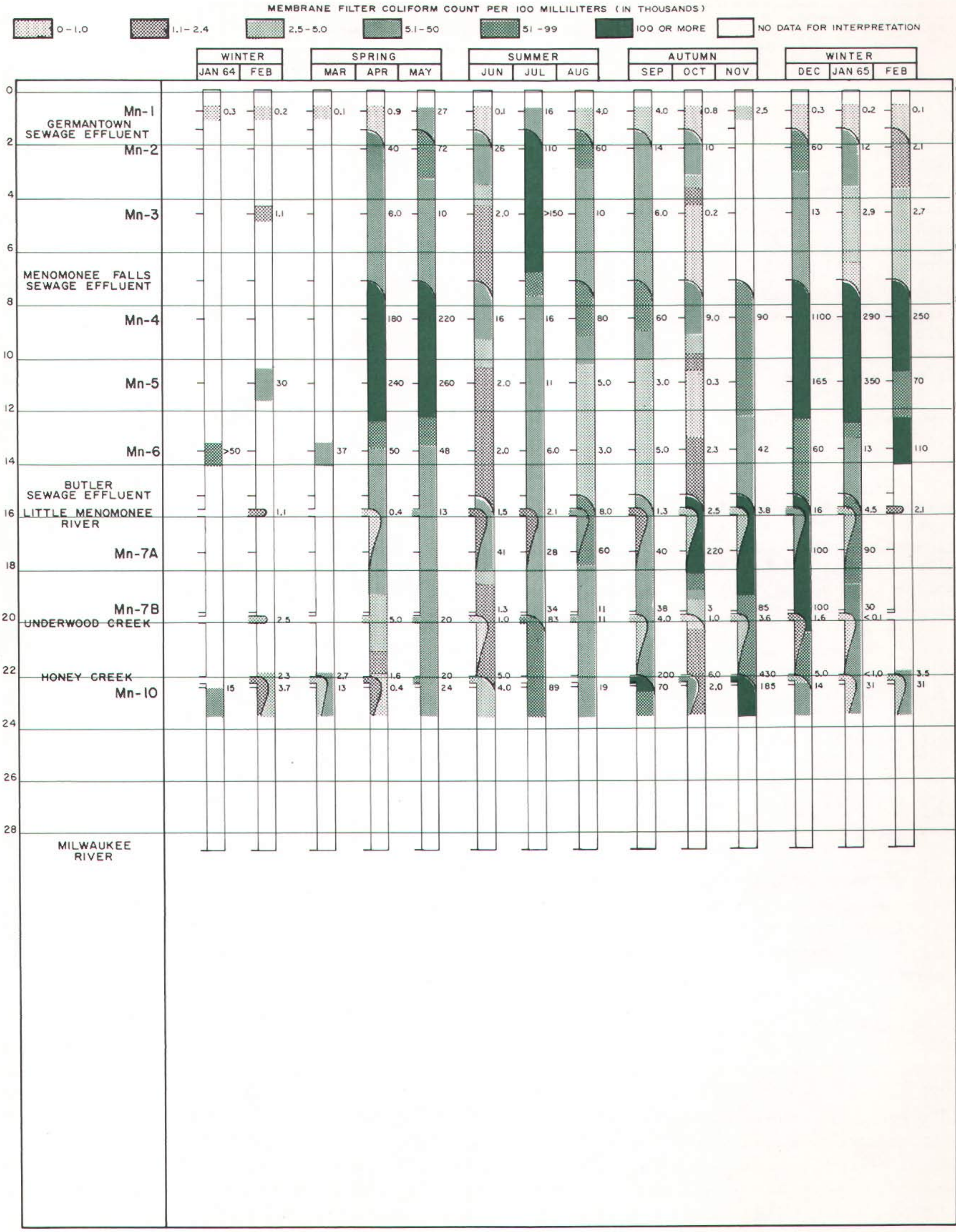
Source: SEWRPC.

The frequent increase in the dissolved oxygen concentration in the Menomonee River between station Mn-3 and station Mn-4 is ascribed to the effects of the falls of the Menomonee River at the Village of Menomonee Falls. Effluent from the sewage treatment plants at the villages of Germantown, Menomonee Falls, and Butler are the most probable cause of the frequent decreases in the dissolved oxygen concentration of the river.

The variations in the coliform counts in the Menomonee River are shown by a series of 14 interpretive stream quality graphs in Figure 19. The coliform counts are recorded in thousands to conserve space on the graphs. As can be seen in Figure 19, the bacteriological quality at station Mn-1 was found to range from 27,000 to 100 MFCC/100 ml, but was less than 1,000 MFCC/100 ml for 9 of 14 months. Effluent from the sewage treatment plants serving the villages of Germantown, Menomonee Falls, and Butler presumably causes the marked increase in coliform count that frequently occurs between stations Mn-1 and Mn-2, between stations Mn-3 and Mn-4, and between stations Mn-6 and Mn-7A, respectively. The Menomonee River is heavily polluted with coliform bacteria of probable human origin over more than 20 miles of its total length. The treated wastes from the sewage treatment plants are being discharged

Figure 19

COLIFORM COUNT IN THE MENOMONEE RIVER



into the river in quantities greatly exceeding the waste assimilation capacity of the river. The river is unsuited for partial- and whole-body contact recreation. Figure 20 shows the coliform count in the Menomonee River in its upper and lower reaches at stations Mn-1 and Mn-10. This figure shows the net changes in coliform count in the Menomonee River between these two sampling stations. It should be noted that the vertical scale in this figure was selected so as to emphasize coliform counts in the range 0 to 5,000 MFCC/100 ml.

The variations in the temperature of the Menomonee River at two selected sampling stations are shown in Figure 21. The maximum temperatures at station Mn-1 and Mn-10 are 70° and 78°F, respectively. Sampling stations Mn-1 and Mn-10 were chosen to show the temperature difference between stations at the extreme ends of that part of the river studied by the SEWRPC. The temperature differential between sampling stations Mn-1 and Mn-10 from June through September 1964 averaged 5.6 degrees and ranged from 1 to 8 degrees. Sampling stations Mn-1 and Mn-10 are located 0.8 and 22.5 miles, respectively, downstream from the source of the Menomonee River. The difference in temperatures between these two stations is due to several causes, principal among which are the difference in volume of water passing each station, the difference in time these volumes have been exposed to subaerial climatic conditions, and probably the difference in absorption of sunlight due to differences in turbidity. The Menomonee River is not subject to significant adverse temperature conditions.

The color of the Menomonee River was very dense following the exceptionally heavy rainfall that occurred on July 18, 1964. At the U. S. Weather Bureau Station at Germantown, which is located in the headwater area of the Menomonee River watershed, the total rainfall on that day was 7.05 inches. On July 22 the SEWRPC made its monthly sampling run of the watershed, and comparative data pertaining to the color density of the Menomonee River are presented in Table 141.

Table 140

WATER QUALITY CONDITIONS OF THE MENOMONEE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	425	100	15	51
Dissolved Solids (ppm)	1,340	705	435	51
Dissolved Oxygen (ppm)	18.9	7.6	0	99
Coliform Count (MFCC/100 ml)	1,100,000	52,000	100	99
Temperature (F)	79	49	32	98

Source: SEWRPC.

Table 141

COLOR OF THE MENOMONEE RIVER: JUNE AND JULY 1964

Sampling Station	Color (in units)	
	June 1964	July 1964
Mn-1	40	375
Mn-6	45	195
Mn-10	30	150

Source: SEWRPC.

Figure 20

COLIFORM COUNT IN THE MENOMONEE RIVER

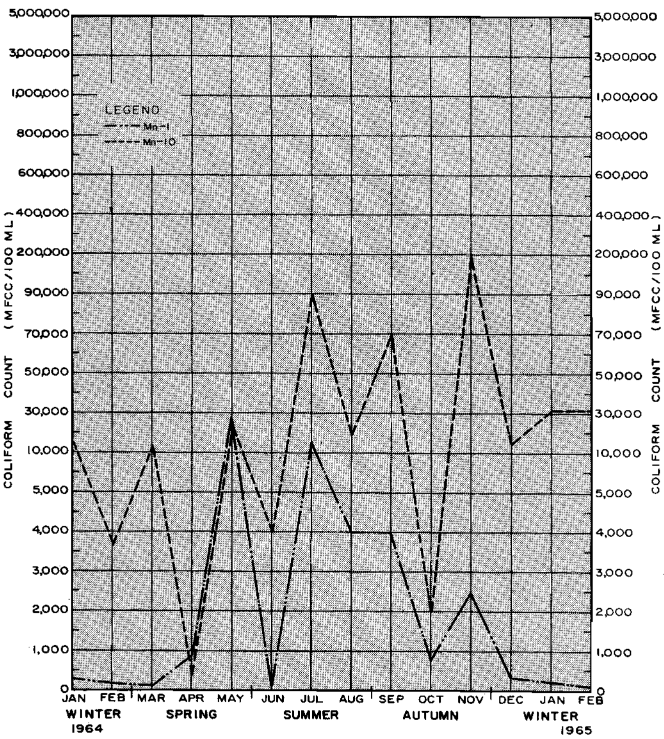
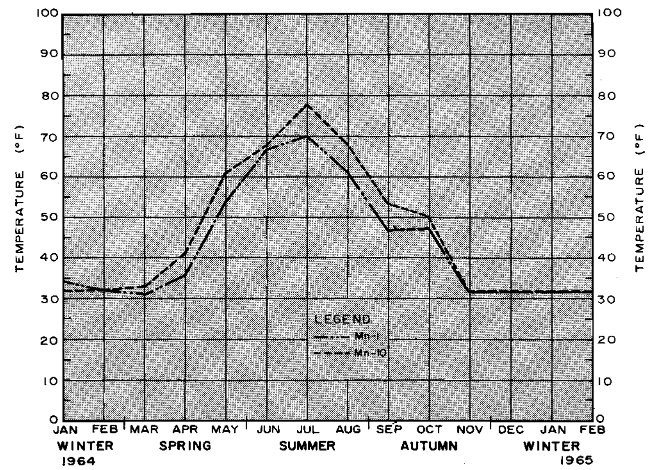


Figure 21

TEMPERATURE OF THE MENOMONEE RIVER



Streamflow and Precipitation: The stage of the Menomonee River is read twice daily at Wauwatosa (at sampling station Mn-10) by the U. S. Geological Survey and converted to streamflow volume. During the present study, the SEWRPC made additional flow measurements in the spring and autumn of 1964. The measurements of both agencies provide flow data at Mn-1, Mn-3, Mn-5, and Mn-10 during periods of relatively high and low flow. These data are listed in Table 142. The U. S. Geological Survey streamflow measurements at Wauwatosa for the period of field study are listed in Table 143, along with days on which the SEWRPC collected stream samples on the Menomonee River.

Table 142

STREAMFLOW MEASUREMENTS OF THE MENOMONEE RIVER: SPRING AND AUTUMN 1964

Date of Measurement	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]	Location of Measurement	Source of Measurement
3-13-64.	0	0	Mn-1	SEWRPC
4- 3-64.	8.4	0.44	Mn-1	SEWRPC
10-15-64.	0	0	Mn-1	SEWRPC
4- 3-64.	31	0.44	Mn-3	SEWRPC
10-13-64.	3.4	0	Mn-3	SEWRPC
4- 3-64.	61	0.44	Mn-5	SEWRPC
10-13-64.	5.7	0	Mn-5	SEWRPC
4- 3-64.	184	0.44	Mn-10	USGS
10-13-64.	8.6	0	Mn-10	USGS

[a] *Measured at U. S. Weather Bureau Station at Germantown, Wisconsin.*

Source: U. S. Weather Bureau, USGS, and SEWRPC.

Table 143

DISCHARGE OF THE MENOMONEE RIVER AT WAUWATOSA, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	Streamflow[a] (in cfs)													
	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	3.4	9.6	10	26	88	11	15	24	15	9.4	11	21	15	7.8
2	5.0	9.8	14	38	148	19	28	20	38	8.1	33	15	190	7.2
3	11.0	10	16	184	112	15	37	18	12	8.8	23	13	90	6.8
4	9.0	11	14	69	67	13	26	17	12	8.3	18	12	35	6.8
5	8.0	12	12	360	61	11	13	17	9.8	7.5	15	11	15	8.0
6	8.4	14	15	481	69	13	16	15	8.8	7.5	13	10	15	35
7	9.0	13	88	526	42	11	13	14	8.6	6.6	12	9.4	17	500
8	6.3	11	59	188	394	11	13	15	11	9.8	11	9.0	29	305
9	5.0	10	40	117	98	11	13	14	11	8.6	9.4	8.2	50	260
10	4.4	10	35	85	53	10	13	11	17	8.3	8.8	8.6	15	330
11	4.0	9.0	55	81	32	9.4	12	81	15	8.2	10	9.4	11	210
12	3.6	9.0	65	67	32	10	11	44	12	8.3	15	13	9.0	160
13	3.3	12	106	53	67	9.8	11	15	9.8	8.6	12	21	8.0	130
14	3.2	13	304	44	49	10	21	12	7.2	11	11	18	7.4	110
15	3.1	11	188	44	30	15	15	15	11	9.8	49	15	6.9	90
16	3.0	9.4	74	35	123	29	14	22	10	9.8	27	13	6.6	80
17	2.9	8.6	59	35	44	13	18	12	9.4	9.2	12	12	6.4	64
18	2.8	8.0	37	57	40	14	2,870	8.8	129	8.4	9.8	11	6.4	58
19	4.5	8.4	28	37	37	19	1,440	7.9	29	7.9	8.8	10	6.4	54
20	50	8.8	24	32	28	16	882	11	23	7.6	8.0	9.6	6.2	504
21	36	9.0	23	468	23	83	400	232	18	7.7	7.6	9.4	8.0	224
22	28	9.0	22	173	18	18	486	90	14	9.0	7.2	9.2	11	170
23	25	9.0	22	90	15	16	300	27	19	10	7.4	9.2	62	110
24	68	8.8	23	63	18	17	139	16	13	9.8	9.0	9.6	45	76
25	56	8.6	26	59	13	17	734	12	7.9	9.8	11	10	25	61
26	44	8.4	29	72	13	15	155	12	29	9.4	12	10	16	44
27	30	8.2	27	114	12	15	81	13	12	13	14	9.6	13	40
28	20	8.3	24	104	12	14	60	12	9.8	11	100	9.0	11	61
29	13	8.4	22	85	11	14	51	11	9.4	11	80	9.0	10	--
30	12	--	20	76	10	13	59	17	8.8	10	40	9.2	9.0	--
31	10	--	20	--	10	--	33	10	--	12	--	11	8.2	--

[a] *Underscored flow measurements indicate days when stream sampling occurred in the Menomonee River watershed.*

Source: U. S. Geological Survey.

The mean daily maximum and minimum flows of the Menomonee River at station Mn-10 during the period of study were 2,870 cfs on July 18, 1964, and 2.8 cfs on January 18, 1964. Maximum and minimum daily flow conditions at the time of sampling on the Menomonee River at station Mn-10 were 468 cfs on July 22, 1964, and 7.9 cfs on August 19, 1964.

Tables 132 and 144 indicate the daily precipitation at West Allis, and at Germantown, Wisconsin, respectively, from January 1964 through February 1965.

Forecast Quality of the Menomonee River for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were 338,600 people living in the Menomonee River watershed. That part of the Menomonee River watershed which is in Milwaukee County is serviced by the Milwaukee metropolitan sewerage system, and the treated wastes are discharged to Lake Michigan. Effluent from the sewage treatment plants serving the villages of Germantown, Menomonee Falls, and Butler enters the Menomonee River at the respective plant outfalls. Major sewerage system improvements are currently in progress which will permit the abandonment of all these plants and the connection of the tributary sewers to the Milwaukee metropolitan sewerage system, so that by the year 1990 the entire population of the watershed will be serviced by this system. Table 145 indicates the estimated population levels within the watershed for the year 1990 under the three alternative regional land use plans. Table 146 shows forecasts of future stream quality in the Menomonee River.

Little Menomonee River

Present Stream Quality: One sampling station, Mn-7, was established on the Little Menomonee River.

Table 144

PRECIPITATION[a] AT GERMANTOWN, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	--	--	--	--	--	--	--	--	--	0.20
2	--	--	--	0.44	0.45	0.14	0.46	--	0.17	--	0.33	--	--	--
3	--	--	--	0.09	--	--	--	--	--	--	--	0.05	--	--
4	--	--	--	--	--	--	--	--	0.11	--	0.04	--	--	--
5	--	--	1.15	0.34	0.14	--	--	--	--	--	--	--	--	--
6	--	--	--	--	0.02	--	0.25	--	0.13	--	0.02	--	--	--
7	--	--	0.05	1.19	--	--	0.10	--	--	--	--	0.08	0.03	--
8	--	--	0.01	--	0.23	--	0.05	--	0.20	0.23	--	--	0.03	0.02
9	0.01	--	0.27	--	0.13	--	--	--	0.08	--	--	--	--	0.15
10	--	0.02	--	--	--	--	--	0.05	0.30	--	--	--	--	--
11	0.13	--	--	--	--	--	--	0.03	--	--	--	0.08	--	0.31
12	0.01	0.01	--	--	--	--	--	--	--	--	0.18	0.13	--	--
13	--	0.05	--	--	0.32	--	0.26	--	--	--	--	--	--	--
14	--	--	0.07	--	--	--	0.38	--	0.06	--	--	--	--	--
15	--	--	--	--	--	0.16	--	--	0.05	--	0.46	--	0.05	--
16	--	--	--	--	0.48	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	0.09	--	--	--	--	--	--	--	--
18	--	--	--	0.40	0.15	--	7.05	--	0.60	--	--	--	--	--
19	--	--	--	--	--	0.26	--	--	0.08	--	--	--	--	--
20	0.13	--	0.01	--	--	0.01	0.26	--	0.03	--	0.05	0.08	--	--
21	--	--	--	1.50	--	0.01	0.03	1.72	0.08	--	--	--	--	--
22	--	--	--	--	--	0.02	0.56	0.48	0.16	--	--	--	0.05	--
23	--	0.01	--	--	--	0.33	--	--	0.04	--	--	0.03	0.45	0.01
24	0.43	--	--	--	0.24	--	--	--	0.03	--	--	--	0.55	0.12
25	0.03	--	0.02	--	--	--	0.39	--	--	--	--	--	--	--
26	--	--	0.17	--	--	--	--	--	0.05	--	--	0.04	0.35	--
27	0.46	--	0.01	0.40	--	--	--	--	--	--	--	--	--	--
28	0.28	--	--	--	--	--	--	--	--	--	1.48	--	--	--
29	--	--	--	0.02	--	--	0.32	--	--	--	--	--	--	--
30	--	--	--	0.12	--	--	--	0.22	--	--	--	--	--	--
31	--	--	--	--	0.04	--	--	--	--	--	--	--	--	--
Total	1.48	0.09	1.76	4.50	2.20	1.02	10.11	2.50	2.17	0.23	2.56	0.49	1.51	0.81

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Station Mn-7 is located 9.4 miles downstream from the source of the Little Menomonee River and about 350 feet upstream from the point where this watercourse enters the Menomonee River.

The Little Menomonee River is a calcium bicarbonate stream subject to small changes in total mineralization. In four complete chemical analyses run on stream samples collected during the study, calcium was the predominant cation in all four samples and ranged in concentration from 117 to 55 ppm. The predominant anions were bicarbonate and sulfate, and each occurred as the predominant anion in two samples. Bicarbonate and sulfate concentrations ranged from 390 to 225 ppm and from 343 to 91 ppm, respectively. Maximum nitrate concentration was 6.5 ppm. On October 14, 1964, total phosphorus was 0.24 ppm. Selected water analyses of the Little Menomonee River at station Mn-7 are indicated in Table 147. Water quality conditions of the Little Menomonee River are indicated in Table 148.

Table 145

ESTIMATED POPULATION OF THE MENOMONEE RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Menomonee River Watershed	338,000	487,000	470,000	459,000

Source: SEWRPC.

Table 146

FORECAST QUALITY OF THE MENOMONEE RIVER AT SAMPLING STATION MN-10:
1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing	Corridor Plan	Satellite City
Menomonee River	Mn-10	Chloride (in ppm)	115[a]	15	15	15
		Dissolved Solids (in ppm)	655[a]	500	500	500
		Dissolved Oxygen (in ppm)	9.5[b]	More than 9.0		
		Coliform Count (in MFCC/ 100 ml)	45,000[b]	Less than 10,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

The chloride concentrations in the Little Menomonee River varied from 100 ppm in April to 30 ppm in October 1964. Assuming a "background" chloride concentration of 10 ppm, there was a chloride impact upon the river quality of 20 ppm to 70 ppm from human sources.

The dissolved solids concentrations varied from 815 ppm in April to 345 ppm in October 1964. The assumed "minimum background" concentration of dissolved solids is about 310 ppm. The principal ions that occurred in higher concentrations in April than in October were sulfate, chloride, calcium, sodium, and magnesium. It is thought that the higher concentrations that occurred in the winter and spring were largely due to increased overland drainage from septic tank systems because of increased seasonal saturation of the relatively tight soils in the area.

The dissolved oxygen concentrations in the Little Menomonee River varied from 13.2 ppm in April to 0.2 ppm in July 1964. During the period June through September, the maximum, average, and minimum concentrations were 10.5, 5.5, and 0.2 ppm, respectively.

Coliform counts in the Little Menomonee River ranged from 16,000 MFCC/100 ml in December to 400 MFCC/100 ml in April 1964. During the months of June through September, the maximum, average, and minimum counts were 8,000, 3,200, and 1,300 MFCC/100 ml.

The maximum temperature of the Little Menomonee River was 78°F in July 1964 and averaged 65°F for the period June through September 1964.

Table 147

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MN-7 ON THE LITTLE MENOMONEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-1-64	1	10-14-64
Iron	0.04	"	0.05	"
Manganese	--	--	0.01	"
Chromium	--	--	< 0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	107	4-1-64	55	"
Magnesium	64	"	28	"
Sodium (and Potassium)	75	"	30	"
Bicarbonate	245	"	225	"
Carbonate	0	"	0	"
Sulfate	343	"	91	"
Chloride	100	"	30	"
Fluoride	--	--	< 0.9	"
Nitrite	0.0	4-1-64	0.0	"
Nitrate	--	--	0.3	"
Phosphorus	--	--	0.24	"
Cyanide	--	--	--	--
Oil	--	--	< 2	10-14-64
Detergents	0.0	4-1-64	0.1	"
Dissolved Solids	815	"	345	"
Hardness	531	"	253	"
Noncarbonate Hardness	330	"	70	"
Calcium Hardness	267	"	138	"
Magnesium Hardness	264	"	115	"
Alkalinity P	0	"	0	"
Alkalinity M	200	"	185	"
Specific Conductance	1,160	"	500	"
pH	8.6	"	8.0	"
Color	55	"	0	"
Turbidity	5	"	6	"
Biochemical Oxygen Demand	2.9	"	1.4	"
Dissolved Oxygen	13.2	"	10.5	"
Coliform Count	400	"	2,500	"
Temperature (°F)	37	"	50	"

Source: SEWRPC.

Table 148

WATER QUALITY CONDITIONS OF THE LITTLE MENOMONEE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	100	65	30	4
Dissolved Solids (ppm)	815	675	345	4
Dissolved Oxygen (ppm)	13.2	7.5	0.2	12
Coliform Count (MFCC/100 ml)	16,000	4,700	400	12
Temperature (°F)	78	49	32	11

Source: SEWRPC.

Streamflow and Precipitation: The Little Menomonee River is a shallow watercourse occupying a channel which has been artificially straightened. At sampling station Mn-7, a distance 9.4 miles from the source, this stream had a maximum depth of 0.8 feet and a width of 14 feet when measured under low-flow conditions in October 1964.

The flow of the Little Menomonee River was measured by the SEWRPC in the spring and autumn of 1964 during periods of relatively high and low flow. The streamflow data are listed in Table 149. Table 144 indicates the daily precipitation at Germantown, Wisconsin.

Forecast Quality of the Little Menomonee River for the Year 1990: By the year 1990, the entire population of the Menomonee River watershed will be serviced by the Milwaukee metropolitan sewerage system. The effects of urbanization upon the quality of the Little Menomonee River may be expected to be reduced by the complete conversion of all urban development within the watershed from private septic tank systems to centralized public sanitary sewer facilities connected to the Milwaukee metropolitan system, which will involve the export of all sewage for treatment and ultimate discharge into Lake Michigan. Table 150 indicates the forecast quality of the Little Menomonee River for the year 1990 at sampling station Mn-7.

Underwood Creek

Present Stream Quality: One sampling station, Mn-8, was established on Underwood Creek. Station Mn-8 is located 8.2 miles downstream from the source of Underwood Creek and 0.8 miles upstream from where the creek enters the Menomonee River. A sewage treatment plant in south-central Brookfield discharges treated wastes into the Dousman Ditch, a watercourse tributary to Underwood Creek.

Underwood Creek is of variable chemical quality and has relatively constant total mineralization. Of four complete chemical analyses run on stream samples collected in February, April, May, and October 1964, calcium and sodium were predominant cations. Calcium occurred as the predominant cation in May and October at concentrations of 115 and 74 ppm, respectively. Sodium occurred as the predominant cation in February and April at concentrations of 205 and 185 ppm, respectively. The predominant anions were bicarbonate, sulfate, and chloride. Bicarbonate was predominant in February and October 1964 at concentrations of 310 and 280 ppm, respectively. Sulfate and chloride each occurred once as the predominant anion, sulfate in May at 353 ppm, and chloride in April at 340 ppm. Maximum nitrate concentration was 1.0 ppm. On October 14, 1964, total phosphorus was 0.16 ppm. Selected water analyses of Underwood Creek at station Mn-8 are indicated in Table 151. Water quality conditions of Underwood Creek are indicated in Table 152.

The chloride concentrations in Underwood Creek varied from 340 ppm in April to 80 ppm in October 1964. Assuming a "background" chloride concentration of 10 ppm, there was a chloride impact upon the river quality of 70 to 330 ppm from human sources.

The dissolved solids concentrations varied from 1,090 ppm in April to 550 ppm in October 1964. The assumed "minimum background" concentration is about 435 ppm. The principal ions that occurred in higher concentrations in April than in October were chloride, sulfate, sodium, calcium, and magnesium. It is thought that the higher concentrations that occurred in the winter and spring were due largely to

Table 149

STREAMFLOW MEASUREMENTS OF THE LITTLE MENOMONEE RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Mn-7	4- 3-64 10-13-64	20 2.7	0.44 0

[a] *Measured at U. S. Weather Bureau Station at Germantown, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 150

FORECAST QUALITY OF THE LITTLE MENOMONEE RIVER AT SAMPLING STATION MN-7: 1990 ALTERNATIVE LAND USE PLAN

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Little Menomonee River	Mn-7	Chloride (in ppm)	30[a]	10	10	10
		Dissolved Solids (in ppm)	345[a]	300	300	300
		Dissolved Oxygen (in ppm)	5.4[b]	More than 6.0 ppm		
		Coliform Count (in MFCC/100 ml)	3,200[b]	Less than 1,500		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

increased overland seepage from septic tank systems because of increased seasonal saturation of the relatively tight soils in the area.

The dissolved oxygen concentrations in Underwood Creek varied from 20.4 ppm in May to 4.2 ppm in July 1964. During the period June through September, the maximum, average, and minimum concentrations were 14.1, 9.3, and 4.2, respectively.

Coliform counts in Underwood Creek ranged from 83,000 MFCC/100 ml in July 1964 to less than 100 MFCC/100 ml in Februa: y 1965. During the months of June through September, the maximum, average, and minimum counts were 83,000, 25,000, and 1,000 MFCC/100 ml.

The maximum temperature of Underwood Creek was 78°F in July 1964 and averaged 66°F for the period June through September 1964.

Streamflow and Precipitation: Underwood Creek is a watercourse occupying a relatively deep channel that was artificially straightened, deepened, and extensively lined with concrete during the course of this study. At sampling station Mn-8 on the original stream channel, a distance 8.0 miles from the source, this stream had a maximum depth of 0.35 feet and a width of 6 1/2 feet when measured under low-flow conditions in October 1964.

Table 151

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MN-8 ON UNDERWOOD CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	4	4-1-64	2	10-14-64
Iron	0.05	"	0.04	"
Manganese.	--	--	0.01	"
Chromium	--	--	0.01	"
Hexavalent Chromium. . . .	--	--	0.00	"
Calcium.	130	4-1-64	74	"
Magnesium.	52	"	37	"
Sodium (and Potassium) . .	185	"	70	"
Bicarbonate.	215	"	280	"
Carbonate.	0	"	0	"
Sulfate.	275	"	144	"
Chloride	340	"	80	"
Fluoride	--	--	< 0.85	"
Nitrite.	0.0	4-1-64	0.0	"
Nitrate.	--	--	1.0	"
Phosphorus	--	--	0.16	"
Cyanide.	--	--	--	--
Oil.	--	--	< 2	10-14-64
Detergents	0.0	4-1-64	0.1	"
Dissolved Solids	1,090	"	550	"
Hardness	541	"	336	"
Noncarbonate Hardness. . .	365	"	105	"
Calcium Hardness	325	"	184	"
Magnesium Hardness	216	"	152	"
Alkalinity P	0	"	0	"
Alkalinity M	175	"	230	"
Specific Conductance . . .	1,850	"	760	"
pH	8.5	"	8.1	"
Color.	40	"	10	"
Turbidity.	3	"	2	"
Biochemical Oxygen Demand.	4.8	"	2.6	"
Dissolved Oxygen	20.4	"	11.8	"
Coliform Count	5,000	"	1,000	"
Temperature (°F)	41	"	49	"

Source: SEWRPC.

Table 152

WATER QUALITY CONDITIONS OF UNDERWOOD CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	340	210	80	4
Dissolved Solids (ppm)	1,090	880	550	4
Dissolved Oxygen (ppm)	20.4	12.6	4.2	11
Coliform Count (MFCC/100 ml) .	83,000	12,100	100	11
Temperature (°F)	78	49	32	11

Source: SEWRPC.

The flow of Underwood Creek was measured by the SEWRPC in its natural channel in the spring and autumn of 1964 during periods of relatively high and low flow. The streamflow data are listed in Table 153. Table 132 indicates the daily precipitation at West Allis, Wisconsin.

Forecast Quality of Underwood Creek for the Year 1990: By the year 1990, the entire population of the Menomonee River watershed will be serviced by the Milwaukee metropolitan sewerage system. The effects of urbanization upon the quality of Underwood Creek will be reduced by the complete conversion from private septic tank systems to connection with the Milwaukee metropolitan sewerage system and by the export of all sewage from the watershed for treatment and ultimate discharge into Lake Michigan. It appears, however, that industrial wastes may be affecting the quality of Underwood Creek at Mn-8 more than drainage from private septic tank filter fields. Forecasts of the quality of Underwood Creek for the year 1990 are indicated in Table 154. These estimates assume that no industrial wastes will be permitted to be discharged into Underwood Creek or its tributaries in the future.

Honey Creek

Present Stream Quality: One sampling station, Mn-9, was established on Honey Creek. Station Mn-9 is located 9.4 miles downstream from the source of Honey Creek and 0.2 miles upstream from where the creek enters the Menomonee River.

Honey Creek is predominantly a sodium bicarbonate stream that is subject to large changes in total mineralization. Of 10 complete chemical analyses run on stream samples collected in February, April, May, June, September through December 1964, and in January and February 1965, sodium and calcium were predominant cations. Sodium occurred as the predominant cation in eight of the analyses at concentrations ranging from 800 ppm to 70 ppm. Calcium occurred in one analysis as the predominant cation at a concentration of 59 ppm. The predominant anions were bicarbonate and chloride. Bicarbonate was the predominant anion in six analyses, ranging in concentration from 330 to 240 ppm. Chloride occurred as the predominant anion at concentrations ranging from 1,270 to 405 ppm. Maximum nitrate concentration was 5.1 ppm. On October 14, 1964, total phosphorus was 0.32 ppm. Selected water analyses of Honey Creek at station Mn-9 are indicated in Table 155. Water quality conditions of Underwood Creek are indicated in Table 156.

The chloride concentrations in Honey Creek varied from 1,270 ppm in December 1964 to 50 ppm in September 1964. Assuming a "background" chloride concentration of 10 ppm, there was a chloride impact upon the creek of 1,260 ppm to 40 ppm from human sources.

The dissolved solids concentrations varied from 2,460 ppm in December to 375 ppm in September 1964. The assumed "minimum background" concentration of dissolved solids is about 310 ppm. The principal ions that occurred in higher concentrations in December than in September were chloride, sodium, calcium, sulfate, and magnesium. It is thought that the frequently very high concentrations that occurred in Honey Creek were largely from industrial sources.

The dissolved oxygen concentrations in Honey Creek varied from 15.9 ppm in April to 8.0 ppm in October 1964. During the period June through September, only two samples were collected at sampling station Mn-9. In June and in September, the dissolved oxygen concentrations were 8.8 and 8.3 ppm, respectively.

Table 153

STREAMFLOW MEASUREMENTS OF UNDERWOOD CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Mn-8	4- 3-64 10-13-64	23 0.6	0.73 0

[a] *Measured at U. S. Weather Bureau Station at West Allis, Wisconsin.*

Source: *U. S. Weather Bureau and SEWRPC.*

Table 154

FORECAST QUALITY OF UNDERWOOD CREEK AT SAMPLING STATION MN-8: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Underwood Creek	Mn-8	Chloride (in ppm)	80[a]	20	20	20
		Dissolved Solids (in ppm)	550[a]	450	450	450
		Dissolved Oxygen (in ppm)	9.3[b]	More than 9.0		
		Coliform Count (in MFCC/ 100 ml)	25,000[b]	Less than 10,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Coliform counts in Honey Creek ranged from 430,000 MFCC/100 ml in November 1964 to less than 1,000 MFCC/100 ml in January 1965. In the months of June and September, the coliform counts were 5,000 and 200,000 MFCC/100 ml, respectively.

The maximum temperature of Honey Creek was 67°F in June 1964. No temperature data were available for July and August 1964.

Streamflow and Precipitation: Honey Creek is a watercourse occupying a channel that is artificially deepened, widened, and locally lined with concrete. At sampling station Mn-9, a distance 9.4 miles from the source, this stream had a maximum depth of 0.4 feet and a width of 2.6 feet when measured under low-flow conditions in October 1964.

The flow of Honey Creek was measured by the SEWRPC in the spring and autumn of 1964 during periods of relatively high and low flow. The streamflow data are listed in Table 157. Table 132 lists the daily precipitation at West Allis, Wisconsin.

Forecast Quality of Honey Creek for the Year 1990: The entire population of the Menomonee River watershed will be serviced by the Milwaukee metropolitan sewerage system by the year 1990, and industrial wastes presumably will not continue to be discharged into Honey Creek. Table 158 indicates the quality of Honey Creek in 1990 with respect to four selected parameters.

Table 155

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MN-9 ON HONEY CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-1-64	7	10-14-64
Iron	0.12	"	0.45	"
Manganese.	--	--	0.01	"
Chromium	--	--	< 0.01	"
Hexavalent Chromium. . . .	--	--	0.00	"
Calcium.	96	4-1-64	69	"
Magnesium.	39	"	29	"
Sodium (and Potassium) . .	320	"	80	"
Bicarbonate.	225	"	310	"
Carbonate.	10	"	5	"
Sulfate.	98	"	112	"
Chloride	560	"	65	"
Fluoride	--	--	< 0.95	"
Nitrite.	0.0	4-1-64	0.0	"
Nitrate.	--	--	0.8	"
Phosphorus	--	--	0.32	"
Cyanide.	--	--	--	--
Oil.	--	--	3	10-14-64
Detergents	0.1	4-1-64	0.1	"
Dissolved Solids	1,240	"	525	"
Hardness	401	"	291	"
Noncarbonate Hardness. . .	200	"	30	"
Calcium Hardness	240	"	172	"
Magnesium Hardness	161	"	119	"
Alkalinity P	5	"	2.5[a]	"
Alkalinity M	195	"	220	"
Specific Conductance . . .	2,220	"	620	"
pH	8.8	"	7.5	"
Color.	45	"	10	"
Turbidity.	10	"	50	"
Biochemical Oxygen Demand.	4.1	"	6.3	"
Dissolved Oxygen	15.9	"	8.0	"
Coliform Count	1,600	"	6,000	"
Temperature (°F)	41	"	49	"

[a] *Estimated.*

Source: SEWRPC.

Table 156

WATER QUALITY CONDITIONS OF HONEY CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	1,270	370	50	10
Dissolved Solids (ppm)	2,460	985	375	10
Dissolved Oxygen (ppm)	15.9	11.9	8.0	11
Coliform Count (MFCC/100 ml) .	430,000	62,000	1,000	11
Temperature (°F)	67	42	32	11

Source: SEWRPC.

Table 157

STREAMFLOW MEASUREMENTS OF HONEY CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Mn-9	4- 3-64 10-13-64	10 0.6	.73 0

[a] *Measured at U. S. Weather Bureau Station at West Allis, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 158

FORECAST QUALITY OF HONEY CREEK AT SAMPLING STATION MN-9: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Honey Creek	Mn-9	Chloride (in ppm)	65[a]	20	20	20
		Dissolved Solids (in ppm)	525[a]	450	450	450
		Dissolved Oxygen (in ppm)	8.5[b]	More than 9.0		
		Coliform Count (in MFCC/ 100 ml)	102,000[b]	Less than 10,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for June and September 1964.*

Source: SEWRPC.

MILWAUKEE RIVER WATERSHED

The Milwaukee River watershed ranks first in population and third in size as compared to the other 11 watersheds of the Region. An estimated 508,600[6] persons reside within this watershed, which has a total area of 431.7 square miles within southeastern Wisconsin and an average population density of 1,180 people per square mile. Principal land uses include agricultural and woodland, wetland, and unused land areas, which together comprise 80.2 percent of the area of the watershed. The areas within the watershed devoted to each of eight major use categories are listed in Table 159.

Three streams were studied by the SEWRPC in the Milwaukee River watershed: the Milwaukee River proper and two first-rank tributaries—the North Branch of the Milwaukee River and Cedar Creek. The Milwaukee River rises outside the Region, in marshes located about seven miles north and northeast of the Village of Campbellsport in southeastern Fond du Lac County, and flows 101.5 miles southeasterly to Lake Michigan at Milwaukee. Approximately 81 miles of this stream is within the Region. The North Branch of the Milwaukee River has its source outside the Region about three miles northeast of the Village of Cascade in southwestern Sheboygan County and flows southerly about 26 miles to join the Milwaukee River about two miles west of the Village of Waubeka. Approximately 6.7 miles of this stream is within the Region. The source of Cedar Creek is Cedar Lake in west-central Washington County. From this source Cedar Creek flows a distance of about 33.2 miles southeasterly to join the Milwaukee River about two miles east of the City of Cedarburg.

The Milwaukee River watershed comprises an area underlain by glacial deposits of diverse origin and diverse hydrologic characteristics. In the Region the eastern boundary of the watershed lies along the eastern slope, within, and along the western edge of the end-moraine system of red glacial drift. The western watershed boundary coincides with the eastern and northern boundaries of the Menomonee River watershed and of the Rock River watershed. This boundary cuts northwesterly across end moraines and ground moraine deposited by the Lake Michigan glacier. In the northern half of Washington County, the watershed boundary of the Milwaukee River crosses into an area underlain by morainal deposits of the Green Bay glacier. In Sheboygan, Fond du Lac, and Dodge counties, where the watershed includes the headwaters of the Milwaukee River, the eastern and western boundaries converge and enclose an area underlain by ground and end-morainal deposits and by drumlins, outwash deposits, and eskers of the Green Bay and Lake Michigan glaciers. Included in the area are numerous marsh deposits.

[6] *Based on SEWRPC estimate for 1963.*

Table 159

EXISTING LAND USE IN THE MILWAUKEE RIVER WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	255.5	163,549	59.19
Woodland, Wetland, and Unused Land	90.8	58,131	21.04
Residential	37.7	24,100	8.72
Transportation-Communication	31.0	19,823	7.18
Park and Recreation	6.5	4,135	1.50
Governmental-Institutional	4.5	2,877	1.04
Industrial	3.7	2,400	0.87
Commercial	2.0	1,261	0.46
Total	431.7	276,276	100.00

Source: SEWRPC.

Milwaukee River

Present Stream Quality: Eight sampling stations, Ml-1, Ml-2, Ml-3, Ml-5, Ml-6, Ml-9, Ml-10, and Ml-11, were established on the Milwaukee River. Another station, Ml-12, is located also on the Milwaukee River but is included under the discussion on the Milwaukee River estuary. The eight sampling stations are located upstream and downstream from the sewage treatment plant outfalls at the cities and villages of Kewaskum, West Bend, Fredonia, Saukville, Grafton, and Mequon and upstream and downstream from the points where the North Branch of the Milwaukee River and Cedar Creek join the Milwaukee River. The eight sampling stations, the sewage treatment plant outfalls, and the confluences of the Milwaukee River and the two tributaries are significant selected points of reference on the Milwaukee River. Their distances downstream from sampling station Ml-1 and the distances between consecutive points of reference are listed in Table 160.

The Milwaukee River is predominantly a calcium bicarbonate stream that is subject to small changes in mineralization. Of the 55 complete chemical analyses run on stream samples collected from the Milwaukee River, the predominant cations were calcium and sodium. Calcium was the predominant cation in 51 analyses at concentrations ranging from 98 ppm in December 1964 at station Ml-5 to 43 ppm in March 1964 at station Ml-11. Sodium was the predominant cation in four analyses at concentrations ranging from 115 ppm in December 1964 to 50 ppm in February 1965 at station Ml-11. Bicarbonate was the predominant anion in all 55 analyses at concentrations ranging from 455 ppm at station Ml-5 in December 1964

Table 160

DISTANCES OF SELECTED POINTS OF REFERENCE ON THE MILWAUKEE RIVER DOWNSTREAM FROM SAMPLING STATION ML-1 AND BETWEEN CONSECUTIVE POINTS OF REFERENCE

Point of Reference	Distance From Station Ml-1 (in miles)	Distance Between Points of Reference (in miles)
Ml-1	0.0	--
Kewaskum STPO[a]	4.4	4.4
Ml-2	7.2	2.8
West Bend STPO	15.0	7.8
Ml-3	23.6	8.6
North Branch Milwaukee River	33.8	10.2
Fredonia STPO	38.0	4.2
Ml-5	45.3	7.3
Saukville	46.3	1.0
Ml-6	51.2	4.9
Grafton STPO	52.1	0.9
Cedar Creek	54.5	2.4
Ml-9	55.8	1.3
Mequon STPO[b]	58.9	3.1
Thiensville STPO	62.6	3.7
Ml-10	63.1	0.5
Mequon STPO[c]	66.8	3.7
Ml-11	74.7	7.9
Menomonee River	81.6	6.9
Ml-12	81.8	0.2
Lake Michigan	82.5	0.7

[a] *STPO—Sewage treatment plant outfall.*

[b] *Ville du Parc facility.*

[c] *Lac du Cours facility.*

Source: SEWRPC.

to 190 ppm at station Ml-11 in July 1964. Maximum nitrate concentration was 7.1 ppm. Total phosphorus at stations Ml-1, Ml-5, Ml-9, and Ml-11 were 0.24, 0.56, 0.40, and 0.28 ppm on September 30, 1964. Selected water analyses of the Milwaukee River at sampling stations Ml-1 and Ml-11 are listed in Tables 161 and 162. Water quality conditions of the Milwaukee River are indicated in Table 163.

The chloride concentrations of the Milwaukee River varied from 170 ppm in December 1964 at station Ml-11 to 0 ppm in August 1964 at station Ml-1. Assuming a "background" concentration of 5 ppm, the Milwaukee River had a chloride impact of 15 to 165 ppm from human sources. The variations in the chloride concentrations of the Milwaukee River are shown in Figure 22 in a series of 14 interpretive stream quality graphs. A conspicuous interpretive feature of these graphs is the relative uniformity of the chloride concentrations over a distance of about 75 miles of the stream from sampling station Ml-1 to station Ml-11 during 9 of 14 months of record. Eight analyses define the water quality with respect to the chloride concentration in the Milwaukee River in February, April, and September 1964. Assuming relative constant quality and

Table 161

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION ML-1 ON THE MILWAUKEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-27-64	10	9-30-64
Iron	0.03	"	0.02	"
Manganese	--	--	0.01	"
Chromium	--	--	<0.02	"
Hexavalent Chromium	--	--	0.00	"
Calcium	69	4-27-64	77	"
Magnesium	38	"	40	"
Sodium (and Potassium)	5	"	--	--
Bicarbonate	260	"	380	9-30-64
Carbonate	10	"	0	"
Sulfate	93	"	--	--
Chloride	5	"	30	9-30-64
Fluoride	--	--	<0.45	"
Nitrite	0.0	4-27-64	0.0	"
Nitrate	--	--	1.8	"
Phosphorus	--	--	0.24	"
Cyanide	--	--	<0.01	12-21-64
Oil	--	--	1.4	9-30-64
Detergents	0.2	4-27-64	0.0	"
Dissolved Solids	350	"	--	--
Hardness	329	"	360	9-30-64
Noncarbonate Hardness	95	"	50	"
Calcium Hardness	171	"	194	"
Magnesium Hardness	158	"	166	"
Alkalinity P	5	"	0	"
Alkalinity M	225	"	310	"
Specific Conductance	584	"	664	"
pH	8.3	"	7.8	"
Color	70	"	--	--
Turbidity	4	"	2	9-30-64
Biochemical Oxygen Demand	4.4	"	2.1	"
Dissolved Oxygen	8.5	"	9.9	"
Coliform Count	1,400	"	3,000	"
Temperature (°F)	56	"	51	"

Source: SEWRPC.

Figure 22

CHLORIDE CONCENTRATION IN THE MILWAUKEE RIVER

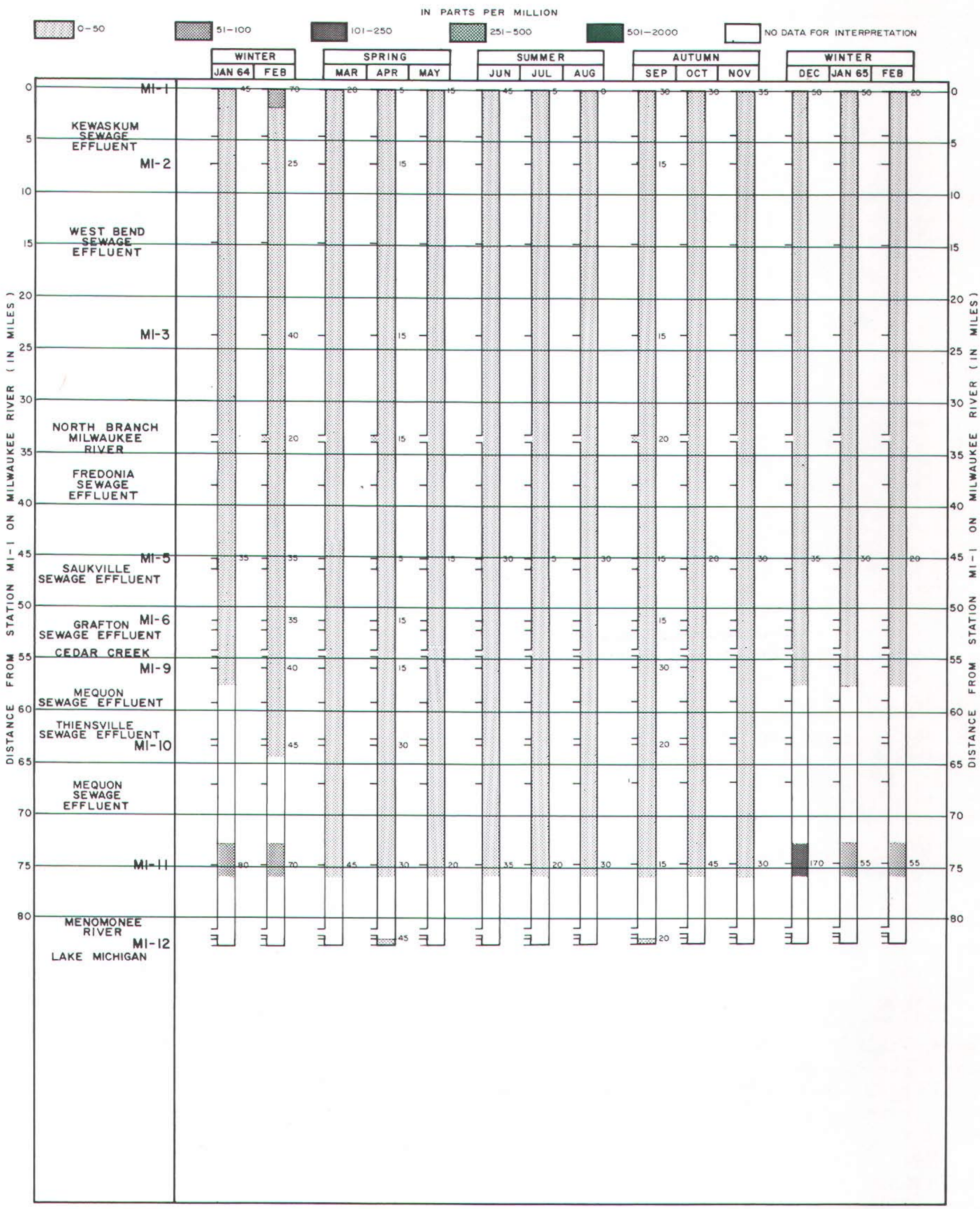


Table 162

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION ML-11 ON THE MILWAUKEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-27-64	10	9-30-64
Iron	0.07	"	0.04	"
Manganese.	--	--	0.03	"
Chromium	--	--	<0.02	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	75	4-27-64	75	"
Magnesium.	30	"	34	"
Sodium (and Potassium)	15	"	35	"
Bicarbonate.	270	"	340	"
Carbonate.	0	"	5	"
Sulfate.	80	"	91	"
Chloride	30	"	15	"
Fluoride	--	--	<0.55	"
Nitrite.	0.0	4-27-64	0.1	"
Nitrate.	--	--	2.1	"
Phosphorus	--	--	0.28	"
Cyanide.	--	--	<0.01	12-21-64
Oil.	--	--	1.6	9-30-64
Detergents	0.1	4-27-64	0.1	"
Dissolved Solids	360	"	435	"
Hardness	312	"	327	"
Noncarbonate Hardness.	90	"	40	"
Calcium Hardness	189	"	187	"
Magnesium Hardness	123	"	140	"
Alkalinity P	0	"	2.5[a]	"
Alkalinity M	220	"	285	"
Specific Conductance	620	"	618	"
pH	7.8	"	7.9	"
Color.	30	"	85	"
Turbidity.	6	"	7	"
Biochemical Oxygen Demand. . . .	7.3	"	2.6	"
Dissolved Oxygen	7.6	"	8.5	"
Coliform Count	24,000	"	32,000	"
Temperature (°F)	56	"	58	"

[a] *Estimated.*

Source: SEWRPC.

normal seasonal variations in the sewage discharge from the eight sewage treatment plants into the Milwaukee River, the flow of the Milwaukee River in April and September 1964 appears adequate to dilute the chloride wastes to concentrations that are within the range of 0 to 50 ppm from as far upstream as station Ml-1 to station Ml-10.

The dissolved solids concentrations in the Milwaukee River varied from 620 ppm in December 1964 at station Ml-1 to 245 ppm in July 1964 at station Ml-5. The "background" concentration of dissolved solids is about 385 ppm. The dissolved solids concentrations in the Milwaukee River are shown in Figure 23 by a series of 14 interpretive stream quality graphs. A characteristic feature of these graphs is the relatively uniform concentrations of dissolved solids that occur throughout reaches of considerable length. Cedar Creek is presumed to be the source of higher concentrations of dissolved solids that occurred in the Milwaukee River in July, September, and December 1964. The effluent from the sewage treatment plant at Kewaskum may be the source of high dissolved solids concentrations that were determined in the upper reaches of the Milwaukee River in September 1964.

Figure 23
DISSOLVED SOLIDS CONCENTRATION IN THE MILWAUKEE RIVER

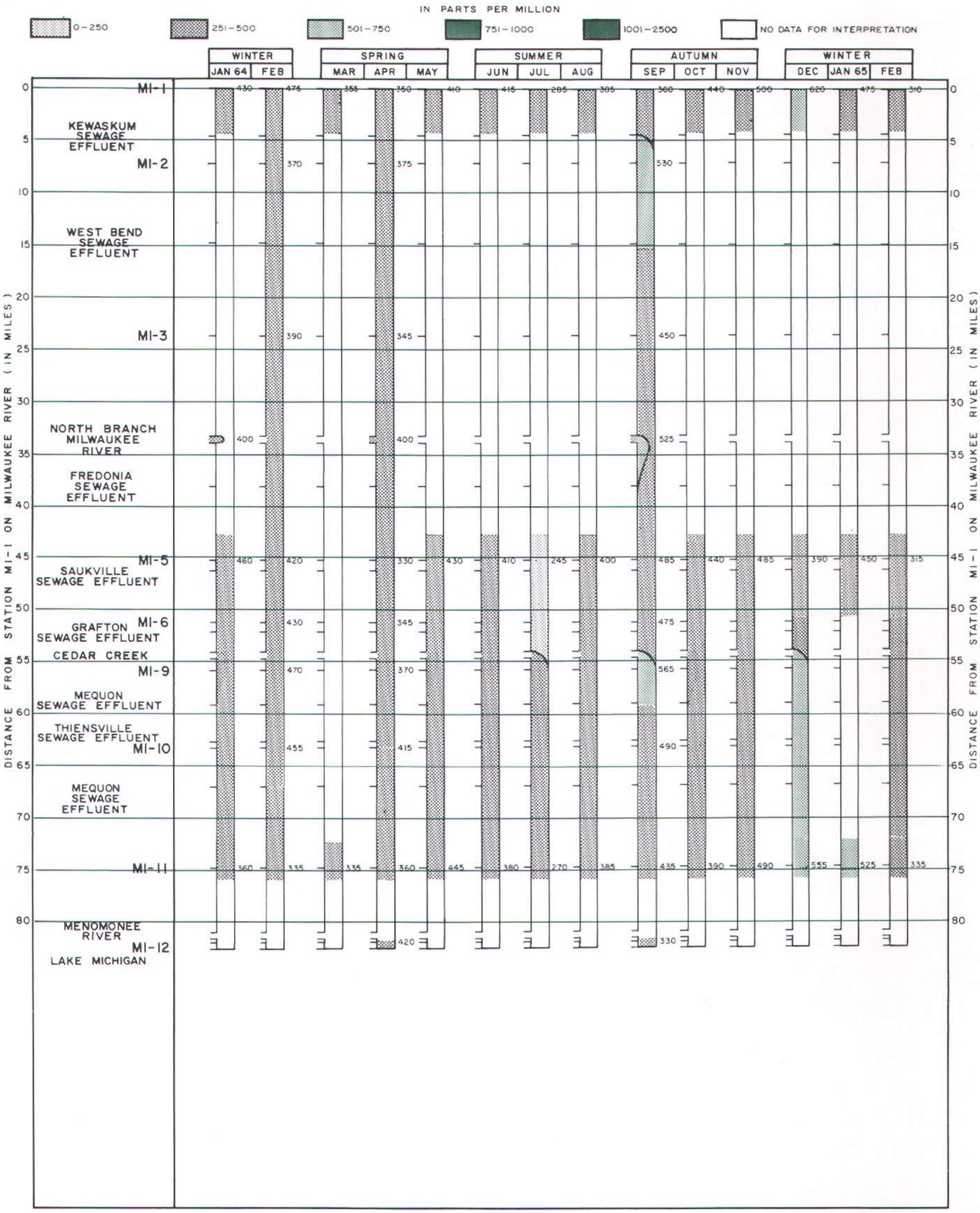


Table 163

WATER QUALITY CONDITIONS OF THE MILWAUKEE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	170	30	0	56
Dissolved Solids (ppm)	620	415	245	55
Dissolved Oxygen (ppm)	24.2	10.2	0.5	102
Coliform Count (MFCC/100 ml) .	170,000	14,800	100	103
Temperature (°F)	87	50	32	103

Source: SEWRPC.

The variations in the dissolved oxygen concentrations in the Milwaukee River are shown by a series of 14 interpretive stream quality graphs in Figure 24. A conspicuous interpretive feature of these graphs is the generally high dissolved oxygen concentrations that occur in the Milwaukee River from sampling station Ml-2 to station Ml-11. This feature is emphasized by the critically low dissolved oxygen concentrations that occurred infrequently at stations Ml-1 and Ml-6. The heavy rainfall which occurred during the 17th and 18th of July 1964 lowered the dissolved oxygen concentrations of the upper reaches of the Milwaukee River in the same manner as described herein under the discussion of the dissolved oxygen concentrations of the Fox and Menomonee rivers. On July 24, 1964, the dissolved oxygen concentrations at sampling stations Ml-1, Ml-2, Ml-3, Ml-5, Ml-6, Ml-9, Ml-10, and Ml-11 were 2.3, 0.7, 2.4, 4.0, 3.1, 5.9, 5.0, and 4.6 ppm, respectively. The average dissolved oxygen concentrations at these stations for the three months of June, August, and September were 6.5, 6.8, 9.8, 7.7, 7.8, 12.3, 9.5, and 9.0 ppm, respectively. The average dissolved oxygen concentration in July 1964 at all eight stations previously listed was 3.5 ppm as compared to 8.7 ppm for these same stations for the three months of June, August, and September.

The variations in the coliform counts in the Milwaukee River are shown in a series of 14 stream quality graphs in Figure 25. The Milwaukee River was subject to bacteriological pollution throughout its length from station Ml-1 to station Ml-11 at one time or another during the 14-month period of field study. Presumed sources of persistent bacteriological pollution are the sewage treatment plants at Kewaskum, West Bend, Saukville, and Grafton. Heaviest and most persistent pollution occurred between stations Ml-10 and Ml-11. The sources that may contribute to this condition are not definitely known. The Lac du Cours sewage treatment facility at Mequon near the Milwaukee County line is not thought to be a principal source of bacteriologic pollution at station Ml-11, because of the low average daily sewage flow rate of less than 100,000 gpd, or less than 0.2 cfs, and because of the low connected population of less than 200 persons.

Figure 26 indicates the variations in the coliform counts in the Milwaukee River at stations Ml-1 and Ml-11. The magnitude of the separation between the two graphs represents the net increase or decrease in the coliform counts that occurred between stations Ml-1 and Ml-11 as a result of opposing processes that increase or decrease the coliform counts in a stream.

The temperature variations of the Milwaukee River at stations Ml-1 and Ml-11 are shown in Figure 27. The maximum temperature of 87°F occurred in June 1964 at station Ml-10. The maximum, average, and minimum temperatures for the period June through September 1964 at stations Ml-1 and Ml-11 were 79°, 67°, and 51°F and 85°, 73°, and 58°F, respectively.

Streamflow and Precipitation: The Milwaukee River is a shallow meandering stream, which most of the year occupies a relatively wide channel between stations Ml-1 and Ml-11. At stations Ml-1 and Ml-9, which are 19.0 and 74.8 miles, respectively, from the river source, the stream had maximum depths of 1.7 feet and 2.3 feet and widths of 43 1/2 feet and 196 feet, respectively, when measured under low-flow conditions in September 1964.

The U. S. Geological Survey maintains a water-stage recorder 2,000 feet downstream from sampling station Ml-11. Table 164 lists the SEWRPC and selected U. S. Geological Survey flow determinations for

Figure 24

DISSOLVED OXYGEN CONCENTRATION IN THE MILWAUKEE RIVER

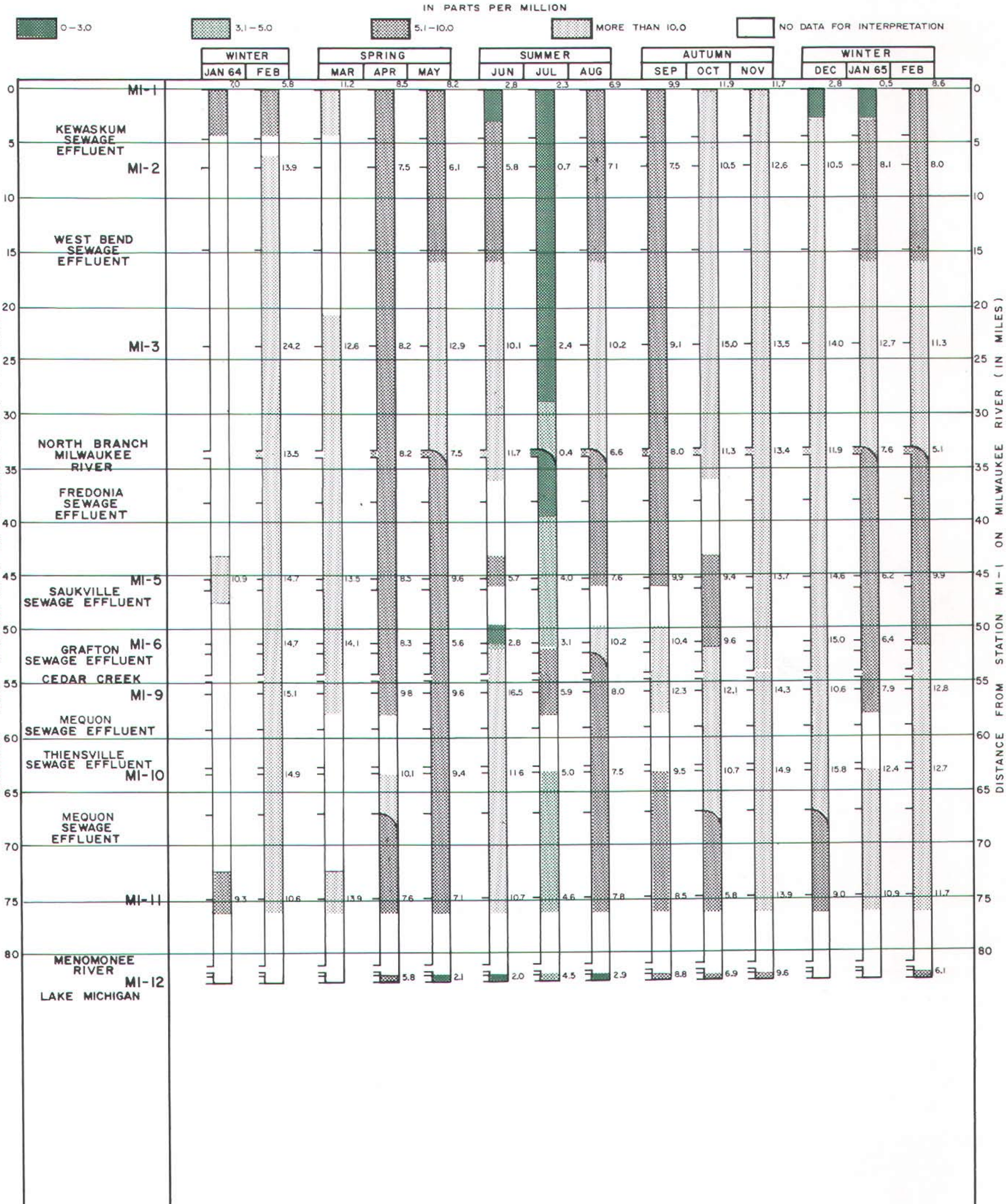


Figure 25

COLIFORM COUNT IN THE MILWAUKEE RIVER

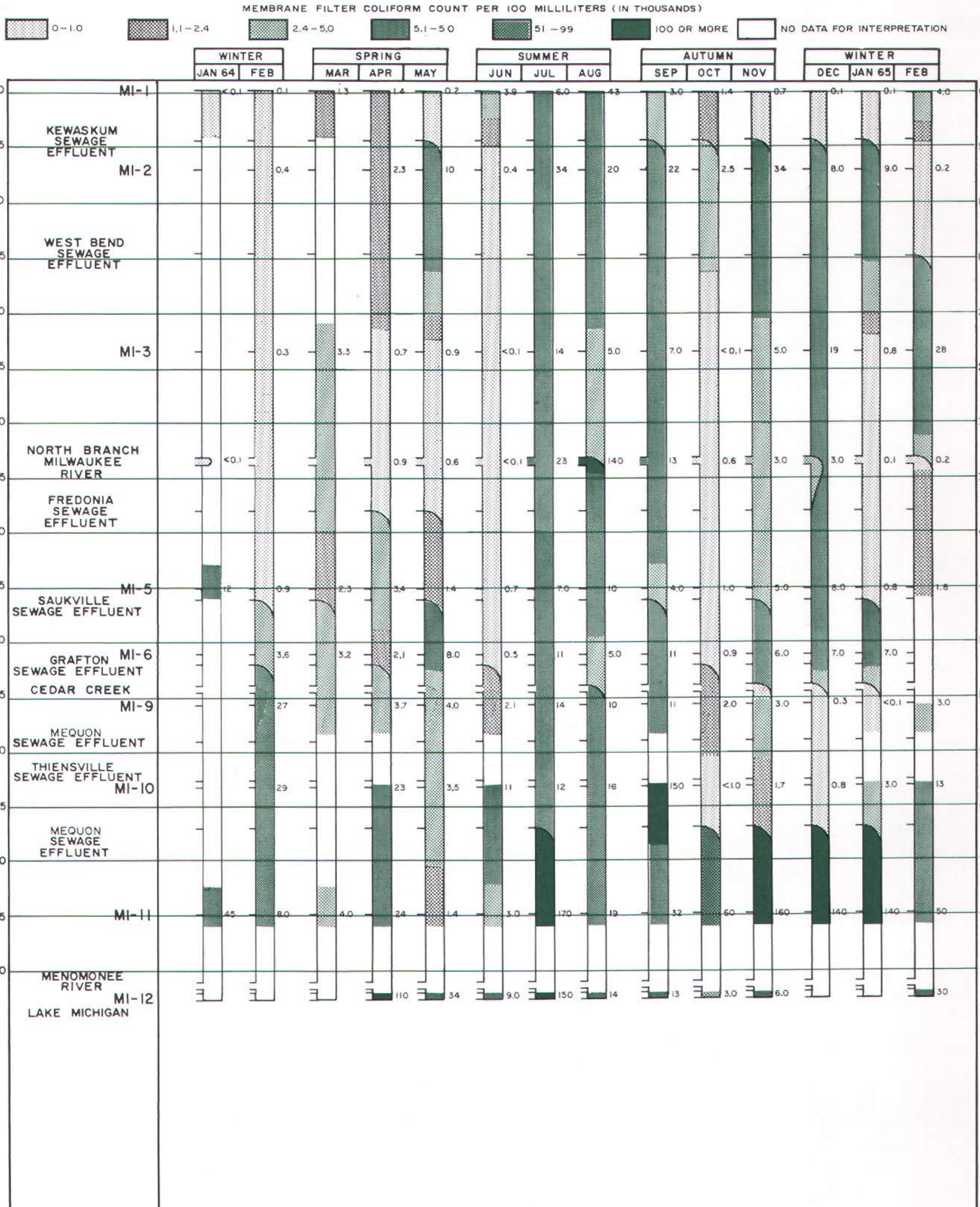


Figure 26

COLIFORM COUNT IN THE MILWAUKEE RIVER

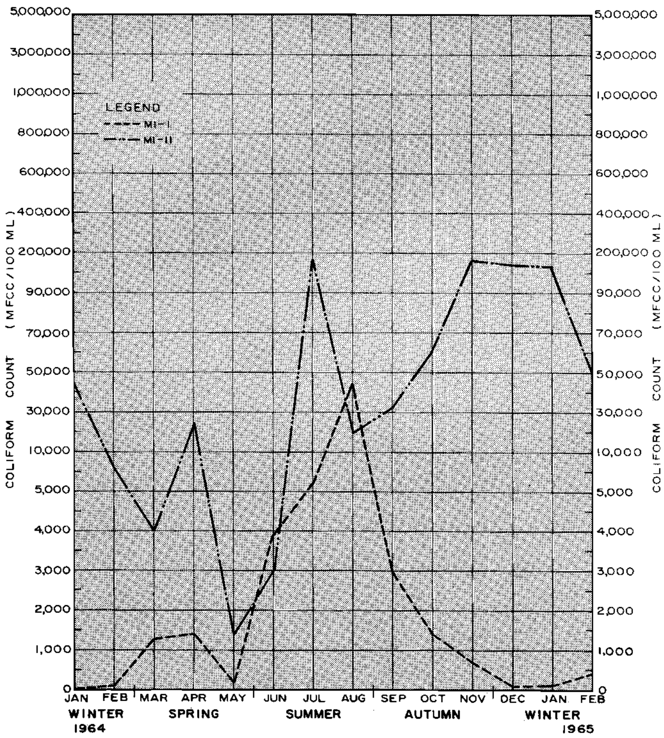
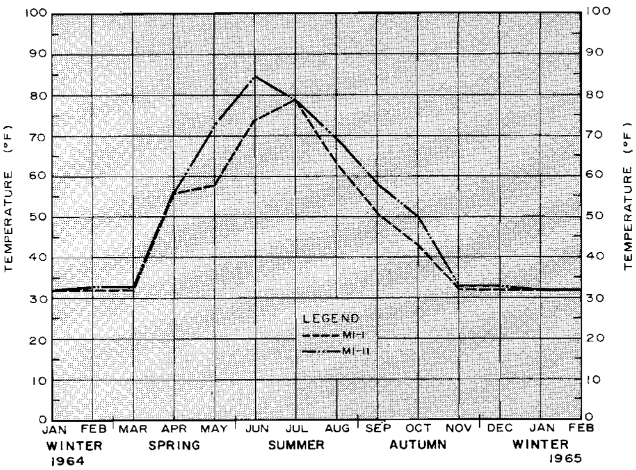


Figure 27

TEMPERATURE OF THE MILWAUKEE RIVER



periods of relative high and low flow in April and September 1964. Table 165 lists the mean daily discharge at this station computed from the water-stage records covering the period from January 1964 through February 1965. Precipitation data pertaining to the same period of time are listed in Tables 166 and 167.

Forecast Quality of the Milwaukee River for the Year 1990: Population studies of the SEWRPC indicate that in 1963 there were an estimated 508,600 people living in the Milwaukee River watershed. Table 168 indicates the estimated 1990 population levels of the watershed under the three alternative regional land use plans. These plans also indicate that the public sewage treatment plants in the watershed exclusive of those of the Milwaukee metropolitan sewerage system will have connected populations as indicated in Table 169. The estimated average daily sewage flow rates for the year 1990 of existing and proposed sewage treatment plants with outfalls on the Milwaukee River are listed in Table 170.

The forecast quality of the Milwaukee River for the year 1990 is indicated in Table 171. This forecast quality is related only to those municipal sewage treatment plants having outfalls on the Milwaukee River. In making the forecast, consideration was given to planned post-chlorination of the effluent from the West Bend sewage treatment plant. The populations of Grafton, Cedarburg, Mequon, and Thiensville are expected to be serviced by the Milwaukee metropolitan sewerage system by the year 1990, thus eliminating these sources of pollution of the Milwaukee River. The treated effluent wastes from the Milwaukee metropolitan sewerage system are discharged into Lake Michigan.

North Branch Milwaukee River

Present Stream Quality: One sampling station, Ml-4, was established on the North Branch of the Milwaukee River about 17.7 miles from the river source. The effluent wastes from the sewage treatment plants at the villages of Adell and Random Lake in Sheboygan County are discharged into tributaries of the North Branch of the Milwaukee River above this station.

The North Branch of the Milwaukee River is a calcium bicarbonate stream of relatively constant total mineralization. In the three complete chemical analyses run on stream samples collected from the North

Table 164

STREAMFLOW MEASUREMENTS OF THE MILWAUKEE RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
MI-1	4-28-64	44	0.64
	9-29-64	19	0.12
MI-3	4-28-64	159	0.64
	9-29-64	76	0.12
MI-9	4-29-64	651	0.75
	9-29-64	237	0.12
MI-11	4-28-64	362	0.64
	4-29-64	564	0.75
	9-29-64	276	0.12

[a] *Measured at U. S. Weather Bureau Station at West Bend, Wisconsin.*

Source: U. S. Weather Bureau, USGS, and SEWRPC.

Table 165

DISCHARGE[a] OF THE MILWAUKEE RIVER AT MILWAUKEE, WISCONSIN JANUARY 1964 THROUGH FEBRUARY 1965

Day	Streamflow (in cfs)													
	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1 . . .	25	82	58	198	485	87	55	193	117	188	110	270	110	95
2 . . .	27	82	74	367	528	121	50	170	129	188	153	240	140	95
3 . . .	32	81	90	398	578	87	46	162	129	179	136	200	162	100
4 . . .	38	82	102	451	624	84	50	144	117	162	133	160	170	120
5 . . .	46	84	106	626	586	87	55	125	193	157	144	150	170	300
6 . . .	52	84	100	1,060	639	87	121	114	244	153	157	140	148	478
7 . . .	56	82	140	1,250	839	81	186	106	203	144	153	130	140	768
8 . . .	59	78	114	937	874	75	75	100	179	148	144	120	160	420
9 . . .	58	76	112	811	471	78	125	97	162	144	148	120	170	330
10 . . .	52	74	116	678	431	72	40	94	208	140	140	120	160	828
11 . . .	48	72	122	564	366	70	78	106	379	136	136	130	140	768
12 . . .	45	71	136	471	335	68	78	94	385	136	153	140	120	855
13 . . .	42	70	180	404	323	65	87	90	293	133	144	150	100	700
14 . . .	39	60	310	372	293	62	81	87	249	133	140	160	95	540
15 . . .	37	57	420	347	282	84	65	65	198	129	193	150	90	460
16 . . .	36	56	600	317	444	60	60	52	162	129	153	130	90	400
17 . . .	35	57	560	299	215	60	297	55	148	129	136	110	90	350
18 . . .	36	58	450	323	329	60	1,490	58	223	121	136	100	90	320
19 . . .	40	59	352	282	624	58	604	60	179	121	136	100	95	310
20 . . .	45	60	465	299	372	65	1,800	65	213	121	133	100	100	350
21 . . .	52	58	391	698	229	62	2,080	462	282	121	106	100	117	400
22 . . .	64	56	288	616	38	157	2,220	198	424	121	78	100	223	320
23 . . .	90	54	254	578	218	87	1,670	305	686	121	117	100	129	260
24 . . .	130	52	254	485	198	60	1,240	431	710	121	121	100	136	220
25 . . .	130	52	260	417	179	58	858	311	594	114	121	100	140	180
26 . . .	124	51	228	372	136	58	503	244	678	358	117	97	157	160
27 . . .	112	51	179	458	103	55	208	188	266	129	140	97	150	150
28 . . .	104	51	168	362	106	52	288	157	293	117	438	103	140	160
29 . . .	96	52	160	564	106	50	226	140	276	117	213	114	130	--
30 . . .	90	--	160	528	100	48	203	133	233	114	250	110	110	--
31 . . .	86	--	164	--	94	--	223	121	--	114	--	97	100	--

[a] *Underscored flow measurements indicate days when sampling occurred on the Milwaukee River.*

Source: USGS.

Table 166

PRECIPITATION[a] AT SHOREWOOD, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

	1964												1965	
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.12	--	0.12	--	--	--	--	0.01	0.08	0.31
2	--	--	--	0.36	0.25	0.37	0.17	--	0.15	--	0.34	0.12	0.38	--
3	--	--	--	0.48	--	--	--	--	--	--	0.05	0.02	--	--
4	--	--	0.01	--	0.03	--	--	--	--	--	--	0.19	--	--
5	--	--	1.48	0.56	--	--	--	--	--	--	0.03	--	--	--
6	--	--	--	0.36	0.08	--	0.48	--	--	0.05	--	--	--	--
7	--	--	--	0.71	--	--	0.56	--	--	--	--	0.05	0.02	--
8	--	--	0.13	--	1.26	--	0.01	--	0.05	0.16	--	--	0.01	0.22
9	0.06	0.02	0.35	--	--	--	--	--	--	0.02	--	--	--	0.07
10	--	--	--	--	--	--	--	0.02	0.24	--	--	--	--	0.18
11	0.01	--	--	--	--	--	--	1.03	--	--	--	0.10	--	--
12	--	0.01	--	--	--	--	--	--	--	--	0.13	--	--	0.36
13	--	0.17	--	0.05	0.21	--	0.18	--	--	--	--	0.32	--	--
14	--	--	0.10	--	--	--	0.32	--	0.06	--	--	--	--	--
15	--	--	--	--	--	0.39	--	--	0.16	--	0.46	--	0.11	--
16	0.05	0.05	--	--	0.95	--	--	--	--	--	--	--	--	--
17	--	--	--	0.02	--	--	--	--	--	--	--	--	--	--
18	--	--	--	0.47	0.18	--	3.60	0.07	0.71	--	--	--	0.01	--
19	--	--	--	--	--	--	--	--	0.08	--	--	0.03	--	--
20	0.05	--	0.13	--	--	0.02	0.03	0.04	--	--	0.13	0.02	--	--
21	--	--	0.01	1.48	--	--	--	1.68	0.12	--	--	--	--	--
22	--	--	--	--	--	0.04	--	0.08	0.11	--	--	--	0.55	--
23	--	0.01	--	--	--	1.01	--	--	0.14	--	--	--	1.30	0.07
24	0.57	--	--	--	0.09	--	--	--	0.01	--	--	0.01	0.51	0.15
25	0.38	--	--	--	--	--	1.02	--	--	--	--	--	--	--
26	--	--	0.64	0.17	--	--	--	--	0.12	--	--	0.07	0.46	--
27	0.01	--	0.06	0.77	--	--	--	--	0.12	--	0.02	--	--	--
28	--	--	0.02	0.12	--	--	0.08	--	--	--	1.13	--	--	--
29	--	--	--	0.07	--	--	0.01	--	--	--	--	0.04	--	--
30	--	--	--	0.10	--	--	--	0.15	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	1.13	0.26	2.93	5.72	3.17	1.83	6.58	3.07	2.07	0.23	2.29	0.98	3.43	1.36

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Branch of the Milwaukee River, the calcium concentrations ranged from 88 to 63 ppm. Bicarbonate concentrations ranged from 395 to 300 ppm. Maximum nitrate concentration was 2.2 ppm. Total phosphorus was 0.20 ppm at station Ml-4 on September 30, 1964. Selected water analyses of the North Branch of the Milwaukee River are listed in Table 172. Water quality conditions of the river are indicated in Table 173. The average numerical values in this table are weighted averages.

The chloride concentrations of the North Branch of the Milwaukee River varied from 20 ppm in February and September 1964 to 15 ppm in April 1964 at station Ml-4. Assuming a "background" concentration of 5 ppm, the chloride impact upon the North Branch of the Milwaukee River was as much as 15 ppm from human sources.

The dissolved solids concentrations in the North Branch of the Milwaukee River varied from 525 ppm in September 1964 to 400 ppm in February and April 1964 at station Ml-4. The "background" concentration of dissolved solids is about 500 ppm.

The dissolved oxygen concentrations in the North Branch of the Milwaukee River varied from 13.5 ppm in February to 0.4 ppm in July 1964 at station Ml-4. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 11.7, 6.7, and 0.4 ppm. Figure 28 indicates the variations in the dissolved oxygen concentrations at station Ml-4. The low dissolved oxygen concentration that occurred at the time of sampling in July probably reflects the same phenomenon that has previously been described in the discussion of the Fox River.

The coliform counts of the North Branch of the Milwaukee River varied from 140,000 MFCC/100 ml in August to less than 100 MFCC/100 ml in February and June 1964 at station Ml-4. The maximum, average,

Table 167

PRECIPITATION[a] AT WEST BEND, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.25	--	0.33	--	--	--	--	0.01	0.12	0.28
2	--	--	--	0.37	0.57	0.34	0.25	--	1.03	--	0.30	0.03	0.19	--
3	--	--	--	0.28	--	0.06	--	--	0.57	--	--	--	--	--
4	--	--	0.01	--	--	--	--	--	0.75	--	--	0.03	--	--
5	--	--	0.90	0.57	0.75	--	--	--	--	--	--	--	--	--
6	--	--	0.01	0.47	0.11	--	0.54	--	--	--	--	--	--	--
7	--	--	0.13	0.35	--	--	0.11	--	--	--	0.01	--	--	--
8	0.02	--	0.26	0.01	0.12	--	0.06	--	0.60	0.21	--	--	0.06	0.13
9	0.01	0.01	--	--	0.07	--	--	--	--	--	--	--	--	0.04
10	--	--	--	--	--	--	--	0.04	0.74	--	--	--	--	0.05
11	0.05	--	--	--	--	--	--	0.03	--	--	0.02	0.12	--	--
12	0.11	0.03	--	--	--	--	--	0.01	--	--	0.13	0.03	--	0.35
13	--	0.05	--	--	0.29	--	0.51	--	--	--	--	0.11	0.01	--
14	--	--	0.09	--	--	--	0.22	--	0.15	--	--	--	--	--
15	--	--	--	--	--	0.41	--	--	--	--	0.20	--	0.06	--
16	--	--	--	--	0.89	--	--	0.05	--	--	--	--	--	--
17	--	--	--	0.32	--	0.26	0.68	--	--	--	--	--	--	--
18	--	--	--	0.04	0.09	--	6.57	0.18	0.65	--	--	--	--	--
19	--	--	--	--	--	--	--	--	0.10	--	--	0.02	--	--
20	--	--	0.01	--	--	--	0.47	0.37	0.47	--	0.10	--	--	--
21	--	--	--	0.72	--	0.14	0.16	1.64	0.98	--	--	--	--	--
22	--	--	--	--	--	0.19	0.03	0.50	0.19	--	--	--	0.10	--
23	--	0.02	--	--	--	--	--	--	0.03	--	--	0.01	0.45	0.04
24	0.54	--	--	--	0.21	--	--	--	0.06	--	--	--	0.40	0.03
25	0.15	--	0.01	--	--	--	0.06	--	--	--	--	--	--	--
26	--	--	0.25	0.07	--	--	--	--	0.12	--	--	--	0.38	--
27	--	--	0.03	0.57	--	--	0.05	--	--	--	0.02	--	--	--
28	--	--	0.02	0.11	--	--	0.29	--	--	--	1.04	--	0.03	--
29	--	--	0.03	0.01	--	--	--	--	--	--	--	--	--	--
30	--	--	--	0.04	--	--	--	0.47	--	--	--	--	--	--
31	--	--	--	--	0.05	--	--	--	--	--	--	--	--	--
Total	0.88	0.11	1.75	3.93	3.40	1.40	10.33	3.29	6.44	0.21	1.82	0.36	1.80	0.92

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Table 168

ESTIMATED POPULATION OF THE MILWAUKEE RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Milwaukee River Watershed	508,600	635,000	628,000	665,000

Source: SEWRPC.

Table 169

ESTIMATED POPULATION CONNECTED TO EXISTING AND PROPOSED SEWAGE TREATMENT PLANTS IN THE MILWAUKEE RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Kewaskum	1,600	4,000	4,200	5,800
City of West Bend	12,500	27,200	23,500	46,700
Village of Fredonia	800	1,800	3,500	3,600
Village of Saukville. . . .	1,100	2,400	4,500	2,600
Village of Grafton.	3,900	Population expected to be in the service area of the Milwaukee metropolitan sewerage system.		
Village of Jackson[a]	500	1,600	2,000	2,600
City of Cedarburg	5,400	Population expected to be in the service area of the Milwaukee metropolitan sewerage system.		
City of Mequon[b]	100			
Village of Thiensville. . .	2,800			
City of Mequon[c]	200			
Total Connected Population	28,800	37,000	37,700	61,300

[a] *New sewage treatment plant to be constructed at Jackson.*

[b] *Ville du Parc Facility.*

[c] *Lac du Cours Facility.*

Source: SEWRPC.

and minimum counts for the period June through September 1964 were 140,000, 44,000, and less than 100 MFCC/100 ml. Figure 29 indicates the variations in coliform counts at station Ml-4.

The maximum temperature of the North Branch of the Milwaukee River was 86°F in June 1964 at station Ml-4. For the period June through September 1964, the maximum, average, and minimum stream temperatures were 86°, 70°, and 52°F.

Streamflow and Precipitation: The North Branch of the Milwaukee River is a meandering stream, which most of the year occupies a relatively deep channel from the Washington County line to its confluence with the Milwaukee River. At station Ml-4, the stream had a maximum depth of 3.9 feet and a width of 67 feet when measured under low-flow conditions in September 1964. The SEWRPC measured the flow of the North Branch of the Milwaukee River during periods of relatively high and low flow in April and September 1964. The SEWRPC flow determinations are listed in Table 174.

Forecast Quality of the North Branch Milwaukee River for the Year 1990: It is anticipated that no significant growth in population will occur in the sub-watershed of the North Branch of the Milwaukee River by the year 1990. The forecasts of future stream quality, as shown in Table 175, reflect this expected condition of a relatively stable population level.

Cedar Creek

Present Stream Quality: Two sampling stations, Ml-7 and Ml-8, were established by the SEWRPC on Cedar Creek at locations 17.3 and 26.2 miles downstream from the river source. The effluent wastes from the sewage treatment plants at the Village of Jackson and the City of Cedarburg and from several industries are discharged into Cedar Creek.

Table 170

ESTIMATED AVERAGE DAILY SEWAGE FLOW RATES OF EXISTING AND PROPOSED SEWAGE TREATMENT PLANTS IN THE MILWAUKEE RIVER WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Average Daily Sewage Flow Rate			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Kewaskum.	200,000[d] 0.3[e]	500,000 0.8	500,000 0.8	1,000,000 1.5
City of West Bend	2,200,000[d] 3.4[e]	4,900,000 7.6	4,200,000 6.5	8,400,000 13.0
Village of Fredonia.	100,000[d] 0.2[e]	200,000 0.3	400,000 0.6	400,000 0.6
Village of Saukville	100,000[d] 0.2[e]	300,000 0.5	500,000 0.8	300,000 0.5
Village of Grafton	500,000 0.8[e]	Population expected to be in the service area of the Milwaukee metropolitan sewerage system.		
Village of Jackson[a].	<100,000[d] < 0.2[e]	200,000 0.3	200,000 0.3	300,000 0.5
City of Cedarburg	1,100,000[d] 1.5[e]	Population expected to be in the service area of the Milwaukee metropolitan sewerage system.		
City of Mequon[b]	<100,000[d] < 0.2[e]			
Village of Thiensville	300,000[d] 0.5[e]			
City of Mequon[c]	<100,000[d] < 0.2[e]			
Total Daily Sewage Flow Rate	<4,700,000[d] < 7.3[e]	6,100,000 9.4	5,800,000 9.0	10,400,000 16.1

[a] *New sewage treatment plant to be constructed at Jackson.*

[b] *Ville du Park Facility.*

[c] *Lac du Cours Facility.*

[d] *Gallons per day.*

[e] *Cubic feet per second.*

Source: SEWRPC.

Cedar Creek is a calcium bicarbonate stream that is subject to small changes in total mineralization. In the 16 complete chemical analyses run on stream samples collected from Cedar Creek, calcium concentrations ranged from 101 to 52 ppm at station Ml-8. Bicarbonate concentrations ranged from 470 to 270 ppm. Maximum nitrate concentration was 3.6 ppm. The total phosphorus concentration at Ml-8 was 0.32 ppm on September 30, 1964. Selected water analyses of Cedar Creek at sampling station Ml-8 are listed in Table 176. Water quality conditions of Cedar Creek are indicated in Table 177.

The chloride concentrations of Cedar Creek varied from 130 ppm in May 1964 to 15 ppm in September 1964 at station Ml-8. Assuming a "background" concentration of 5 ppm, the chloride impact upon Cedar Creek was as much as 125 ppm from human sources. The relatively high chloride concentration of 130 ppm in Cedar Creek that occurred in May 1964 is exceptional for this stream and apparently was due to a "slug" of high chloride wastes that were discharged into the creek from an unknown source.

Table 171

FORECAST QUALITY OF THE MILWAUKEE RIVER: 1990 ALTERNATIVE LAND USE PLANS

Stream	Parameter	Sampling Station	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Milwaukee River	Chloride (in ppm)	Ml-1	30[a]	40[b]	40[b]	40[b]
		Ml-2	15	20	20	30
		Ml-3	15	20	20	30
		Ml-5	15	20	30	30
		Ml-6	15	20	30	20
		Ml-9	30	Less than 20		
		Ml-10	20			
		Ml-11	15			
	Dissolved Solids (in ppm)	Ml-1	430[a]	450	450	450
		Ml-2	530	550	550	550
		Ml-3	450	450	450	450
		Ml-5	485	500	500	500
		Ml-6	475	500	500	500
		Ml-9	565	From 400 to 500		
		Ml-10	490			
		Ml-11	435			
	Dissolved Oxygen (in ppm)	Ml-1	5.5[c]	From 3.0 to 5.0		
		Ml-2	5.3			
		Ml-3	7.9	From 5.5 to 7.0		
		Ml-5	6.8			
		Ml-6	6.6			
		Ml-9	10.7	More than 8.0		
		Ml-10	8.4			
		Ml-11	7.9			
	Coliform Count (in MFCC/ 100 ml)	Ml-1	14,000[c]	20,000[b]	20,000[b]	20,000[b]
		Ml-2	19,100	40,000	50,000	60,000
		Ml-3	6,500	<5,000	<5,000	<5,000
		Ml-5	5,400	10,000	20,000	20,000
		Ml-6	6,900	10,000	20,000	10,000
		Ml-9	9,300	Less than 5,000		
		Ml-10	47,000			
		Ml-11	56,000			

[a] *All chloride and dissolved solids concentrations in this column are based on water analyses for September 1964. Dissolved solids concentration at station Ml-1 is estimated.*

[b] *Presumed numerical value.*

[c] *All dissolved oxygen concentrations and coliform counts in this column are based on average for the period June through September 1964.*

Source: SEWRPC.

The dissolved solids concentrations in Cedar Creek varied from 730 ppm in May 1964 to 330 ppm in June 1964 at station Ml-8. The "background" concentration of dissolved solids ranges from about 560 to 305 ppm. The difference between the maximum and minimum "background" concentration of dissolved solids is presumably due largely to natural increases in the sulfate and calcium concentrations of the stream during periods of heavy drainage from marshes.

The dissolved oxygen concentrations of Cedar Creek varied from 13.4 ppm in November at station Ml-8 to 0 ppm in July at stations Ml-7 and Ml-8. The maximum, average, and minimum dissolved oxygen con-

Table 172

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION ML-4 ON THE NORTH BRANCH MILWAUKEE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	4	4-27-64	14	9-30-64
Iron	0.07	"	0.04	"
Manganese.	--	--	0.01	"
Chromium	--	--	0.02	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	71	4-27-64	88	"
Magnesium.	43	"	44	"
Sodium (and Potassium)	15	"	45	"
Bicarbonate.	300	"	395	"
Carbonate.	20	"	30	"
Sulfate.	86	"	87	"
Chloride	15	"	20	"
Fluoride	--	--	0.45	"
Nitrite.	0.0	4-27-64	0.0	"
Nitrate.	--	--	2.0	"
Phosphorus	--	--	0.20	--
Cyanide.	--	--	--	--
Oil.	--	--	1.4	9-30-64
Detergents	0.1	4-27-64	0.0	"
Dissolved Solids	400	"	525	"
Hardness	356	"	401	"
Noncarbonate Hardness.	80	"	25	"
Calcium Hardness	178	"	221	"
Magnesium Hardness	178	"	180	"
Alkalinity P	10	"	15	"
Alkalinity M	265	"	355	"
Specific Conductance	610	"	690	"
pH	8.4	"	7.8	"
Color.	60	"	80	"
Turbidity.	7	"	10	"
Biochemical Oxygen Demand. . .	2.4	"	1.4	"
Dissolved Oxygen	8.2	"	8.0	"
Coliform Count	900	"	13,000	"
Temperature (°F)	56	"	52	"

Source: SEWRPC.

Table 173

WATER QUALITY CONDITIONS OF THE NORTH BRANCH MILWAUKEE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	20	20	15	3
Dissolved Solids (ppm)	525	440	400	3
Dissolved Oxygen (ppm)	13.5	8.8	0.4	12
Coliform Count (MFCC/100 ml) .	140,000	15,000	100	12
Temperature (°F)	86	50	32	12

Source: SEWRPC.

Table 174

STREAMFLOW MEASUREMENTS OF THE NORTH BRANCH OF THE MILWAUKEE RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Ml-4	4-29-64 9-29-64	137 63	0.75 0.12

[a] *Measured at U. S. Weather Bureau Station at West Bend, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 175

FORECAST QUALITY OF THE NORTH BRANCH OF THE MILWAUKEE RIVER AT SAMPLING STATION ML-4: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
North Branch Milwaukee River	Ml-4	Chloride (in ppm)	20[a]	20	20	20
		Dissolved Solids (in ppm)	525[a]	500	500	500
		Dissolved Oxygen (in ppm)	6.7[b]	More than 6.5		
		Coliform Count (in MFCC/ 100 ml)	44,000[b]	More than 40,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

centrations during the period June through September at station Ml-7 were 8.7, 5.4, and 0.0 ppm. For the same period, but exclusive of the exceptionally low concentration that occurred in Cedar Creek (as in many other streams of the Region following the heavy precipitation on the 17th and 18th of July, 1964), the average dissolved oxygen concentration was 7.2 ppm. At sampling station Ml-8, the maximum, average, and minimum concentrations for the period June through September were 11.9, 7.0, and 6.4 ppm. For the same period, but with the July determination excluded, the average dissolved oxygen concentration was 9.3 ppm. The variations in the dissolved oxygen concentrations of Cedar Creek at station Ml-8 are shown graphically in Figure 28.

Table 176

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION ML-8 ON CEDAR CREEK

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	4	4-27-64	9	9-30-64
Iron	0.14	"	0.07	"
Manganese	--	--	0.02	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	96	4-27-64	85	"
Magnesium	47	"	44	"
Sodium (and Potassium)	0	"	60	"
Bicarbonate	295	"	365	"
Carbonate	0	"	30	"
Sulfate	160	"	150	"
Chloride	20	"	15	"
Fluoride	--	--	<0.5	"
Nitrite	0.0	4-27-64	0.0	"
Nitrate	--	--	2.1	"
Phosphorus	--	--	0.32	"
Cyanide	--	--	<0.01	12-21-64
Oil	--	--	<1	9-30-64
Detergents	0.1	4-27-64	0.0	--
Dissolved Solids	470	"	575	"
Hardness	431	"	394	"
Noncarbonate Hardness	190	"	45	"
Calcium Hardness	239	"	213	"
Magnesium Hardness	192	"	181	"
Alkalinity P	0	"	15	"
Alkalinity M	240	"	330	"
Specific Conductance	730	"	708	"
pH	8.0	"	8.0	"
Color	65	"	60	"
Turbidity	10	"	7	"
Biochemical Oxygen Demand	2.6	"	3.1	"
Dissolved Oxygen	8.5	"	9.7	"
Coliform Count	1,200	"	--	--
Temperature (°F)	56	"	56	9-30-64

Source: SEWRPC.

Table 177

WATER QUALITY CONDITIONS OF CEDAR CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	130	25	15	16
Dissolved Solids (ppm)	730	505	330	16
Dissolved Oxygen (ppm)	13.4	7.5	0	25
Coliform Count (MFCC/100 ml)	120,000	17,200	100	24
Temperature (°F)	91	51	32	25

Source: SEWRPC.

Figure 28

DISSOLVED OXYGEN CONCENTRATIONS IN THE NORTH BRANCH MILWAUKEE RIVER AND CEDAR CREEK

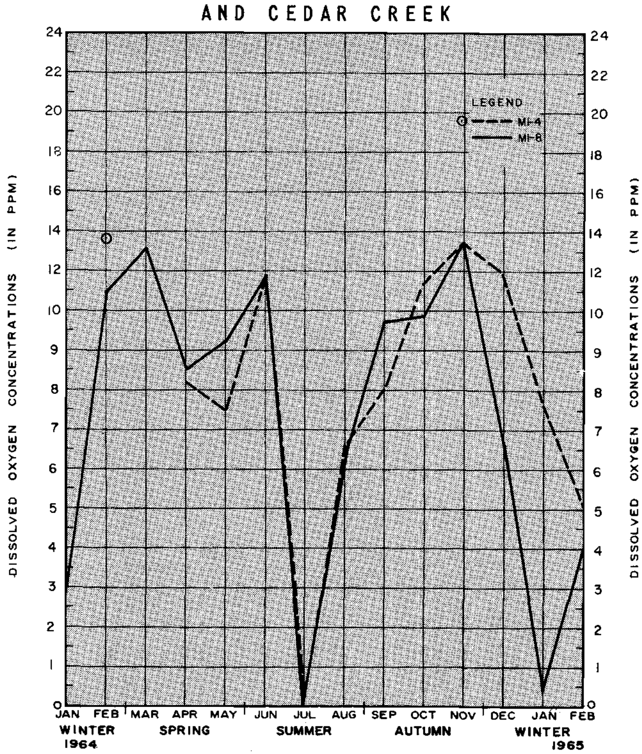
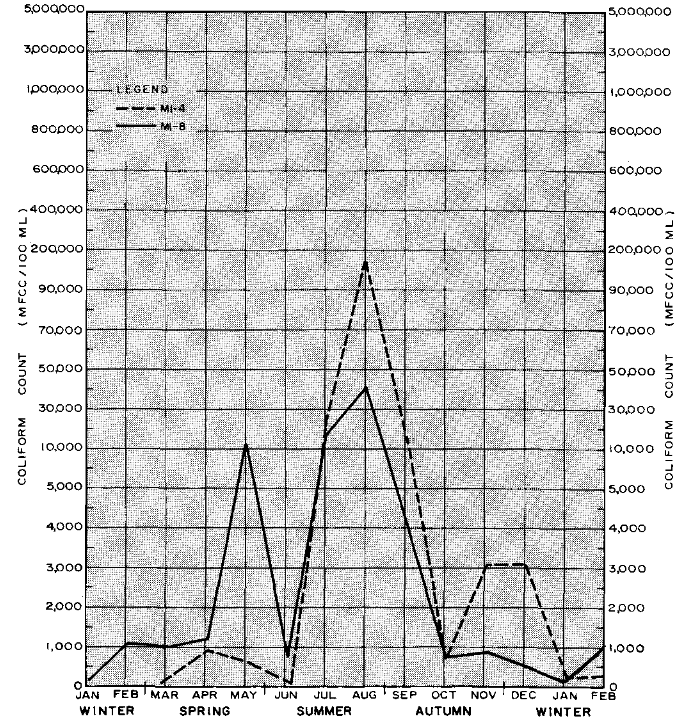


Figure 29

COLIFORM COUNT IN THE NORTH BRANCH MILWAUKEE RIVER AND CEDAR CREEK



The coliform counts of samples collected from Cedar Creek at stations Ml-7 and Ml-8 varied from 120,000 MFCC/100 ml at station Ml-7 in August 1964 to less than 100 MFCC/100 ml in January 1965 at station Ml-8. The maximum, average, and minimum coliform counts for the period June through September 1964 at stations Ml-7 and Ml-8 were 120,000, 65,000, and 100 MFCC/100 ml and 40,000, 19,300, and 800 MFCC/100 ml, respectively. The variations in the coliform counts of Cedar Creek at station Ml-8 are shown in Figure 29.

The maximum temperature of Cedar Creek of 91^{O}F occurred in June 1964 at station Ml-7. The maximum, average, and minimum temperatures for the period June through September 1964 at stations Ml-7 and Ml-8 were 91^{O}, 74^{O}, and 58^{O}F and 85^{O}, 72^{O}, and 56^{O}F at stations Ml-7 and Ml-8, respectively.

Streamflow and Precipitation: Cedar Creek is a shallow meandering stream, which most of the year occupies a relatively wide channel between stations Ml-7 and Ml-8. At station Ml-8, Cedar Creek had maximum depth of 1 1/2 feet and a width of 83 feet when surveyed in January 1964.

The U. S. Geological Survey has a wire-weight gaging station on Cedar Creek near Cedarburg (at sampling station Ml-8). The gage is read twice daily. Flow measurements computed from the stream stage readings are listed in Table 178 for the period January 1964 through February 1965. Precipitation data are listed in Table 167.

Forecast Quality of Cedar Creek for the Year 1990: Population studies by the SEWRPC indicate that significant growth in population will occur in the sub-watershed of Cedar Creek by the year 1990 in and around the City of Cedarburg and the Village of Jackson. The estimated population of Cedarburg was 5,400 in 1963 and is expected to be as much as 15,300 by the year 1990, according to the alternative regional land use plans. The service area of the Milwaukee metropolitan sewerage system, however, may be extended to include Cedarburg; and, thus, the pollution impact from this urbanized area would be diverted from Cedar Creek to Lake Michigan. At Jackson the estimated population was 500 persons in 1963. The sewage effluent from this village will continue to be discharged into Cedar Creek. Tables 169 and 170 list the estimated populations connected to, and the estimated sewage flow rates of, the existing and proposed

Table 178

DISCHARGE[a] OF CEDAR CREEK NEAR CEDARBURG, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	Streamflow (in cfs)													
	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	3.2	9.4	8.0	28	65	13.8	3.0	27	10.6	24	12.4	30	10	7.0
2	3.3	9.2	12	35	121	13.8	5.5	24	13.8	22	18.0	20	13	6.8
3	3.7	9.0	15	118	130	14.5	9.0	22	20	20	18.0	15	20	6.6
4	5.4	9.2	17	91	102	14.5	7.4	20	26	16.6	15.9	14	18	6.4
5	8.0	10	15	86	116	13.8	5.8	15.9	28	15.9	15.2	13	15	6.2
6	15	11	14	167	107	13.1	6.7	14.5	26	15.9	15.2	12	13	40
7	11	12	25	230	88	13.1	7.8	13.1	21	15.9	14.5	11	13	50
8	8.0	11	22	173	91	13.1	11.7	11.7	21	15.9	14.5	10	14	60
9	6.6	10	19	118	86	13.1	11.7	10.2	21	16.6	14.5	10	13	90
10	5.6	9.4	17	93	73	9.8	8.6	9.8	20	17.3	14.5	10	11	110
11	4.9	9.2	18	75	63	7.8	7.4	10.6	23	16.6	14.5	14	9.0	150
12	4.6	9.2	22	65	56	7.4	7.4	9.8	21	15.9	14.5	16	7.8	170
13	4.3	8.8	35	63	53	7.8	8.2	9.0	17.3	15.2	13.8	17	6.8	180
14	4.1	8.4	100	58	51	6.7	7.8	7.8	16.6	14.5	13.8	18	6.4	150
15	4.0	8.2	150	53	48	7.0	7.4	7.0	16.6	14.5	13.8	17	6.0	120
16	4.0	8.0	250	51	63	7.8	6.4	6.7	17.3	13.8	16.6	15	5.8	94
17	4.0	8.2	150	46	68	8.2	6.1	6.4	15.9	13.8	15.2	14	5.6	88
18	4.4	8.4	39	51	60	7.8	86	6.4	15.9	12.4	14.5	12	5.6	86
19	5.4	8.8	37	48	51	7.4	488	7.8	27	12.4	11.7	10	6.0	84
20	7.0	9.2	50	44	41	7.8	901	8.6	39	11.0	9.0	9.2	7.0	88
21	9.0	8.8	46	287	35	6.7	847	24	63	11.0	8.6	8.8	10	86
22	13	8.4	47	121	30	6.7	568	60	91	11.0	8.2	9.0	15	70
23	18	7.8	48	88	25	8.2	379	141	102	12.4	10.0	9.2	19	56
24	25	7.6	48	65	24	8.2	236	83	78	12.4	12.4	9.6	20	46
25	60	7.5	37	53	22	5.8	121	44	53	12.4	13.8	10	19	38
26	46	7.4	30	46	21	4.9	78	26	42	12.4	14.5	9.8	16	34
27	34	7.4	27	65	19.0	4.3	60	21	35	12.4	15.2	9.2	13	30
28	25	7.3	25	99	16.6	3.8	60	16.6	30	11.7	40	9.0	11	70
29	17	7.2	24	96	15.9	3.2	53	14.5	28	12.4	60	9.0	8.2	--
30	13	--	24	78	15.2	2.9	37	13.8	27	12.4	50	9.2	7.6	--
31	10	--	25	--	13.8	--	32	12.4	--	12.4	--	9.2	7.6	--

[a] Underscored flow measurements indicate days when sampling occurred on Cedar Creek.

Source: USGS.

sewage treatment plants in the Milwaukee River watershed for the year 1990, including the Village of Jackson. The forecast quality of Cedar Creek for the year 1990 is indicated in Table 179.

Milwaukee River Estuary

Present Stream Quality: One sampling station, Ml-12, was established by the SEWRPC in the Milwaukee River estuary. The flow system in this part of the Milwaukee River is extremely complex, with massive movements of water in constantly shifting currents at differing depths and in varying directions. Currents tens of feet wide and at least three feet deep have been observed to move upstream parallel to one bank, then suddenly shift to a downstream direction at about a 30 degree angle away from the same bank. Lake Michigan water probably enters the lower reaches of the Milwaukee River and moves as far upstream as station Ml-12 (or even farther upstream), causing an equally complex variety of constantly changing admixtures of river and lake water.

The establishment of sampling station Ml-12 was intended to provide data on the quality of the Milwaukee River estuary solely for comparison purposes. Representative samples of the Milwaukee River estuary cannot be expected from a point sample at a given instant at a given stream depth. Consequently, the stream quality data presented in Tables 180 and 181 should be used with extreme caution and only within context. No forecast of stream quality of the Milwaukee River estuary for the year 1990 is made in this study.

MINOR STREAMS TRIBUTARY TO LAKE MICHIGAN

The composite watershed comprising minor streams that are tributary to Lake Michigan ranks third in population and seventh in size as compared to the other 11 watersheds of the Region. An estimated 218,000[7]

[7] *Based on SEWRPC estimate for 1963.*

Table 179

FORECAST QUALITY OF CEDAR CREEK: 1990 ALTERNATIVE LAND USE PLANS

Stream	Parameter	Sampling Station	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Cedar Creek	Chloride (in ppm)	MI-7 MI-8	20[a] 15[a]	40 30	50 30	60 40
	Dissolved Solids (in ppm)	MI-7 MI-8	565[a] 575[a]	600 600	650 600	650 650
	Dissolved Oxygen (in ppm)	MI-7 MI-8	5.4[b] 7.0	More than 4.0 More than 6.0		
	Coliform Count (in MFCC/ 100 ml)	MI-7 MI-8	65,000[b] 19,300	200,000 50,000	250,000 70,000	330,000 90,000

[a] *Based on analyses for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

persons reside in this composite watershed, which has a total area of 93 square miles and an average population density of 2,350 people per square mile. Principal land uses include agricultural and residential, which together comprise over 66 percent of the total area of the composite watershed. The areas within the watershed devoted to each of eight major land use categories, are listed below in Table 182.

Three streams were studied by the SEWRPC in the composite watershed: Sucker Creek in Ozaukee County and Pike Creek and Barnes Creek in Kenosha County, Wisconsin. Sucker Creek rises within the Region about two miles northeast of the Village of Belgium and flows southward to its point of discharge into Lake Michigan, about three miles north of the harbor at the City of Port Washington. Pike Creek rises near the north central suburbs of the City of Kenosha and flows east and southeastward through the City of Kenosha to Lake Michigan. The lower reaches of the creek flow through a large-diameter subterranean culvert. The source of Barnes Creek is at a point two miles north of the Illinois State line and less than one mile from Lake Michigan. This small creek flows northeast, east, and southeast to Lake Michigan.

Sucker Creek flows through a low broad valley between two end moraines of red glacial drift paralleling Lake Michigan. Pike Creek flows off the eastern slope of a broad end moraine paralleling Lake Michigan immediately west of the City of Kenosha and deepens its channel as it meanders through a belt of emerged beach deposits located between the end moraine and Lake Michigan. Barnes Creek rises within this belt of emerged beach deposits, forms a large bend directed northward, and flows to Lake Michigan.

Sucker Creek

Present Stream Quality: One sampling station, Mh-1, was established on Sucker Creek. Station Mh-1 is located 5.5 miles downstream from the source of Sucker Creek and 3.3 miles upstream from where the creek enters Lake Michigan.

Sucker Creek apparently has a relatively constant total mineralization. In two complete chemical analyses run on stream samples collected from Sucker Creek, calcium was the predominant cation at concentrations of 129 and 140 ppm in April and October 1964, respectively. Sulfate and bicarbonate were the predominant anions, sulfate being predominant in April at 420 ppm. Bicarbonate was the predominant

Table 180

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION ML-12 AT THE MILWAUKEE RIVER ESTUARY: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	1	4-27-64	4	9-30-64
Iron	0.12	"	0.06	"
Manganese.	--	--	0.03	"
Chromium	--	--	--	--
Hexavalent Chromium.	--	--	--	--
Calcium.	81	4-27-64	57	9-30-64
Magnesium.	40	"	25	"
Sodium (and Potassium)	15	"	30	"
Bicarbonate.	270	"	255	"
Carbonate.	5	"	5	"
Sulfate.	105	"	62	"
Chloride	45	"	20	"
Fluoride	--	--	--	--
Nitrite.	0.0	4-27-64	0.1	9-30-64
Nitrate.	--	--	2.4	"
Phosphorus	--	--	--	--
Cyanide.	--	--	--	--
Oil.	--	--	--	--
Detergents	0.0	4-27-64	0.1	9-30-64
Dissolved Solids	420	"	330	"
Hardness	366	"	247	"
Noncarbonate Hardness.	140	"	30	"
Calcium Hardness	202	"	142	"
Magnesium Hardness	164	"	105	"
Alkalinity P	2.5	"	2.5	"
Alkalinity M	225	"	215	"
Specific Conductance	696	"	508	"
pH	8.4	"	7.6	"
Color.	45	"	40	"
Turbidity.	6	"	10	"
Biochemical Oxygen Demand. . . .	5.6	"	4.3	"
Dissolved Oxygen	5.8	"	8.8	"
Coliform Count	110,000	"	13,000	"
Temperature (^{o}F)	57	"	58	"

Source: SEWRPC.

Table 181

WATER QUALITY CONDITIONS OF THE MILWAUKEE RIVER ESTUARY (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	45	35	20	2
Dissolved Solids (ppm)	420	375	330	2
Dissolved Oxygen (ppm)	12.0	6.1	2.0	9
Coliform Count (MFCC/100 ml) . .	150,000	41,000	3,000	9
Temperature (^{o}F)	79	59	33	9

Source: SEWRPC.

Table 182

EXISTING LAND USE IN THE COMPOSITE WATERSHED:[a] 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	38.2	24,431	41.05
Residential.	23.6	15,087	25.35
Transportation-Communication . . .	11.7	7,453	12.52
Woodland, Wetland, and Unused Land	9.9	6,347	10.67
Park and Recreational.	3.4	2,153	3.62
Governmental-Institutional	2.6	1,697	2.85
Industrial	2.6	1,688	2.84
Commercial	1.0	652	1.10
Total	93.0	59,508	100.00

[a] *Comprised of minor streams within the Region which are tributary to Lake Michigan.*

Source: SEWRPC.

anion in October at 415 ppm. Maximum nitrate concentration was 2.4 ppm. Total phosphorus was 0.24 ppm on October 15, 1964. Selected water analyses of Sucker Creek at station Mh-1 are listed in Table 183. Water quality conditions of Sucker Creek are indicated in Table 184.

The chloride concentration in Sucker Creek was 30 ppm in April and in October 1964. Assuming a "background" chloride concentration of 10 ppm, there was a chloride impact upon the stream of 20 ppm from human sources.

The dissolved solids concentrations were 790 ppm in April and 725 ppm in October 1964. The assumed "minimum background" concentration of dissolved solids is 690 ppm. Sulfate and bicarbonate were the principal ions involved in the change in chemical quality of Sucker Creek. Sulfate concentrations were 420 and 258 ppm in April and October, respectively. Bicarbonate concentrations were 220 ppm in April and 415 ppm in October.

The dissolved oxygen concentrations in Sucker Creek varied from 10.0 ppm in February 1965 to 0.3 ppm in November 1964. During the period June through September, the maximum, average, and minimum concentrations were 9.1, 4.1, and 0.4 ppm, respectively. As shown in Figure 30, the dissolved oxygen concentrations in Sucker Creek were less than 5.0 ppm during six consecutive monthly samplings from August 1964 through January 1965. Critical concentrations of 3.0 ppm or less occurred in August, September, October, and November.

Coliform counts in Sucker Creek were found to be extremely variable and ranged from 140,000 MFCC/100 ml in November to less than 100 MFCC/100 ml in June 1964. During the period June through September, the maximum, average, and minimum coliform counts were more than 6,000, 2,000, and less than 100 MFCC/100 ml. Sucker Creek is a small stream and has a sluggish flow. The lack of consistency in the coliform counts in this stream probably indicates a source or sources of bacteriological pollution that affect the quality of the stream intermittently. Higher counts in Sucker Creek occurred when the stream was sampled one to two days after a moderate rainfall that followed a period of no precipitation. An evaluation of available data indicates that the occasional bacteriological pollution of Sucker Creek may be from agricultural sources. Figure 31 shows the coliform counts in the minor streams of the Lake Michigan watershed. It should be noted that the vertical scale in this figure emphasizes coliform counts in the range 0 to 5,000 MFCC/100 ml.

The maximum temperature of Sucker Creek was 78°F in June 1964 and averaged 66°F for the period June through September 1964. Figure 32 shows the monthly variations in the temperature of Sucker Creek at station Mh-1 as compared to the temperature of Pike Creek and Barnes Creek.

Table 183

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MH-1 ON SUCKER CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-16-64	9	10-15-64
Iron	0.03	"	0.04	"
Manganese	--	--	0.00	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	129	4-16-64	140	"
Magnesium	63	"	62	"
Sodium (and Potassium)	35	"	20	"
Bicarbonate	220	"	415	"
Carbonate	0	"	0	"
Sulfate	420	"	258	"
Chloride	30	"	30	"
Fluoride	--	--	0.85	"
Nitrite	0.0	4-16-64	0.0	"
Nitrate	--	--	2.4	"
Phosphorus	--	--	0.24	"
Cyanide	--	--	--	--
Oil	--	--	<2	10-15-65
Detergents	0.1	4-16-64	0.1	"
Dissolved Solids	790	"	725	"
Hardness	582	"	606	"
Noncarbonate Hardness	400	"	265	"
Calcium Hardness	322	"	349	"
Magnesium Hardness	260	"	257	"
Alkalinity P	0	"	0	"
Alkalinity M	180	"	340	"
Specific Conductance	1,020	"	1,030	"
pH	8.0	"	7.2	"
Color	125	"	75	"
Turbidity	2	"	2	"
Biochemical Oxygen Demand	1.6	"	1.1	"
Dissolved Oxygen	7.4	"	3.0	"
Coliform Count	400	"	1,600	"
Temperature (^{o}F)	46	"	52	"

Source: SEWRPC.

Streamflow and Precipitation: Sucker Creek is a relatively shallow stream occupying a narrow channel. Near sampling station Mh-1, a distance 5.5 miles downstream from the source, the stream had a maximum depth of approximately 1 foot and a width of 9 feet when observed under low-flow conditions in October 1964.

The flow of Sucker Creek was measured by the SEWRPC in the spring and autumn of 1964 during periods of relatively high and low flow. The streamflow data are listed in Table 185. Table 186 indicates the daily precipitation at Port Washington, Wisconsin.

Forecast Quality of Sucker Creek for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were 950 people living in the Sucker Creek sub-watershed. Table 187 indicates the estimated populations for the year 1990 under the three alternative regional land use plans. No estimates of sewage flow rates are listed because the population of this sub-watershed is presently served by and will probably continue to be served by private septic tank systems to 1990. Table 188 indicates the future quality of Sucker Creek.

Figure 30
DISSOLVED OXYGEN CONCENTRATIONS IN MINOR STREAMS OF THE LAKE MICHIGAN WATERSHED

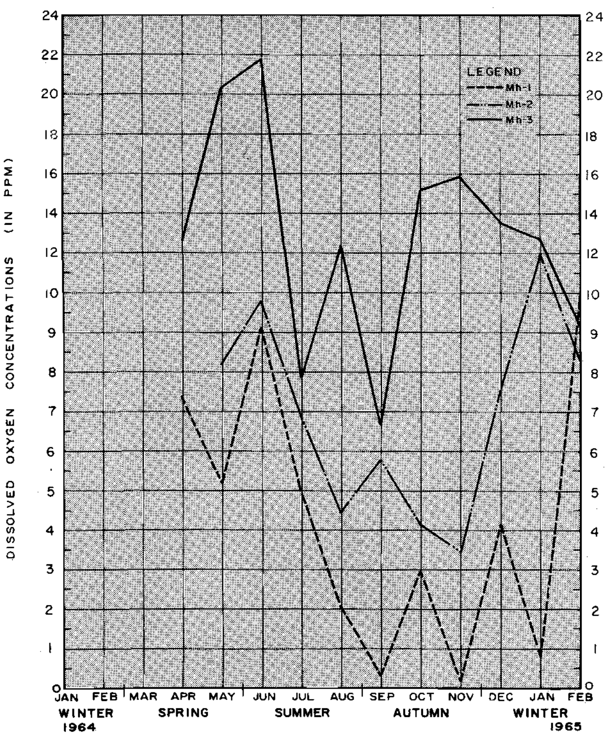


Figure 31
COLIFORM COUNT IN MINOR STREAMS OF THE LAKE MICHIGAN WATERSHED

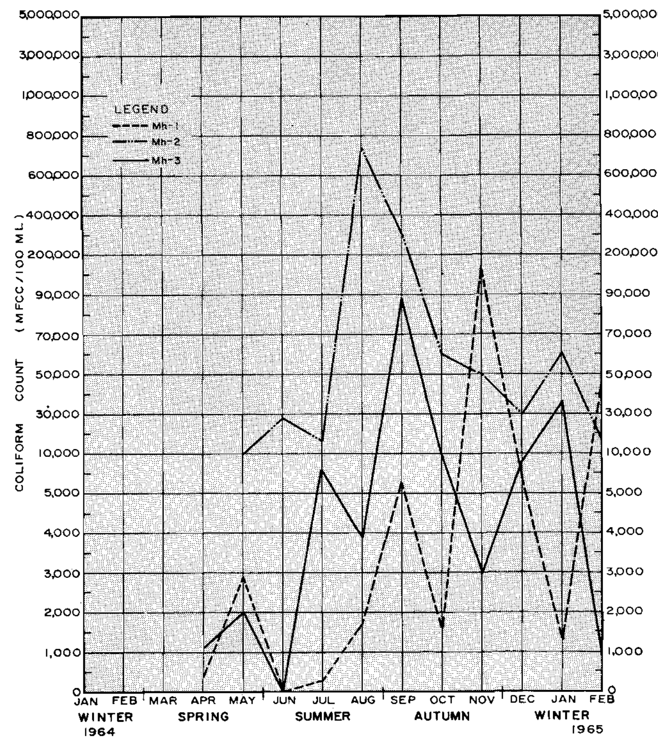
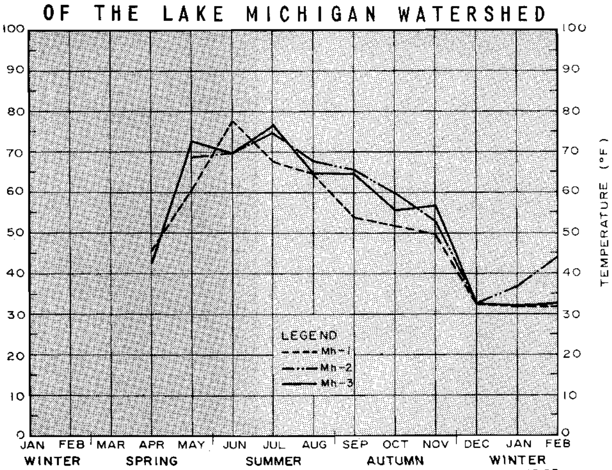


Figure 32
TEMPERATURES OF THE MINOR STREAMS OF THE LAKE MICHIGAN WATERSHED



Pike Creek

Present Stream Quality: One sampling station, Mh-2, was established on Pike Creek. Station Mh-2 is located 2.8 miles downstream from the source of Pike Creek and 1.4 miles upstream from where the creek enters Lake Michigan.

Pike Creek is predominantly a calcium bicarbonate stream subject to medium changes in total mineralization. In seven complete chemical analyses run on samples collected from Pike Creek, calcium and sodium were the predominant cations. Calcium occurred as the predominant cation in the four samples collected between June and November at concentrations ranging from 77 to 43 ppm. Sodium occurred as the predominant cation in the three samples collected between December 1964 and February 1965 at concentrations ranging from 175 to 160 ppm. Bicarbonate and chloride were the predominant anions, ranging from 305 to 205 ppm and from 285 to 220 ppm, respectively. Bicarbonate was the predominant anion in the

Table 184

WATER QUALITY CONDITIONS OF SUCKER CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	30	30	30	2
Dissolved Solids (ppm)	790	760	725	2
Dissolved Oxygen (ppm)	10.0	4.3	0.3	11
Coliform Count (MFCC/100 ml) .	140,000	18,800	<100	11
Temperature (°F)	78	52	32	11

Source: SEWRPC.

Table 185

STREAMFLOW MEASUREMENTS OF SUCKER CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Mh-1	4-25-64	5.5	1.25
	10-15-64	0	0

[a] Measured at U. S. Weather Bureau Station at Port Washington, Wisconsin.

Source: U. S. Weather Bureau and SEWRPC.

Table 186

PRECIPITATION[a] AT PORT WASHINGTON, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.30	--	0.79	--	--	--	0.02	0.07	0.15	0.03
2	--	--	--	0.76	0.37	0.19	--	--	0.19	--	0.38	0.04	0.14	--
3	--	--	--	--	--	--	0.02	--	0.46	--	--	0.04	--	--
4	--	--	0.67	--	0.01	--	--	--	--	--	0.05	0.02	--	--
5	--	--	0.92	0.85	0.52	--	--	--	--	--	--	--	--	--
6	--	--	0.04	0.80	0.04	--	1.63	--	0.01	--	--	--	--	--
7	--	--	--	--	0.10	--	0.24	--	--	0.02	--	--	--	0.01
8	0.01	--	0.35	--	0.04	--	0.05	--	0.02	0.15	--	--	--	0.08
9	--	0.02	--	--	--	--	--	--	0.68	--	--	--	--	0.22
10	--	--	--	--	--	--	--	--	0.41	--	--	0.08	--	0.04
11	0.18	--	--	--	--	--	--	0.01	--	--	--	0.01	--	0.24
12	--	0.11	--	--	--	--	--	--	--	--	0.15	0.22	0.01	0.11
13	--	--	--	--	0.11	--	0.67	--	--	--	--	--	--	--
14	--	--	0.04	--	--	0.07	0.03	--	0.14	--	--	--	0.03	--
15	--	--	--	--	--	0.22	--	--	--	--	0.25	--	0.01	--
16	--	--	--	--	1.01	--	--	--	--	--	--	--	--	--
17	--	--	--	0.20	--	0.18	0.50	--	--	--	--	--	--	--
18	--	--	--	--	0.02	--	0.84	0.26	1.11	--	--	--	--	--
19	0.04	--	--	--	--	--	--	--	--	--	--	0.02	--	--
20	0.30	--	0.04	--	--	--	0.86	0.86	0.57	--	0.19	--	--	--
21	--	--	--	1.25	--	0.03	0.10	1.60	0.27	--	--	--	--	--
22	--	--	--	--	--	0.45	--	0.11	--	--	--	--	0.38	--
23	--	0.03	--	--	--	--	--	--	0.06	--	--	--	0.61	0.20
24	0.75	--	--	--	0.15	--	0.07	--	--	--	--	--	0.19	0.09
25	0.02	--	0.28	--	--	--	0.77	--	--	--	--	0.02	0.01	--
26	--	--	0.17	0.37	--	--	--	--	0.08	--	1.12	--	0.72	--
27	--	--	0.03	0.89	--	--	1.03	--	--	--	0.26	--	0.01	--
28	--	--	--	0.10	--	--	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	0.07	--	--	--	0.05	--	--	--	--	--	--
31	--	--	--	--	0.01	--	--	--	--	--	--	--	0.41	--
Total	1.30	0.16	2.54	5.29	2.68	1.14	7.60	2.89	4.00	0.17	2.42	0.52	2.67	1.02

[a] Precipitation measured in inches. Trace quantities not included.

Source: U. S. Weather Bureau.

Table 187

ESTIMATED POPULATION OF THE SUCKER CREEK SUB-WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sucker Creek Sub-Watershed	950	950	950	1,080

Source: SEWRPC.

Table 188

FORECAST QUALITY OF SUCKER CREEK AT SAMPLING STATION MH-1: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sucker Creek	Mh-1	Chloride (in ppm)	20[a]	20	20	20
		Dissolved Solids (in ppm)	590[a]	600	600	600
		Dissolved Oxygen (in ppm)	4.1[b]	From 3.5 to 4.5		
		Coliform Count (in MFCC/ 100 ml)	2,000[b]	From 1,500 to 3,000		

[a] Based on analysis for October 1964.

[b] Based on average for the period June through September 1964.

Source: SEWRPC.

samples where calcium was the predominant cation. Conversely, chloride was the predominant anion in those samples where sodium was the predominant cation. Maximum nitrate concentration was 6.1 ppm. Total phosphorus was 0.80 ppm on October 16, 1964. Selected analyses of Pike Creek at station Mh-2 are listed in Table 189. Water quality conditions of Pike Creek are indicated in Table 190.

The chloride concentrations in Pike Creek varied from 285 ppm in February 1965 to 20 ppm in June and November 1964. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon the stream was as much as 275 ppm from human sources.

The dissolved solids concentrations varied from 780 ppm in February 1965 to 260 ppm in November 1964. The assumed "background" concentration of dissolved solids is about 325 ppm. The principal ions that occurred in higher concentration in February than in November were chloride and sodium. In the samples collected in June, September, October, and November 1964, the chloride concentrations ranged from 45 to 20 ppm. The corresponding sodium concentrations ranged from 70 to 35 ppm. In December 1964 and in January and February 1965, the chloride and sodium concentrations increased markedly. During these

Table 189

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MH-2 ON PIKE CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	5	6-11-64	5	10-16-64
Iron	--	--	0.05	"
Manganese	--	--	0.01	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	59	6-11-64	77	"
Magnesium	22	"	33	"
Sodium (and Potassium)	35	"	70	"
Bicarbonate	205	"	305	"
Carbonate	0	"	0	"
Sulfate	112	"	160	"
Chloride	20	"	45	"
Fluoride	--	--	<0.55	"
Nitrite	0.0	6-11-64	0.4	"
Nitrate	--	--	2.0	"
Phosphorus	--	--	0.80	"
Cyanide	--	--	<0.1	11-11-64
Oil	--	--	<1	10-16-64
Detergents	0.1	6-11-64	--	--
Dissolved Solids	355	"	540	10-16-64
Hardness	240	"	327	"
Noncarbonate Hardness	70	"	75	"
Calcium Hardness	147	"	193	"
Magnesium Hardness	93	"	134	"
Alkalinity P	0	"	0	"
Alkalinity M	170	"	250	"
Specific Conductance	538	"	740	"
pH	7.4	"	7.4	"
Color	20	"	5	"
Turbidity	10	"	10	"
Biochemical Oxygen Demand	12.1	"	4.0	"
Dissolved Oxygen	9.8	"	4.2	"
Coliform Count	28,000	"	60,000	"
Temperature (^{o}F)	70	"	60	"

Source: SEWRPC.

last three months of sampling, chloride concentrations ranged from 285 to 220 ppm, and sodium concentrations ranged from 175 to 160 ppm. Pike Creek was also receiving hot liquid wastes in sufficient quantities during the last two winter months to build up the stream temperature to 37^{O}F when sampled in January and to 44^{O}F when sampled in February 1965. The high sodium chloride concentrations of Pike Creek are assumed to be of industrial origin.

The dissolved oxygen concentrations of Pike Creek varied from 12.0 ppm in January 1965 to 3.5 ppm in November 1964. During the period June through September 1964, the maximum, average, and minimum dissolved oxygen concentrations were 9.8, 6.7, and 4.5 ppm, respectively. As shown in Figure 30, the dissolved oxygen concentrations in Pike Creek were less than 5.0 ppm at the time of sampling in August, October, and November 1964. Critical concentrations of 3.0 ppm or less did not occur at the time of sampling during the 10 months of record at station Mh-2.

Coliform counts varied from 740,000 MFCC/100 ml in August to 10,000 MFCC/100 ml in May 1964. The coliform counts in Pike Creek are consistently high, indicating a relatively constant source or sources of bacteriological pollution. The relatively high level of the coliform count in Pike Creek appears unrelated to rainfall, indicating that the coliform bacteria are not carried into the creek principally by overland runoff. There are no known sewage treatment plants on Pike Creek. The high coliform counts may be of industrial origin. Figure 31 shows the variations in coliform counts in the Pike River at sampling station Mh-1 in comparison to the coliform counts in Sucker Creek and in Barnes Creek.

The temperature of Pike Creek varied from 75^{O}F in July to 33^{O}F in December 1964 and averaged 70^{O}F during the period June through September 1964. Figure 32 shows the monthly variations in the temperature of Pike Creek at sampling station Mh-2 as compared to the temperature of Sucker Creek and of Barnes Creek.

Streamflow and Precipitation: Pike Creek is a shallow stream occupying a relatively deep channel. At sampling station Mh-2, a distance 2.8 miles from the source, Pike Creek was 1 foot deep and 12 feet wide when measured in October 1964.

The flow of Pike Creek was measured once by the SEWRPC during low-flow conditions in October 1964, as listed in Table 191. Table 43 indicates the daily precipitation at Union Grove, Wisconsin.

Forecast Quality of Pike Creek for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were 23,000 people living in the Pike Creek sub-watershed. Table 192 indicates the estimated population for the year 1990 under the three alternative regional land use plans. No estimate of sewage flow rates is listed because the population of this sub-watershed will be connected by 1990 to the City of Kenosha sewerage system. Table 193 presents forecasts of future stream quality of Pike Creek.

Barnes Creek

Present Stream Quality: One sampling station, Mh-3, was established on Barnes Creek. Station Mh-3 is

Table 190

WATER QUALITY CONDITIONS OF PIKE CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	285	130	20	7
Dissolved Solids (ppm)	780	515	260	7
Dissolved Oxygen (ppm)	12.0	7.1	3.5	10
Coliform Count (MFCC/100 ml) .	740,000	130,000	10,000	10
Temperature (^{O}F)	75	57	33	10

Source: SEWRPC.

Table 191

STREAMFLOW MEASUREMENT OF PIKE CREEK: AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Mh-2	10-16-64	1.8	0

[a] *Measured at U. S. Weather Bureau Station at Union Grove, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 192

ESTIMATED POPULATION OF PIKE CREEK SUB-WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Pike Creek Sub-Watershed	23,000	31,700	34,400	32,000

Source: SEWRPC.

Table 193

FORECAST QUALITY OF PIKE CREEK AT SAMPLING STATION MH-2: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Pike Creek	Mh-2	Chloride (in ppm)	45[a]	20	20	20
		Dissolved Solids (in ppm)	540[a]	500	500	500
		Dissolved Oxygen (in ppm)	6.7[b]	More than 8		
		Coliform Count (in MFCC/ 100 ml)	268,000[b]	Less than 10,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

located 3.3 miles downstream from the source of Barnes Creek and about 200 feet upstream from where the creek enters Lake Michigan.

Barnes Creek is a calcium bicarbonate stream having relatively constant total mineralization. In two chemical analyses run on stream samples collected in April and October 1964, calcium was the predominant cation at concentrations of 95 and 98 ppm in April and October, respectively. Bicarbonate was the predominant anion at 260 ppm in April and 380 ppm in October. Maximum nitrate concentration was 2.2 ppm. No sample of Barnes Creek was collected for phosphorus analysis. Selected water analyses of samples collected at station Mh-3 are listed in Table 194. Water quality conditions of Barnes Creek are indicated in Table 195.

The chloride concentrations of Barnes Creek varied from 45 ppm in April to 30 ppm in October 1964. If the assumed "background" chloride concentration were 10 ppm, there was a chloride impact upon Barnes Creek of as much as 35 ppm from human sources.

The dissolved solids concentrations varied from 585 ppm in October to 560 ppm in April. Whereas the cations remained relatively constant in concentration, bicarbonate concentrations increased 120 ppm

Table 194

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION MH-3 ON BARNES CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-9-64	10	10-16-64
Iron	0.07	"	0.05	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	95	4-9-64	98	10-16-64
Magnesium	46	"	54	"
Sodium (and Potassium)	35	"	30	"
Bicarbonate	260	"	380	"
Carbonate	20	"	0	"
Sulfate	182	"	176	"
Chloride	45	"	30	"
Fluoride	--	--	--	--
Nitrite	0.0	4-9-64	0.0	10-16-64
Nitrate	--	--	0.7	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.0	4-9-64	0.1	10-16-64
Dissolved Solids	560	"	585	"
Hardness	425	"	469	"
Noncarbonate Hardness	175	"	160	"
Calcium Hardness	236	"	245	"
Magnesium Hardness	189	"	224	"
Alkalinity P	10	"	0	"
Alkalinity M	235	"	310	"
Specific Conductance	780	"	840	"
pH	8.7	"	8.0	"
Color	20	"	0	"
Turbidity	7	"	2	"
Biochemical Oxygen Demand	2.2	"	2.1	"
Dissolved Oxygen	12.5	"	15.2	"
Coliform Count	1,100	"	10,000	"
Temperature (°F)	43	"	56	"

Source: SEWRPC.

(from 260 ppm in April to 380 ppm in October). This increase in the dissolved solids concentration, due principally to increased bicarbonate concentration, was in part offset by decreased carbonate and chloride concentrations.

The dissolved oxygen concentrations of Barnes Creek varied from 20.3 ppm in May to 6.7 ppm in September 1964. During the period June through September, the maximum, average, and minimum dissolved oxygen concentrations were 21.7, 12.2, and 6.7 ppm, respectively. Figure 30 shows the variations in the dissolved oxygen concentrations in Barnes Creek at sampling station Mh-3 in comparison to the dissolved oxygen concentrations in Sucker Creek and Pike Creek.

The coliform counts in Barnes Creek varied from 88,000 MFCC/100 ml in September to less than 100 MFCC/100 ml in June 1964. During the period June through September, the average coliform count was 25,000 MFCC/100 ml. Figure 31 shows the variations in the monthly coliform counts at station Mh-3 in comparison to Sucker Creek and Pike Creek.

The maximum temperature of Barnes Creek was 77°F in July 1964 and averaged 69°F during the period June through September 1964. Figure 32 shows the monthly variations in temperature of Barnes Creek at sampling station Mh-3 in comparison to Sucker Creek and Pike Creek.

Streamflow and Precipitation: Barnes Creek is a shallow stream occupying a relatively wide channel. At sampling station Mh-3, a distance 3.3 miles from the source, the stream had a maximum depth of 0.4 foot and a width of 4.2 feet when measured under low-flow conditions in October 1964.

The flow of Barnes Creek was measured by the SEWRPC in the spring and autumn of 1964 during periods of relatively high and low flow. The streamflow data are listed in Table 196. The daily precipitation at Union Grove, Wisconsin, is listed in Table 43.

Forecast Quality of Barnes Creek for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were 2,500 people living in the Barnes Creek sub-watershed. Table 197 indicates the estimated

Table 195

WATER QUALITY CONDITIONS OF BARNES CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	45	40	30	2
Dissolved Solids (ppm)	585	575	560	2
Dissolved Oxygen (ppm)	21.7	13.5	6.7	11
Coliform Count (MFCC/100 ml) .	88,000	14,700	100	11
Temperature (°F)	73	48	32	11

Source: SEWRPC.

Table 196

STREAMFLOW MEASUREMENTS OF BARNES CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Mh-3	4-10-64	2.5	0.40
	10-16-64	0.2	0

[a] *Measured at U. S. Weather Bureau Station at Union Grove, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 197

ESTIMATED POPULATION OF THE BARNES CREEK SUB-WATERSHED: 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Barnes Creek Sub-Watershed	2,500	13,560	11,530	13,560

Source: SEWRPC.

Table 198

FORECAST QUALITY OF BARNES CREEK AT SAMPLING STATION MH-3: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Barnes Creek	Mh-3	Chloride (in ppm)	30[a]	10	10	10
		Dissolved Solids (in ppm)	585[a]	550	550	550
		Dissolved Oxygen (in ppm)	12.2[b]	More than 10		
		Coliform Count (in MFCC / 100 ml)	25,000[b]	Less than 5,000		

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

population for the year 1990 under the three alternative regional land use plans. No estimate of sewage flow rates are listed because the population of this sub-watershed will be connected to the City of Kenosha sewerage system. Table 198 indicates the forecast quality of Barnes Creek.

OAK CREEK WATERSHED

The Oak Creek watershed ranks eighth in population and tenth in size as compared to the other 11 watersheds of the Region. An estimated 28,500[8] persons reside within this watershed, which has a total area

[8] *Based on SEWRPC estimate for 1963.*

of 26.7 square miles and an average density of about 1,070 people per square mile. Principal land uses include agriculture and woodland, wetland, and unused land, which together comprise 63.9 percent of the area of the watershed. The areas within the watershed devoted to each of eight land use categories are listed in Table 199.

One stream was studied by the SEWRPC in the Oak Creek watershed, Oak Creek proper. This stream rises in south central Milwaukee County in the east central part of the City of Franklin and flows east, northeast, and south through the City of South Milwaukee to Lake Michigan.

The Oak Creek watershed comprises a land area underlain largely by a system of end moraines, which parallel Lake Michigan; by marsh deposits; and by ground moraine. Oak Creek traverses three broad morainal ridges and meanders across marsh deposits and ground moraine before entering Lake Michigan.

Oak Creek

Present Stream Quality: Two sampling stations, Ok-1 and Ok-2, were established on Oak Creek. Station Ok-1 is located 4.5 miles downstream from the source and 6.8 miles upstream from sampling station Ok-2. Station Ok-2 is located 1.6 miles from where the creek enters Lake Michigan.

Table 199

EXISTING LAND USE IN THE OAK CREEK WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	12.6	8,063	47.13
Woodland, Wetland, and Unused Land	4.5	2,871	16.79
Residential.	4.1	2,601	15.21
Transportation-Communication . . .	3.5	2,279	13.33
Park and Recreational.	0.8	533	3.12
Governmental-Institutional	0.5	314	1.84
Industrial	0.5	293	1.71
Commercial	0.2	149	0.87
Total	26.7	17,103	100.00

Source: SEWRPC.

Oak Creek is subject to small changes in total mineralization. In 16 complete chemical analyses run on stream samples collected from Oak Creek, calcium and sodium were the predominant cations. Calcium was the predominant cation in seven analyses at concentrations ranging from 100 ppm to 69 ppm. Sodium occurred as the predominant cation in eight analyses at concentrations ranging from 110 ppm to 50 ppm. The calcium and sodium concentrations of the sample collected at Ok-2 in November 1964 each measured 70 ppm. Bicarbonate was the predominant anion in 15 of 16 complete chemical analyses at concentrations ranging from 315 ppm to 205 ppm. Sulfate was the predominant anion in April 1964 at a concentration of 224 ppm at station Ok-1. Maximum nitrate concentration was 2.8 ppm. Total phosphorus was 0.48 ppm at station Ok-2 on October 4, 1964. Selected water analyses of Oak Creek at station Ok-2 are indicated in Table 200. Water quality conditions of Oak Creek are indicated in Table 201.

The chloride concentrations of Oak Creek varied from 135 ppm in March and April 1964 at stations Ok-2 and Ok-1 to 30 ppm in September 1964 at station Ok-1. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon Oak Creek was as much as 125 ppm from human sources. Figure 33 shows the chloride concentrations on Oak Creek at stations Ok-1 and Ok-2.

The dissolved solids concentrations of Oak Creek varied from 755 ppm in April 1964 at station Ok-1 to 375 ppm in September 1964 at station Ok-2. The principal ions whose decreased concentrations together accounted for most of this difference in dissolved solids concentrations were sulfate, chloride, calcium,

Table 200

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION OK-2 ON OAK CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-9-64	6	9-23-64
Iron	0.06	"	0.29	"
Manganese	--	--	0.00	"
Chromium	--	--	<0.01	"
Hexavalent Chromium	--	--	0.00	"
Calcium	100	4-9-64	46	"
Magnesium	43	"	27	"
Sodium (and Potassium)	75	"	50	"
Bicarbonate	260	"	205	"
Carbonate	0	"	0	"
Sulfate	212	"	112	"
Chloride	115	"	35	"
Fluoride	--	--	<0.75	"
Nitrite	0.0	4-9-64	0.0	"
Nitrate	--	--	--	--
Phosphorus	--	--	0.48	9-23-64
Cyanide	--	--	<0.03	10- 4-64
Oil	--	--	<0.5	9-23-64
Detergents	0.0	4-9-64	0.0	"
Dissolved Solids	685	"	375	"
Hardness	428	"	228	"
Noncarbonate Hardness	215	"	60	"
Calcium Hardness	250	"	115	"
Magnesium Hardness	178	"	113	"
Alkalinity P	0	"	0	"
Alkalinity M	215	"	170	"
Specific Conductance	996	"	544	"
pH	8.2	"	7.3	"
Color	40	"	5	"
Turbidity	7	"	20	"
Biochemical Oxygen Demand	2.4	"	5.9	"
Dissolved Oxygen	11.6	"	7.3	"
Coliform Count	27,000	"	33,000	"
Temperature (°F)	46	"	64	"

Source: SEWRPC.

Table 201

WATER QUALITY CONDITIONS OF OAK CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	135	80	30	16
Dissolved Solids (ppm)	755	605	375	16
Dissolved Oxygen (ppm)	13.7	10.9	6.4	25
Coliform Count (MFCC/100 ml)	33,000	8,500	500	25
Temperature (°F)	77	48	32	24

Source: SEWRPC.

and sodium. The maximum and minimum "background" dissolved solids concentrations of Oak Creek are about 550 and 335 ppm, respectively. Figure 33 shows the dissolved solids concentrations in Oak Creek at stations Ok-1 and Ok-2.

The dissolved oxygen concentrations of Oak Creek varied from 13.7 ppm at station Ok-1 in February 1965 to 6.4 ppm at station Ok-2 in May 1964. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 at stations Ok-1 and Ok-2 were 13.4, 10.9, and 8.6 ppm and 10.3, 9.1, and 7.3 ppm, respectively. Figure 34 shows the dissolved oxygen concentrations at stations Ok-1 and Ok-2.

The coliform counts in Oak Creek varied from 33,000 MFCC/100 ml in September 1964 to 500 MFCC/100 ml in October 1964 at station Ok-2. The maximum, average, and minimum counts for the period June through September 1964 at stations Ok-1 and Ok-2 were 22,000, 7,000, and 11,000 MFCC/100 ml and 33,000, 11,100, and 1,400 MFCC/100 ml, respectively. Figure 35 shows the coliform counts in Oak Creek at stations Ok-1 and Ok-2.

The maximum temperature of Oak Creek was 73°F in July 1964 at station Ok-2 and for the period June through September 1964 averaged 58°F and 67°F at stations Ok-1 and Ok-2, respectively. The temperature of Oak Creek in the upper reaches of the stream at station Ok-1 apparently reflects a low increase in stream temperature above a probable average ground water temperature of 51°F. The stream temperature in June, July, and August 1964 at stations Ok-1 and Ok-2 were 54°, 59°, and 61°F and 60°, 73°, and 71°F, respectively. Figure 36 shows the temperature of Oak Creek at stations Ok-1 and Ok-2.

<u>Streamflow and Precipitation:</u> Oak Creek is a shallow meandering stream occupying a relatively wide channel. At sampling station Ok-2, a distance 11.3 miles downstream from the source, the stream had a maximum depth of 1.2 feet and a width of 18 feet when measured in September 1964.

Figure 33

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN OAK CREEK

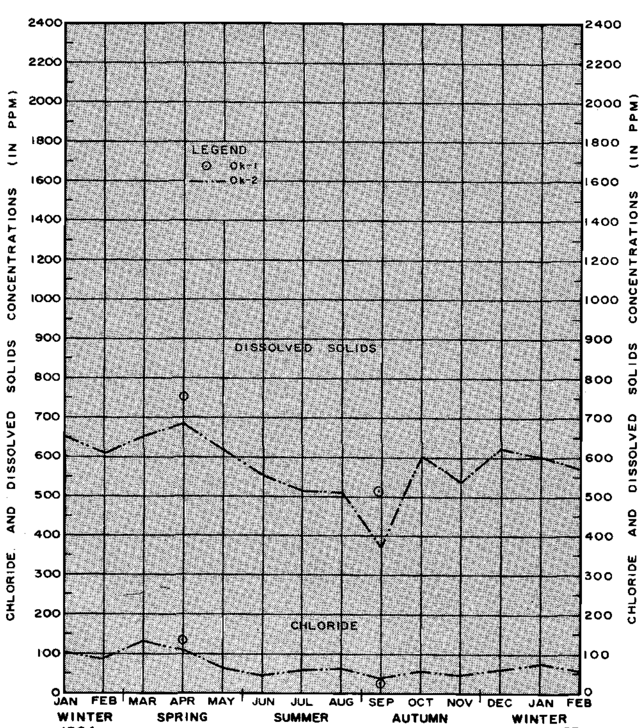


Figure 34

DISSOLVED OXYGEN CONCENTRATIONS IN OAK CREEK

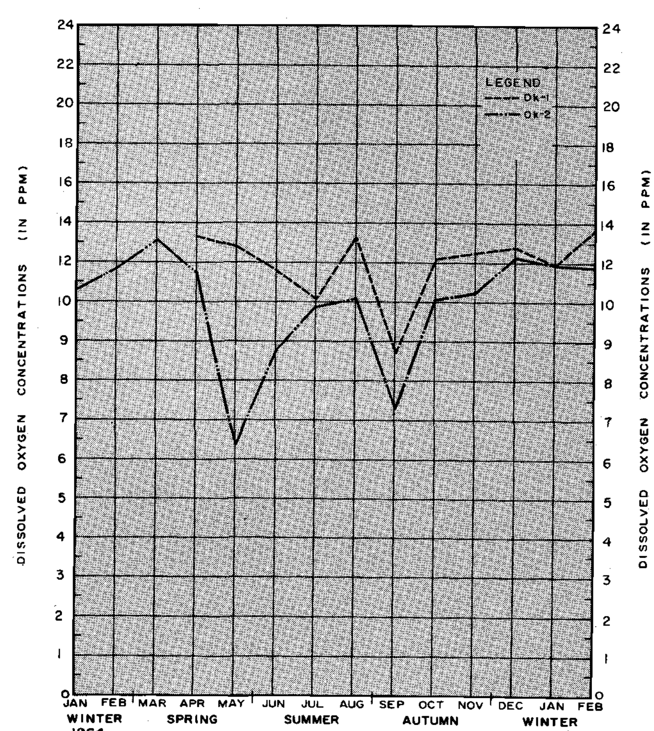


Figure 35

COLIFORM COUNT IN OAK CREEK

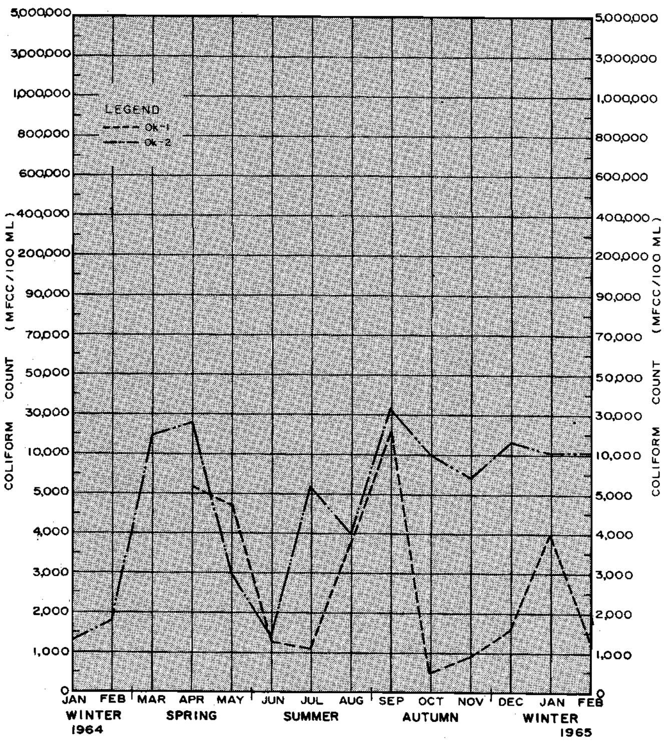
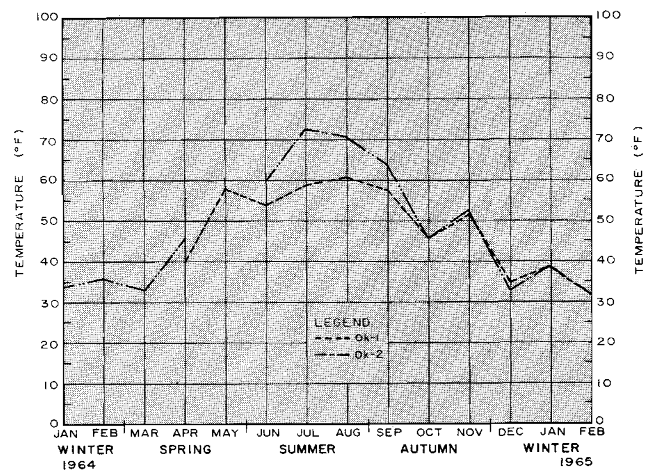


Figure 36

TEMPERATURE OF OAK CREEK



The U. S. Geological Survey, in cooperation with the SEWRPC and Metropolitan Sewerage Commission of Milwaukee County, has established a water-stage recorder on Oak Creek near the 15th Avenue Bridge, about 1.1 miles upstream from station Ok-2. The SEWRPC measured the flow of Oak Creek at station Ok-2 in the spring and autumn of 1964 during periods of relatively high and low flow. Table 202 lists the SEWRPC flow measurements, together with U. S. Geological Survey flow data for the same days of measurement. Table 203 lists the daily U. S. Geological Survey flow data for the period January 1964 through February 1965.

Forecast Quality of Oak Creek for the Year 1990: Population studies by the SEWRPC indicate that the Oak Creek watershed had a total population of 28,500 persons in 1963. By the year 1990, the entire population of the Oak Creek watershed will be serviced by the Milwaukee metropolitan sewerage system and the City of South Milwaukee sewerage system. Table 204 indicates the estimated watershed populations for the year 1990 under the three alternative regional land use plans. The forecast quality conditions in Oak Creek which may be expected in 1990 at sampling station Ok-2 under the three alternative regional land use plans are indicated in Table 205.

Table 202

STREAMFLOW MEASUREMENTS OF OAK CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
OK-2	4-11-64	13	1.34
USGS[b].	4-11-64	9.7	1.34
OK-2	9-22-64	6.0	0.80
USGS[b].	9-22-64	6.1	0.80

[a] *Measured at U. S. Weather Bureau Station at West Allis, Wisconsin.*

[b] *U. S. Geological Survey gaging station near 15th Avenue Bridge in South Milwaukee, Wisconsin.*

Source: U. S. Weather Bureau, USGS, and SEWRPC.

Table 203

DISCHARGE OF OAK CREEK AT SOUTH MILWAUKEE, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	Streamflow (in cfs)[a]													
	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	.6	2.0	2.0	4.7	18	3.8	16	6.3	4.2	3.4	4.0	4.9	10	3.4
2	.6	2.1	2.4	10	20	4.3	17	6.1	4.3	3.7	7.0	4.7	60	3.3
3	.8	2.2	2.7	27	17	4.3	5.8	6.1	4.7	3.7	5.0	4.5	21	3.3
4	.9	2.3	4.6	20	12	4.0	4.7	5.8	4.3	3.5	3.7	4.1	12	3.2
5	1.0	2.5	6.9	22	10	4.0	3.8	5.8	3.8	3.7	3.8	3.8	9.7	3.2
6	1.0	2.5	3.8	72	9.2	3.8	3.7	5.6	4.0	3.5	3.7	3.6	8.4	5.0
7	.9	2.4	8.6	45	18	3.8	3.7	5.4	3.8	3.7	3.7	3.4	8.4	30
8	.8	2.1	17	25	109	3.8	3.8	5.1	3.8	4.2	3.7	3.3	10	72
9	.8	1.9	11	20	68	3.7	3.7	5.2	4.0	4.0	3.7	3.2	9.0	90
10	.7	1.8	9.5	12	28	3.2	3.6	5.6	4.2	4.0	3.7	3.3	8.0	130
11	.7	1.8	8.9	9.7	17	3.1	3.2	8.7	4.0	4.5	4.0	5.0	7.2	120
12	.6	1.9	14	7.7	13	3.1	3.0	5.2	3.8	4.7	4.5	5.4	6.8	100
13	.6	2.0	25	7.2	16	3.1	2.8	4.7	3.7	5.1	3.7	5.6	6.4	70
14	.5	2.0	32	5.8	16	3.1	6.0	4.2	4.0	5.1	3.7	5.0	5.6	36
15	.5	1.9	23	5.1	11	8.4	3.6	4.0	3.8	5.4	8.2	4.5	5.0	20
16	.5	1.9	13	4.9	35	6.1	3.1	3.8	4.0	5.2	7.2	5.0	4.6	25
17	.5	1.8	9.2	5.6	31	5.1	7.7	3.8	4.2	4.9	4.3	4.4	4.2	19
18	.5	1.7	6.1	5.6	16	4.9	215	3.8	8.4	4.3	3.8	3.8	3.8	21
19	2.0	1.7	4.9	5.1	10	4.7	146	4.0	5.6	4.0	3.8	3.4	3.5	16
20	10	1.7	4.3	4.7	7.0	4.3	62	4.2	4.3	3.8	3.7	3.2	3.3	35
21	7.0	1.7	4.0	15	5.8	5.2	33	28	7.2	3.6	3.5	3.4	3.5	80
22	5.6	1.7	4.0	18	5.6	13	19	14	6.1	3.5	3.6	3.8	10	30
23	5.6	1.7	4.0	11	5.2	13	14	16	8.4	3.9	4.0	4.0	24	20
24	9.5	1.7	4.9	7.4	5.4	7.0	13	9.5	4.3	4.2	4.2	4.0	12	15
25	8.0	1.7	5.2	5.8	4.3	5.2	23	6.8	3.5	4.1	4.0	3.7	7.0	11
26	6.0	1.7	4.8	7.0	4.2	4.2	14	5.1	4.9	3.9	3.8	3.4	6.6	9.0
27	4.4	1.7	4.3	13	4.0	3.5	11	4.3	4.0	4.2	4.2	3.2	5.4	8.0
28	3.0	1.7	3.9	20	3.8	3.2	8.4	4.2	3.4	4.0	23	3.1	4.6	7.0
29	2.4	1.7	3.7	17	3.8	3.2	7.2	3.8	3.4	3.8	12	3.0	4.0	--
30	2.2	--	3.6	17	3.8	3.7	6.8	4.5	3.4	3.7	7.0	3.0	3.7	--
31	2.0	--	3.5	--	3.8	--	6.5	4.0	--	4.3	--	3.4	3.5	--

[a] *Underscored flow measurements indicate days when sampling occurred on Oak Creek.*

Source: USGS.

Table 204

ESTIMATED POPULATION OF THE OAK CREEK WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Oak Creek Watershed	28,500	95,000	93,000	95,000

Source: SEWRPC.

Table 205

FORECAST QUALITY OF OAK CREEK AT SAMPLING STATION OK-2: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Oak Creek	Ok-2	Chloride (in ppm)	35[a]	15	15	15
		Dissolved Solids (in ppm)	375[a]	350	350	350
		Dissolved Oxygen (in ppm)	10.9[b]	More than 10		
		Coliform Count (in MFCC/ 100 ml)	11,000[b]	Less than 5,000		

[a] *Based on water analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

PIKE RIVER WATERSHED

The Pike River watershed ranks ninth in population and eighth in size as compared to the other 11 watersheds of the Region. An estimated 13,000[9] persons reside within this watershed, which has a total area of 50.9 square miles and an average density of about 255 people per square mile. The principal land use is agriculture, which comprises 76.3 percent of the watershed. The areas within the watershed devoted to each of eight major land use categories are listed in Table 206.

Two streams were studied by the SEWRPC in the Pike River watershed—Pike River proper and Pike Creek, a first-rank tributary of Pike River. Pike River rises in southeastern Racine County about two miles north of the Village of Sturtevant and flows easterly and southerly through the northern part of the City of Kenosha to Lake Michigan. Pike Creek rises in east central Kenosha County about one mile east of the Kenosha Airport and flows northerly to join the Pike River in the northwestern corner of Petrifying Springs Park at a point 7.2 miles downstream from the source of the Pike River.

The Pike River watershed comprises a land area underlain largely by the system of end moraines which parallel Lake Michigan, by ground moraine, by glacial outwash composed of sand and gravel, and by sandy beach deposits that form a belt along Lake Michigan approximately 1.5 miles wide.

[9] *Based on SEWRPC estimate for 1963.*

Pike River

Present Stream Quality: Two sampling stations, Pk-1 and Pk-4, were established on the Pike River. Station Pk-1 is located 6.7 miles downstream from the source and 8.1 miles upstream from station Pk-4. Station Pk-4 is 1.8 miles upstream from where the Pike River enters Lake Michigan. The sewage treatment plant for the Village of Sturtevant has its outfall on the Pike River.

The Pike River is predominantly a calcium bicarbonate stream subject to small changes in total mineralization. Calcium and sodium were the predominant cations in 17 complete chemical analyses of stream samples collected from the Pike River. Calcium was the predominant cation in 14 analyses at concentrations ranging from 132 ppm in February 1965 at station Pk-4 to 75 ppm in April 1964 at station Pk-1. Sodium occurred as the predominant cation in two analyses at concentrations of 85 ppm in February and 60 ppm in September 1964 at station Pk-1. The calcium and sodium concentrations of the sample collected in November 1964 at Pk-4 both equalled 80 ppm. Bicarbonate and sulfate were predominant anions. Bicarbonate was predominant in 15 of 17 complete chemical analyses at concentrations ranging from 470 ppm in January to 200 ppm in September 1964 at station Pk-4. Sulfate was the predominant anion in April 1964 at station Pk-1 and Pk-4 at concentrations of 270 and 282 ppm, respectively. Maximum nitrate concentration was 6.7 ppm. Total phosphorus was 1.37 ppm at station Pk-4 on September 23, 1964. Selected water analyses of the Pike River at station Pk-4 are indicated in Table 207. Water quality conditions of the Pike River are indicated in Table 208.

The chloride concentrations of the Pike River varied from 90 ppm in January to 35 ppm in September 1964 at station Pk-4. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon the Pike River was as much as 80 ppm from human sources. Figure 37 shows the chloride concentrations in the Pike River at stations Pk-1 and Pk-4.

The dissolved solids concentrations of the Pike River varied from 905 ppm in January to 380 ppm in September 1964 at station Pk-4. The principal ions whose decreased concentrations together accounted for most of this difference in dissolved solids concentrations are sulfate, bicarbonate, sodium, calcium, and chloride. The maximum and minimum "background" dissolved solids concentrations of Pike River are about 775 and 340 ppm, respectively. Figure 37 shows the dissolved solids concentrations in the Pike River at stations Pk-1 and Pk-4.

The dissolved oxygen concentrations of the Pike River varied from 11.8 ppm in April to 0.1 ppm in January 1964 at sampling station Pk-4. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 at stations Pk-1 and Pk-4 were 4.1, 2.9, and 0.7 ppm and 5.9, 4.5, and 3.5 ppm, respectively. Figure 38 shows the dissolved oxygen concentration in the Pike River at station Pk-1 and Pk-4.

Table 206

EXISTING LAND USE IN THE PIKE RIVER WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	38.8	24,861	76.28
Residential	3.9	2,490	7.64
Transportation-Communication	3.4	2,142	6.57
Woodland, Wetland, and Unused Land	2.6	1,689	5.18
Park and Recreational	1.3	807	2.48
Governmental-Institutional	0.4	288	0.88
Industrial	0.4	263	0.81
Commercial	0.1	51	0.16
Total	50.9	32,591	100.00

Source: SEWRPC.

Table 207

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION PK-4 ON THE PIKE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-8-64	6	9-23-64
Iron	0.04	"	0.27	"
Manganese	--	--	0.01	"
Chromium	--	--	< 0.01	"
Hexavalent Chromium	--	--	0.00	"
Calcium	104	4-8-64	52	"
Magnesium	57	"	26	"
Sodium (and Potassium)	55	"	45	"
Bicarbonate	240	"	200	"
Carbonate	20	"	0	"
Sulfate	282	"	112	"
Chloride	65	"	35	"
Fluoride	--	--	< 0.65	"
Nitrite	0.0	4-8-64	0.0	"
Nitrate	--	--	2.6	"
Phosphorus	--	--	1.37	"
Cyanide	--	--	< 0.03	10- 4-64
Oil	--	--	< 1	9-23-64
Detergents	0.0	4-8-64	0.1	"
Dissolved Solids	705	"	380	"
Hardness	493	"	236	"
Noncarbonate Hardness	265	"	70	"
Calcium Hardness	260	"	131	"
Magnesium Hardness	233	"	105	"
Alkalinity P	10	"	0	"
Alkalinity M	215	"	165	"
Specific Conductance	944	"	522	"
pH	8.2	"	7.2	"
Color	20	"	30	"
Turbidity	4	"	65	"
Biochemical Oxygen Demand	2.7	"	4.5	"
Dissolved Oxygen	11.8	"	2.8	"
Coliform Count	6,000	"	30,000	"
Temperature (°F)	40	"	64	"

Source: SEWRPC

Table 208

WATER QUALITY CONDITIONS OF THE PIKE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	90	65	35	17
Dissolved Solids (ppm)	905	600	380	17
Dissolved Oxygen (ppm)	11.8	5.3	0.1	27
Coliform Count (MFCC/100 ml)	1,800,000	260,000	2,000	27
Temperature (°F)	75	49	32	27

Source: SEWRPC.

Figure 37

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN STREAMS OF THE PIKE RIVER WATERSHED

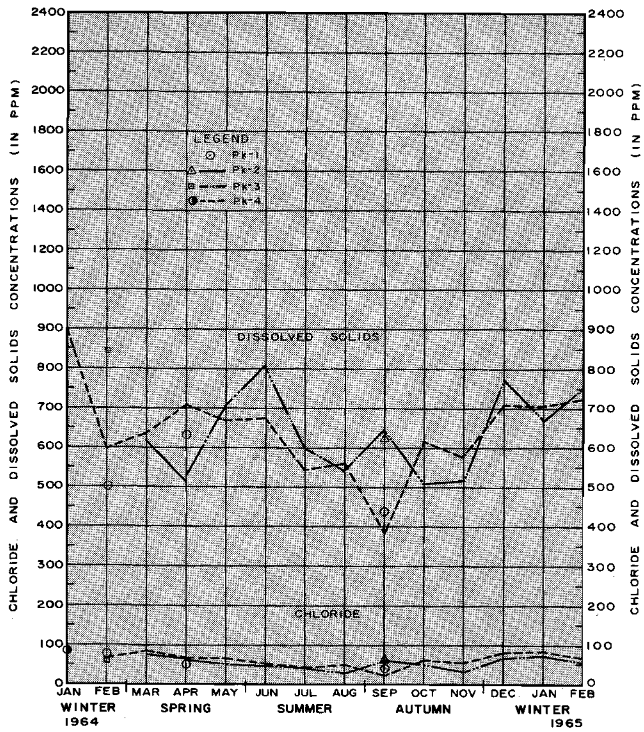
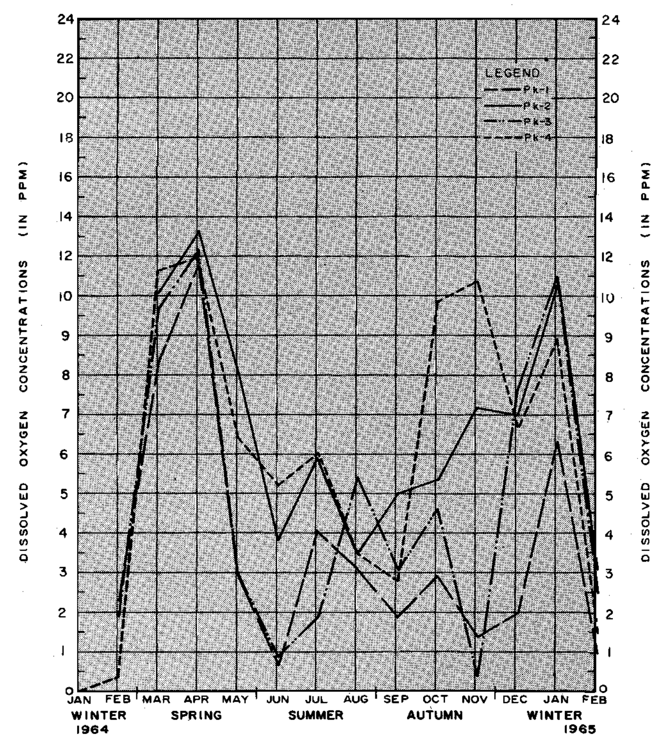


Figure 38

DISSOLVED OXYGEN CONCENTRATIONS IN STREAMS OF THE PIKE RIVER WATERSHED



The coliform counts in the Pike River varied from 1,800,000 MFCC/100 ml in December 1964 at station Pk-1 to 2,000 MFCC/100 ml in May 1964 at station Pk-4. The maximum, average, and minimum coliform counts for the period June through September 1964 at stations Pk-1 and Pk-4 were 560,000, 245,000, and 50,000 MFCC/100 ml and 190,000, 56,000, and 1,200 MFCC/100 ml, respectively. Figure 39 shows the coliform counts in the Pike River.

The maximum temperature of the Pike River was 75^{o}F in July 1964 at sampling station Pk-4. For the period June through September 1964, the temperature averaged 67^{o} and 68^{o}F at stations Pk-1 and Pk-4, respectively. Figure 40 shows the temperature of the Pike River at stations Pk-1 and Pk-4.

Streamflow and Precipitation: The Pike River is a relatively shallow meandering stream occupying a relatively wide channel during much of the year. At distances of 6.7 miles and 14.8 miles from the source of the Pike River, the stream had maximum depths of 0.6 foot and 2.1 feet and widths of 9 feet and 49 feet at sampling stations Pk-1 and Pk-4, respectively.

The flow of the Pike River was measured by the SEWRPC at stations Pk-1 and Pk-4 in the spring and autumn of 1964 during periods of relatively high and low flow. The flow data are listed in Table 209. Table 210 indicates the daily precipitation at Racine, Wisconsin, from January 1964 through February 1965. The precipitation data at this weather station is presumed to represent precipitation in the Pike River watershed.

Forecast Quality of the Pike River for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were about 13,000 people living in the Pike River watershed, of which approximately 1,500 persons were serviced by the sewage treatment plant at Sturtevant. Table 211 indicates the estimated population of the watershed under the three alternative regional land use plans for the year 1990. It is anticipated that by the year 1990 the sewerage systems of the cities of Racine and Kenosha will service all but a negligible portion of the population living within the Pike River watershed. Table 212 presents the forecasts of future stream quality of the Pike River.

Table 209

STREAMFLOW MEASUREMENTS OF THE PIKE RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Pk-1	4- 7-64	27	1.03
Pk-4	4- 7-64	108	1.03
Pk-4	5-26-64	0.9	0.28
Pk-1	9-22-64	2.3	0.36
Pk-4	9-22-64	1.2	0.36

[a] *Measured at U. S. Weather Bureau Station at Racine, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 210

PRECIPITATION[a] AT RACINE, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.21	--	--	--	--	--	0.22	0.05	0.40	0.45
2	--	--	--	0.15	0.10	0.56	0.98	--	--	--	0.25	0.20	0.50	--
3	--	--	0.01	0.55	--	--	0.02	--	--	--	0.12	--	--	--
4	--	--	0.02	--	--	--	--	--	--	--	--	0.41	--	--
5	--	--	1.00	0.75	--	--	--	--	--	--	0.01	--	--	--
6	--	--	--	0.28	0.01	--	--	--	--	--	--	--	--	--
7	--	--	--	0.06	--	--	0.58	--	--	--	--	--	0.05	0.08
8	0.01	--	0.15	--	0.47	--	0.02	--	--	0.12	--	--	0.02	0.25
9	0.01	0.05	0.10	--	0.02	--	0.02	--	0.12	0.01	--	--	--	0.10
10	--	--	--	--	--	--	--	0.10	0.21	--	--	0.01	--	0.01
11	--	--	--	--	--	--	--	0.08	--	--	--	0.12	--	--
12	--	0.25	--	--	--	0.05	--	--	--	--	0.20	--	--	0.27
13	0.15	0.10	--	0.06	0.55	--	0.15	--	--	--	--	0.17	--	--
14	--	--	0.45	--	--	--	0.29	--	--	--	--	--	--	--
15	--	0.05	--	--	--	1.17	--	--	0.07	--	0.90	--	0.36	--
16	0.14	0.07	--	--	0.90	--	--	--	--	--	--	--	--	--
17	--	--	0.10	0.30	--	--	--	0.05	--	--	--	--	--	0.09
18	--	--	--	0.23	0.02	--	2.68	--	0.75	0.02	--	--	--	--
19	--	--	--	--	--	--	--	--	0.06	--	--	0.05	--	--
20	0.70	--	0.48	0.06	--	0.15	0.03	--	--	--	0.08	0.04	--	--
21	--	0.02	0.10	0.58	--	--	0.03	0.83	0.30	--	--	--	--	--
22	--	--	--	--	--	0.03	--	0.83	0.40	--	--	--	0.60	--
23	--	--	--	--	--	0.96	--	--	0.35	--	--	--	0.95	0.12
24	0.32	0.01	0.32	--	0.28	--	--	0.01	--	--	--	--	0.30	0.15
25	0.02	--	0.10	--	--	--	0.10	0.05	--	--	--	--	--	--
26	--	--	0.19	0.41	--	--	--	--	0.32	0.02	--	0.09	0.38	--
27	--	--	0.05	0.39	--	--	--	--	0.03	--	--	--	--	--
28	--	--	--	0.50	--	--	0.22	--	--	--	1.20	--	0.10	--
29	--	--	0.05	0.09	--	--	0.02	--	--	0.02	--	--	--	--
30	--	--	--	0.18	--	--	0.03	0.15	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	1.35	0.55	3.12	4.59	2.56	2.92	5.17	2.10	2.61	0.19	2.98	1.14	3.66	1.52

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Table 211

ESTIMATED POPULATION OF THE PIKE RIVER WATERSHED:
1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Pike River Watershed	13,000	88,000	93,000	84,000

Source: SEWRPC.

Table 212

FORECAST QUALITY OF THE PIKE RIVER AT SAMPLING STATION PK-4:
1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Pike River	Pk-4	Chloride (in ppm)	35[a]	15	15	15
		Dissolved Solids (in ppm)	380[a]	350	350	350
		Dissolved Oxygen (in ppm)	4.5[b]	More than 6		
		Coliform Count (in MFCC/ 100 ml)	56,000[b]	Less than 5,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Figure 39

COLIFORM COUNT IN STREAMS OF THE PIKE RIVER WATERSHED

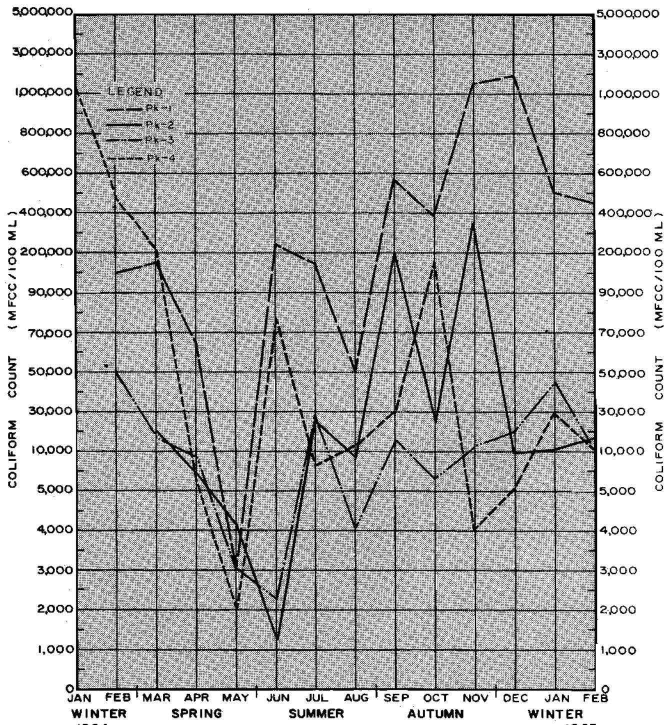
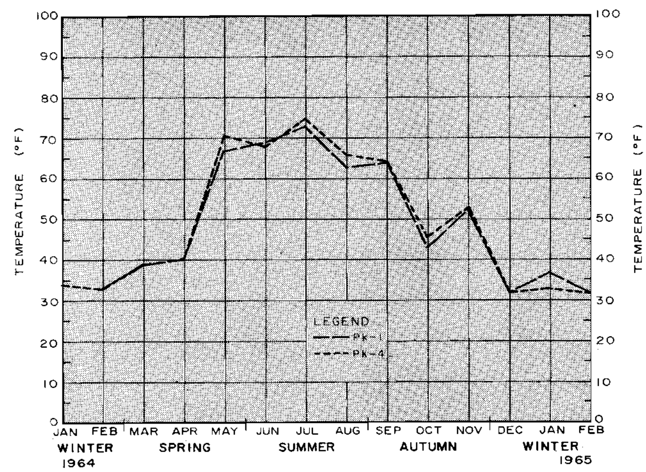


Figure 40

TEMPERATURE OF THE PIKE RIVER



Pike Creek

Present Stream Quality: Two sampling stations, Pk-2 and Pk-3, were established on Pike Creek. Station Pk-2 is located 1.3 miles downstream from the source and 3.0 miles upstream from Station Pk-3. Station Pk-3 is about 275 feet upstream from where Pike Creek enters Pike River.

Pike Creek is predominantly a calcium bicarbonate stream that has relatively constant total mineralization. In 15 complete chemical analyses run of stream samples collected from Pike Creek, calcium and sodium were the predominant cations. Calcium was the predominant cation in 12 analyses at concentrations ranging from 128 ppm in September and June 1964, at stations Pk-2 and Pk-3, respectively, to 48 ppm in April 1964 at station Pk-2. Sodium occurred as the predominant cation in three analyses at concentrations ranging from 140 ppm in February to 75 ppm in October 1964 at station Pk-3. The calcium and sodium concentrations of the sample collected in November 1964 at Pk-4 both equalled 80 ppm. Bicarbonate and sulfate were predominant anions. Bicarbonate was predominant in 14 of the 15 complete chemical analyses at concentrations ranging from 595 ppm in February at station Pk-3 to 205 ppm in April 1964 at station Pk-2. Sulfate was the predominant anion in September 1964 at station Pk-2 at a concentration of 252 ppm. Maximum nitrate concentration was 12.5 ppm. No samples were analyzed for phosphorus concentration. Selected water analyses of Pike Creek at station Pk-3 are indicated in Table 213. Water quality conditions of Pike Creek are indicated in Table 214.

The chloride concentrations of Pike Creek varied from 90 ppm in March 1964 at station Pk-2 to 35 ppm in August 1964 at station Pk-3. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon Pike Creek was as much as 80 ppm from human sources. Figure 37 shows the chloride concentrations in Pike Creek at stations Pk-2 and Pk-3.

The dissolved solids concentrations of Pike Creek varied from 840 ppm in February to 505 ppm in October 1964 at station Pk-3. The principal ions whose decreased concentrations together accounted for most of this difference in dissolved solids concentrations are sulfate, bicarbonate, sodium, calcium, and chloride. The maximum and minimum "background" dissolved solids concentrations of Pike Creek are

Table 213

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION PK-3 ON PIKE CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-8-64	8	9-23-64
Iron	0.00	"	0.04	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	62	4-8-64	86	9-23-64
Magnesium	77	"	43	"
Sodium (and Potassium)	5	"	80	"
Bicarbonate	215	"	340	"
Carbonate	10	"	0	"
Sulfate	185	"	198	"
Chloride	70	"	55	"
Fluoride	--	--	--	--
Nitrite	0.0	4-8-64	0.0	9-23-64
Nitrate	--	--	2.1	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0	4-8-64	0.1	9-23-64
Dissolved Solids	525	"	640	"
Hardness	469	"	394	"
Noncarbonate Hardness	275	"	115	"
Calcium Hardness	154	"	216	"
Magnesium Hardness	315	"	178	"
Alkalinity P	5	"	0	"
Alkalinity M	185	"	280	"
Specific Conductance	950	"	980	"
pH	8.2	"	7.2	"
Color	40	"	70	"
Turbidity	3	"	5	"
Biochemical Oxygen Demand	4.4	"	4.3	"
Dissolved Oxygen	12.3	"	3.1	"
Coliform Count	9,000	"	14,000	"
Temperature (°F)	40	"	63	"

Source: SEWRPC.

Table 214

WATER QUALITY CONDITIONS OF PIKE CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	90	65	35	15
Dissolved Solids (ppm)	840	620	505	15
Dissolved Oxygen (ppm)	13.2	6.0	0.4	25
Coliform Count (MFCC/100 ml)	300,000	35,000	1,200	25
Temperature (°F)	71	49	32	25

Source: SEWRPC.

about 740 and 440 ppm, respectively. Figure 37 shows the dissolved solids concentrations in Pike Creek at stations Pk-2 and Pk-3.

The dissolved oxygen concentrations of Pike Creek varied from 13.2 ppm in April at station Pk-2 to 0.4 ppm in November 1964 at sampling station Pk-3. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 at stations Pk-2 and Pk-3 were 5.9, 4.5, and 3.5 ppm and 5.4, 2.8, and 0.9 ppm, respectively. Figure 38 shows the dissolved oxygen concentrations in Pike Creek at stations Pk-2 and Pk-3.

The coliform counts in Pike Creek varied from 330,000 MFCC/100 ml in November 1964 at station Pk-1 to 1,200 MFCC/100 ml in June 1964 at station Pk-2. The maximum, average, and minimum coliform counts for the period June through September 1964 at stations Pk-2 and Pk-3 were 190,000, 56,000, and 1,200 MFCC/100 ml and 27,000, 11,800, and 2,200 MFCC/100 ml, respectively. Figure 39 shows the coliform counts in Pike Creek.

The maximum temperature of Pike Creek was 71°F in July 1964 at sampling station Pk-3 and for the period of June through September 1964 averaged 65°F at stations Pk-2 and Pk-3, respectively.

Streamflow and Precipitation: Pike Creek is a relatively shallow meandering stream occupying a relatively wide channel during much of the year. At distances of 1.3 miles and 4.3 miles from the source of Pike Creek, the stream had maximum depths of 0.6 feet and 2.4 feet and widths of 4 feet and 17 1/2 feet at sampling stations Pk-2 and Pk-3, respectively, when measured under low-flow conditions.

The flow of the Pike River was measured by the SEWRPC at stations Pk-2 and Pk-3 in the spring and autumn of 1964 during periods of relatively high and low flow. The flow data are listed in Table 215.

Forecast Quality of Pike Creek for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were about 13,000 people living in the Pike River watershed. Table 211 indicates the estimated population of the watershed under the three alternative regional land use plans for the year 1990. It is anticipated that by the year 1990 the sewerage systems of the cities of Racine and Kenosha will service all but a negligible part of the population living within the Pike River watershed. Table 216 presents the forecasts of future stream quality of Pike Creek.

ROCK RIVER WATERSHED

The Rock River watershed ranks seventh in population and second in size as compared to the other 11 watersheds of the Region. An estimated 68,800[10] persons reside within this watershed, which has a total area of 609.4 square miles and an average population density of 113 people per square mile. The principal land use is agricultural, comprising 68.8 percent of the total area of the watershed. The area within the watershed devoted to each of eight major land use categories is listed in Table 217.

[10] *Based on SEWRPC estimate for 1963.*

Table 215

STREAMFLOW MEASUREMENTS OF PIKE CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Pk-2	4- 7-64	17	1.03
Pk-3	4- 7-64	31	1.03
Pk-2	9-22-64	0.3	0.36
Pk-3	9-22-64	0	0.36

[a] *Measured at U. S. Weather Bureau Station at Racine, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 216

FORECAST QUALITY OF PIKE CREEK AT SAMPLING STATION PK-3: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Pike Creek	Pk-3	Chloride (in ppm)	50[a]	20	20	20
		Dissolved Solids (in ppm)	505[a]	450	450	450
		Dissolved Oxygen (in ppm)	2.8[b]	More than 4		
		Coliform Count (in MFCC/ 100 ml)	11,800[b]	Less than 5,000		

[a] *Based on analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Table 217

EXISTING LAND USE IN THE ROCK RIVER WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	419.6	268,534	68.8
Woodland, Wetland, and Unused Land	139.5	89,271	22.9
Residential.	21.1	13,486	3.5
Transportation-Communication . . .	19.8	12,685	3.3
Park and Recreational.	4.5	2,856	0.7
Industrial	2.5	1,626	0.4
Governmental-Institutional	1.7	1,117	0.3
Commercial	0.7	454	0.1
Total	609.4	390,029	100.0

Source: SEWRPC.

Ten streams were studied by the SEWRPC in the Rock River watershed: East Branch of the Rock River, Kohlsville River, Rubicon River, Ashippun River, Oconomowoc River, Bark River, Whitewater Creek, Jackson Creek, Delavan Lake Outlet, and Turtle Creek. The East Branch of the Rock River rises where Limestone Creek and Allenton Creek join in a marshy area about two miles southeast of the Village of Allenton and flows northwest to the Dodge County line. Kohlsville River, a tributary of the East Branch of the Rock River, originates about four miles northeast of the Village of Kohlsville and flows northwest through Kohlsville to join the East Branch of the Rock River near the Dodge County line. The Rubicon River rises in the low marshy area north of Pike Lake, which is two miles east of the City of Hartford, and flows west through Hartford and into Dodge County. The Ashippun River flows in a general southwesterly direction from its origin, which is about two miles southwest of the City of Hartford. The river flows through Druid Lake and, after traversing part of Dodge County, enters the northwestern corner of Waukesha County and leaves the Region upon passing into Jefferson County. The Oconomowoc River originates in south central Washington County, about two miles northeast of Friess Lake, and flows in a general southwesterly direction through Friess Lake, North Lake, Okauchee Lake, Oconomowoc Lake, Fowler Lake, and Lac La Belle into Jefferson County. The Bark River rises at Bark Lake in south central Washington County and flows southwestward through Nagawicka Lake, Upper and Lower Nemahbin lakes, and Crooked Lake into Jefferson County. Whitewater Creek originates in Rice Lake, which is located about four miles southeast of the City of Whitewater, and flows northwest through Trapp Lake and Cravath Lake and through the City of Whitewater into Jefferson County. Jackson Creek originates about two miles southeast of the City of Elkhorn, flows generally westward to Delavan Lake. Delavan Lake Outlet flows from Delavan Lake through the City of Delavan to Turtle Creek. Turtle Creek originates at Turtle Lake, located about seven miles northwest of the City of Delavan, and flows south and east to Comus Lake, past the City of Delavan, and westward into Rock County.

The Rock River watershed in southeastern Wisconsin is located in the western parts of Washington, Waukesha, and Walworth counties and is underlain by glacial deposits of diverse origin. In Washington County the East Branch of the Rock River, Kohlsville River, Rubicon River, and Ashippun River lie within an area underlain by deposits laid down by the Green Bay glacial lobe. In southwestern Washington County, the Rock River watershed is underlain in part by the interlobate moraine formed along the contact of the Green Bay and Lake Michigan glacial lobes, in part by the end-moraine system of the Lake Michigan glacial lobe, and by associated ground moraine and outwash deposits. The headwaters of the Oconomowoc River and the Bark River are developed in the area underlain by deposits of the Lake Michigan glacial lobe. In Waukesha County the watershed is also underlain by glacial deposits laid at and on either side of the interlobate moraine. In the northeastern part of the Rock River watershed in Waukesha County, the Oconomowoc River and the Bark River flow southwesterly across the glacial deposits laid down by the Lake Michigan glacial lobe and then traverse the interlobate moraine and flow across areas underlain by deposits of the Green Bay glacial lobe. In the northern part of Walworth County, Whitewater Creek drains an area underlain by deposits of the Green Bay lobe. The central and southern part of the watershed in Walworth County is underlain by deposits derived in part from the Lake Michigan glacial lobe of Wisconsin Age and from the previous (Illinoisan) period of glaciation. Jackson Creek, Delavan Lake Outlet, and Turtle Creek flow largely upon deposits laid down by the Lake Michigan glacial lobe.

East Branch Rock River

Present Stream Quality: One sampling station, Rk-1, was established by the SEWRPC on the East Branch of the Rock River at a point approximately 11.3 miles downstream from the river source. This stream receives the effluent of the sewage treatment plant serving the Allenton sanitary district.

The East Branch of the Rock River is a calcium bicarbonate stream that is subject to small changes in total mineralization. In the 12 complete chemical analyses run on stream samples collected from the East Branch of the Rock River, the predominant cation and anion were calcium and bicarbonate, respectively. Calcium concentrations ranged from 101 ppm in May 1964 to 24 ppm in February 1965. Bicarbonate concentrations ranged from 480 to 145 ppm in January and February 1965, respectively. Maximum nitrate concentration was 2.5 ppm. Total phosphorus at station Rk-1 was 0.24 ppm on September 16, 1964. Selected water analyses of the East Branch of the Rock River at station Rk-1 are listed in Table 218. Water quality conditions of the river are indicated in Table 219.

The chloride concentrations in the East Branch of the Rock River varied from 30 ppm in September to 0 ppm in April 1964 at sampling station Rk-1. Assuming a "background" chloride concentration of 5 ppm, the chloride impact upon the East Branch of the Rock River was as much as 25 ppm from human sources.

The dissolved solids concentrations varied from 570 ppm in September 1964 to 195 ppm in February 1965 at sampling station Rk-1. The maximum and minimum "background" concentration of dissolved solids are assumed to be 510 and 435 ppm.

Table 218

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-1 ON THE EAST BRANCH ROCK RIVER: 1964

Parameter	Analyses	Date of Collection	Analyses	Date of Collection
Silica	8	4-2-64	16	9-16-64
Iron	0.03	"	0.06	"
Manganese.	--	--	0.00	"
Chromium	--	--	<0.005	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	92	4-2-64	98	"
Magnesium.	48	"	45	"
Sodium (and Potassium)	15	"	45	"
Bicarbonate.	330	"	400	"
Carbonate.	40	"	40	"
Sulfate.	120	"	112	"
Chloride	0	"	15	"
Fluoride	--	--	<0.55	"
Nitrite.	0.0	4-2-64	0.0	"
Nitrate.	--	--	1.0	"
Phosphorus	--	--	0.24	"
Cyanide.	--	--	<0.01	11-18-64
Oil.	--	--	<2	9-16-64
Detergents	0.0	4-2-64	0.0	"
Dissolved Solids	485	"	570	"
Hardness	428	"	431	"
Noncarbonate Hardness.	90	"	35	"
Calcium Hardness	229	"	245	"
Magnesium Hardness	199	"	186	"
Alkalinity P	20	"	20	"
Alkalinity M	310	"	370	"
Specific Conductance	680	"	730	"
pH	8.3	"	7.6	"
Color.	40	"	90	"
Turbidity.	7	"	7	"
Biochemical Oxygen Demand. . . .	1.8	"	1.7	"
Dissolved Oxygen	11.7	"	7.6	"
Coliform Count	1,100	"	2,800	"
Temperature (^{o}F)	41	"	53	"

Source: SEWRPC.

Table 219

WATER QUALITY CONDITIONS OF EAST BRANCH ROCK RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	30	15	0	12
Dissolved Solids (ppm)	570	440	195	12
Dissolved Oxygen (ppm)	12.8	8.0	0	12
Coliform Count (MFCC/100 ml) .	21,000	3,800	300	12
Temperature (^{o}F)	71	46	32	12

Source: SEWRPC.

The dissolved oxygen concentrations in the East Branch of the Rock River ranged from 12.8 ppm in November to 0.0 ppm in March 1964 at station Rk-1. The maximum, average, and minimum concentrations for the period June through September were 8.1, 7.5, and 7.1 ppm, respectively.

The coliform counts in the East Branch of the Rock River ranged from 21,000 MFCC/100 ml in January 1965 to 300 MFCC/100 ml in December 1964 at station Rk-1. The maximum, average, and minimum coliform counts in the river for the period June through September 1964 were 2,800, 1,500, and 700 MFCC/100 ml, respectively.

The maximum temperature of the Rock River, as determined by the SEWRPC during the period of the study, was 71°F in July 1964. The maximum, average, and minimum temperatures of the river during the period June through September 1964 were 71°, 61°, and 53°F, respectively.

Streamflow and Precipitation: The East Branch of the Rock River is a shallow meandering stream, which most of the year occupies a relatively wide channel in its lower reaches within the Region. At sampling station Rk-1, which is about 11.3 miles downstream from the river source, the East Branch of the Rock River had a maximum depth of 2.8 feet and a width of 44 feet when measured under low-flow conditions in September 1964.

Table 220 lists the SEWRPC flow determinations for periods of relatively high and low flow in April and September 1964 at station Rk-1. Precipitation data for the period January 1964 to February 1965 are listed in Table 221.

Forecast Quality of the East Branch Rock River for the Year 1990: Population and land use studies by the SEWRPC indicate that there will be a minor increase in the population of the sub-watershed of the East Branch of the Rock River in southeastern Wisconsin by the year 1990. Most of the expected increase will center about the Village of Allenton, which in 1963 had an estimated population of 400. Table 222 lists the estimated future population by the year 1990 for each of the three regional alternative land use plans. The forecast quality of the East Branch of the Rock River is listed in Table 223.

Kohlsville River

Present Stream Quality: One sampling station, Rk-2, was established by the SEWRPC on the Kohlsville River, at a point approximately 6.6 miles downstream from the river source.

The Kohlsville River apparently is a calcium bicarbonate stream of relatively constant total mineralization. In the two complete chemical analyses run on stream samples collected from the Kohlsville River, the predominant cation and anion were calcium and bicarbonate, respectively. Calcium concentrations were 87 ppm in September and 80 ppm in April 1964. Bicarbonate concentrations were 340 and 305 ppm in September and April 1964, respectively. Maximum nitrate concentration was 2.7 ppm. No samples of the Kohlsville River were analyzed for phosphorus concentration. Selected water analyses of the Kohlsville River at station Rk-2 are listed in Table 224. Water quality conditions of the river are indicated in Table 225.

The chloride concentrations in the Kohlsville River varied from 15 ppm in April to 5 ppm in September 1964 at sampling station Rk-2. Assuming a "background" chloride concentration of 5 ppm, the chloride impact upon the Kohlsville River was as much as 10 ppm from human sources.

The dissolved solids concentrations of the Kohlsville River varied from 490 ppm in April to 470 ppm in September 1964 at station Rk-2. The assumed minimum "background" concentration of dissolved solids is about 470 ppm.

Table 220

STREAMFLOW MEASUREMENTS OF THE EAST BRANCH ROCK RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Rk-1	4- 6-64	83	0.76
	9-17-64	9.0	0.12

[a] *Measured at U. S. Weather Bureau Station at Hartford, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 221

PRECIPITATION[a] AT HARTFORD, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.10	--	--	--	--	--	--	--	--	0.32
2	--	--	--	0.05	0.70	0.17	0.34	--	0.37	--	0.39	0.08	0.32	--
3	--	--	--	0.45	--	0.05	--	--	--	--	0.01	--	--	--
4	--	--	--	--	--	--	--	--	0.80	--	--	0.05	--	--
5	--	--	1.57	0.26	0.94	--	--	--	--	--	--	--	--	--
6	--	--	--	0.40	0.11	--	--	--	0.01	--	--	--	--	--
7	--	--	0.24	0.30	--	--	0.16	--	--	--	--	0.01	--	--
8	--	--	--	--	0.11	--	0.02	--	--	0.23	--	--	0.09	0.15
9	--	--	0.45	--	0.02	--	--	--	0.60	--	--	--	--	--
10	--	--	--	--	--	--	--	0.04	0.05	--	--	--	--	0.09
11	0.05	--	--	--	--	--	--	--	--	--	--	0.10	--	--
12	0.03	--	--	--	--	0.02	--	--	--	--	0.27	--	--	0.26
13	--	0.16	--	0.05	0.36	--	0.08	--	--	--	--	0.13	--	--
14	--	--	0.12	--	--	--	0.56	--	0.01	--	--	--	--	--
15	--	--	--	--	--	0.21	--	--	0.11	--	0.36	--	0.06	--
16	0.01	--	--	--	0.81	--	--	--	--	--	--	--	0.01	--
17	--	--	--	0.01	--	0.27	--	--	--	--	--	--	--	--
18	--	--	--	0.12	0.23	0.03	2.00	--	0.43	--	--	--	--	--
19	--	--	--	--	--	--	--	--	0.18	--	--	0.02	--	--
20	0.14	--	0.01	--	--	--	0.99	0.05	0.77	--	0.11	--	--	--
21	--	--	0.08	0.65	--	--	0.76	1.32	0.40	--	0.06	--	--	--
22	--	--	--	--	--	0.08	--	0.27	0.86	--	--	--	0.09	--
23	--	0.02	--	--	--	0.22	--	--	--	--	--	--	0.63	0.03
24	0.24	--	--	--	0.27	--	--	--	0.11	--	--	--	0.40	0.19
25	0.62	--	--	--	--	--	0.15	--	--	--	--	--	--	--
26	--	--	0.48	--	--	--	--	--	0.25	--	--	--	0.38	--
27	--	--	0.05	0.27	--	--	--	--	--	--	--	--	--	--
28	--	--	0.07	0.15	--	--	0.25	--	--	--	1.03	0.03	0.02	--
29	--	--	--	0.06	--	--	--	--	--	--	--	--	--	--
30	--	--	--	0.05	--	--	--	0.27	--	--	--	--	--	--
31	--	--	--	--	0.01	--	--	--	--	--	--	--	--	--
Total	1.09	0.18	3.07	2.82	3.66	1.05	5.31	1.95	4.95	0.23	2.23	0.42	2.00	1.04

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Table 222

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE VILLAGE OF ALLENTON SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
East Branch Rock River	400	1,400	2,400	1,400
	Estimated Average Daily Sewage Flow Rate			
	40,000 [a] < 0.1 [b]	140,000 0.2	240,000 0.4	140,000 0.2
	Estimated Low Flow of the East Branch Rock River at Station Rk-1			
	< 9.0 [b]	< 9.0	< 9.0	< 9.0

[a] *Gallons per day.*
[b] *Cubic feet per second.*
Source: SEWRPC.

Table 223

FORECAST QUALITY OF THE EAST BRANCH ROCK RIVER AT SAMPLING STATION RK-1: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
East Branch Rock River	Rk-1	Chloride (in ppm)	15[a]	40	70	40
		Dissolved Solids (in ppm)	475[b]	500	550	500
		Dissolved Oxygen (in ppm)	7.5[c]	More than 6.0		
		Coliform Count (in MFCC/100 ml)	1,500[c]	More than 5,000		

[a] *Based on analyses for September 1964.*

[b] *Based on analyses for October 1964.*

[c] *Based on average for the period June through September 1964.*

Source: SEWRPC.

The dissolved oxygen concentrations varied from 13.4 ppm in January to 6.0 ppm in February 1965 at sampling station Rk-2. The maximum, average, and minimum concentrations for the period June through September were 12.3, 10.7, and 10.0 ppm, respectively.

The coliform counts varied from 6,000 MFCC/100 ml in February to 300 MFCC/100 ml in January 1965 at station Rk-2. The maximum, average, and minimum coliform counts for the period June through September 1964 were 3,300, 1,900, and 1,300 MFCC/100 ml, respectively.

The maximum temperature of the Kohlsville River was $70^{O}F$ in July 1964. The maximum, average, and minimum temperature during the period June through September was 70^{O}, 59^{O}, and $50^{O}F$, respectively.

Streamflow and Precipitation: The Kohlsville River is a relatively shallow meandering stream, which most of the year occupies a relatively wide channel in its lower reaches. At sampling station Rk-2, which is 6.6 miles downstream from the river source, the Kohlsville River had a maximum depth of 2.2 feet and a width of 30 feet when measured under low-flow conditions in September 1964.

Table 226 lists the SEWRPC flow determinations for periods of relatively high and low flow in April and September 1964 at sampling station Rk-2. Precipitation data for the period January 1964 to February 1965 are listed in Table 221.

Forecast Quality of the Kohlsville River for the Year 1990: Population and land use studies by the SEWRPC indicate that there will be only a very slight increase in the population of the sub-watershed of the Kohls-

Table 224

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-2 ON THE KOHLSVILLE RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	9	4-2-64	13	9-16-64
Iron	0.04	"	0.03	"
Manganese.	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium.	--	--	--	--
Calcium.	80	4-2-64	87	9-16-64
Magnesium.	48	"	41	"
Sodium (and Potassium) . . .	25	"	25	"
Bicarbonate.	305	"	340	"
Carbonate.	20	"	30	"
Sulfate.	144	"	96	"
Chloride	15	"	5	"
Fluoride	--	--	--	--
Nitrite.	0.0	4-2-64	0.0	9-16-64
Nitrate.	--	--	1.1	"
Phosphorus	--	--	--	--
Cyanide.	--	--	--	--
Oil.	--	--	--	--
Detergents	0.0	4-2-64	0.0	9-16-64
Dissolved Solids	490	"	470	"
Hardness	397	"	387	"
Noncarbonate Hardness. . . .	115	"	55	"
Calcium Hardness	199	"	217	"
Magnesium Hardness	198	"	170	"
Alkalinity P	10	"	15	"
Alkalinity M	270	"	310	"
Specific Conductance	644	"	660	"
pH	8.3	"	7.8	"
Color.	30	"	25	"
Turbidity.	5	"	6	"
Biochemical Oxygen Demand. .	2.1	"	1.4	"
Dissolved Oxygen	11.7	"	10.0	"
Coliform Count	2,300	"	1,400	"
Temperature (^{o}F)	40	"	50	"

Source: SEWRPC.

Table 225

WATER QUALITY CONDITIONS OF KOHLSVILLE RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	15	10	5	2
Dissolved Solids (ppm)	490	480	470	2
Dissolved Oxygen (ppm)	14.5	10.7	6.0	11
Coliform Count (MFCC/100 ml) .	6,000	1,700	300	11
Temperature (^{o}F)	70	46	32	11

Source: SEWRPC.

Table 226

STREAMFLOW MEASUREMENTS OF THE KOHLSVILLE RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Rk-2	4- 6-64 9-17-64	26 0	0.71 0.12

[a] *Measured at U. S. Weather Bureau Station at Hartford, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 227

FORECAST QUALITY OF THE KOHLSVILLE RIVER AT SAMPLING STATION RK-2: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990: Controlled Existing Trend Plan	Forecast Quality for 1990: Corridor Plan	Forecast Quality for 1990: Satellite City Plan
Kohlsville River	Rk-2	Chloride (in ppm)	5[a]	Less than 10		
		Dissolved Solids (in ppm)	470[a]	Less than 500		
		Dissolved Oxygen (in ppm)	10.7[b]	More than 10		
		Coliform Count (in MFCC/ 100 ml)	1,900[b]	Less than 2,400		

[a] *Based on analyses for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

ville River in southeastern Wisconsin by the year 1990. The estimated population of the Village of Kohlsville in 1963 was about 100 according to SEWRPC estimates. The population of this village is not anticipated to increase significantly by the year 1990. Forecast quality of the Kohlsville River for the year 1990 is indicated in Table 227.

Rubicon River

Present Stream Quality: Two sampling stations, Rk-3 and Rk-4, were established by the SEWRPC on the Rubicon River at points 6.1 and 11.9 miles downstream from the river source. Effluent from the sewage treatment plants at the Village of Slinger and at the City of Hartford is discharged into the Rubicon River. Station Rk-3 is located between Slinger and Hartford. Station Rk-4 is downstream from the sewage treatment plant at Hartford.

The Rubicon River is a calcium bicarbonate stream at station Rk-3 and is predominantly a sodium chloride stream at station Rk-4. The river is subject to large changes in total mineralization. In the 16 complete chemical analyses run on stream samples collected from the Rubicon River, the predominant cations were sodium and calcium. Sodium was the predominant cation in 12 analyses at concentrations ranging from 590 ppm in January to 55 ppm in February 1965 at station Rk-4. Calcium was the predominant cation in four analyses at concentrations ranging from 91 ppm at station Rk-4 to 49 ppm at station Rk-3 in April 1964. Chloride and bicarbonate were predominant anions. Chloride was predominant in nine analyses at concentrations ranging from 850 to 440 ppm at station Rk-4 in January 1965 to 440 in October 1964. Calcium was the predominant anion in six analyses at concentrations ranging from 380 ppm in May 1964 to 225 ppm in July 1964 at station Rk-4. Maximum nitrate concentration was 5.1 ppm. Total phosphorus was 4.0 ppm at station Rk-4 on September 16, 1964. Selected water analyses are listed in Tables 228 and 229. Water quality conditions of the Rubicon River are indicated in Table 230.

The chloride concentrations in the Rubicon River varied from 850 ppm in January 1965 to 15 ppm in September 1964 at sampling stations Rk-4 and Rk-3, respectively. Assuming a "background" chloride con-

Table 228

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-3 ON THE RUBICON RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	9	4-2-64	6	9-16-64
Iron	0.06	"	0.02	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	74	4-2-64	74	9-16-64
Magnesium	41	"	46	"
Sodium (and Potassium)	30	"	30	"
Bicarbonate	270	"	330	"
Carbonate	40	"	30	"
Sulfate	93	"	96	"
Chloride	20	"	15	"
Fluoride	--	--	--	--
Nitrite	0.0	4-2-64	0.1	9-16-64
Nitrate	--	--	0.6	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.1	4-2-64	0.0	9-16-64
Dissolved Solids	435	"	460	"
Hardness	353	"	375	"
Noncarbonate Hardness	65	"	55	"
Calcium Hardness	185	"	184	"
Magnesium Hardness	168	"	191	"
Alkalinity P	20	"	15	"
Alkalinity M	260	"	300	"
Specific Conductance	600	"	674	"
pH	8.4	"	8.0	"
Color	30	"	50	"
Turbidity	6	"	2	"
Biochemical Oxygen Demand	3.4	"	1.7	"
Dissolved Oxygen	13.5	"	13.1	"
Coliform Count	300	"	600	"
Temperature (°F)	42	"	53	"

Source: SEWRPC.

Table 229

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-4 ON THE RUBICON RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	7	4-2-64	4	9-16-64
Iron	0.03	"	0.04	"
Manganese.	--	--	0.00	"
Chromium	--	--	< 0.02	"
Hexavalent Chromium. . . .	--	--	0.00	"
Calcium.	91	4-2-64	73	"
Magnesium.	36	"	35	"
Sodium (and Potassium) . .	75	"	360	"
Bicarbonate.	295	"	340	"
Carbonate.	30	"	40	"
Sulfate.	93	"	112	"
Chloride	105	"	455	"
Fluoride	--	--	< 0.85	"
Nitrite.	0.0	4-2-64	0.3	"
Nitrate.	--	--	4.1	"
Phosphorus	--	--	4.0	"
Cyanide.	--	--	< 0.01	11-18-64
Oil.	--	--	< 1	9-16-64
Detergents	0.2	4-2-64	0.4	"
Dissolved Solids	580	"	1,250	"
Hardness	373	"	325	"
Noncarbonate Hardness. . .	85	"	0	"
Calcium Hardness	226	"	182	"
Magnesium Hardness	147	"	143	"
Alkalinity P	15	"	20	"
Alkalinity M	270	"	320	"
Specific Conductance . . .	924	"	2,030	"
pH	8.4	"	8.0	"
Color.	30	"	15	"
Turbidity.	4	"	4	"
Biochemical Oxygen Demand.	3.1	"	2.9	"
Dissolved Oxygen	14.3	"	10.3	"
Coliform Count	200	"	39,000	"
Temperature (°F)	44	"	57	"

Source: SEWRPC.

Table 230

WATER QUALITY CONDITIONS OF THE RUBICON RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	850	195	15	16
Dissolved Solids (ppm)	1,970	745	275	16
Dissolved Oxygen (ppm)	17.1	11.8	4.2	27
Coliform Count (MFCC/100 ml) .	270,000	22,000	100	27
Temperature (°F)	77	47	32	27

Source: SEWRPC.

centration of 5 ppm, the chloride impact upon the Rubicon River was as much as 845 ppm from human sources. The variations in the chloride concentrations in the Rubicon River are shown in a series of 14 interpretive stream quality graphs in Figure 41. Several industries at the City of Hartford produce liquid wastes high in chloride concentration that are discharged into the municipal sewerage system and enter the Rubicon River at the sewage treatment plant outfall. Effluent from the Village of Slinger sewage treatment plant is discharged into an intermittent headwater tributary of the Rubicon River, with little or no apparent effect on the quality of the river at sampling station Rk-3.

The dissolved solids concentrations in the Rubicon River varied from 1,970 ppm in January 1965 to 275 ppm in February 1965 at station Rk-4. Assuming a "background" dissolved solids concentration of about 445 ppm, the dissolved solids impact from human activities upon the Rubicon River was as much as 1,520 ppm. The variations in the dissolved solids concentrations in the Rubicon River are shown in a series of 14 interpretive stream quality graphs in Figure 42. Figure 43 shows the variations in the chloride and dissolved solids concentrations at stations Rk-3 and Rk-4. Much of the variations in dissolved solids concentration are due to variations in the chloride and sodium concentrations of the river.

The dissolved oxygen concentrations in the Rubicon River varied from 17.1 ppm in January 1964 at station Rk-3 to 4.2 ppm in January 1965 at station Rk-4. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 13.1, 12.2, and 10.9 ppm and 13.9, 11.7, and 10.5 ppm, at sampling stations Rk-3 and Rk-4, respectively. A series of 14 interpretive stream quality graphs in Figure 44 show the variations in dissolved oxygen in the Rubicon River. Figure 45 shows the variations in dissolved oxygen at sampling stations Rk-3 and Rk-4.

The coliform counts in the Rubicon River varied from 270,000 MFCC/100 ml in January 1965 at station Rk-4 to less than 100 MFCC/100 ml in February 1964 and in January 1965 at station Rk-3. The maximum, average, and minimum counts for the period June through September 1964 were 2,000, 1,000, and 600 MFCC/100 ml and 39,000, 13,200, and 2,000 MFCC/100 ml at sampling stations Rk-3 and Rk-4, respectively. Figure 46 is a series of 14 interpretive stream quality graphs showing the variations in coliform counts in the Rubicon River. Figure 47 shows the variations in coliform counts at stations Rk-3 and Rk-4.

The maximum temperature of the Rubicon River was 77°F in July 1964 at stations Rk-3 and Rk-4. The maximum, average, and minimum temperatures for the period June through September 1964 were 77°, 64°, and 53°F and 77°, 65°, and 57°F at station Rk-3 and Rk-4, respectively.

Streamflow and Precipitation: Much of the year, the Rubicon River is a shallow meandering stream occupying a narrow channel. At sampling station Rk-4, this stream had a maximum depth of 1.3 feet and was 24 feet wide when measured under low-flow conditions in September 1964.

The flow of the Rubicon River was measured by the SEWRPC at station Rk-4 in April and September 1964, as indicated in Table 231. Daily precipitation at Hartford, Wisconsin, from January 1964 through February 1965 is listed in Table 221.

Table 231

STREAMFLOW MEASUREMENTS OF THE RUBICON RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 3-Day Rainfall (in inches)[a]
Rk-4	4- 6-64	63	0.71
	9-17-64	2.4	0.12

[a] *Measured at U. S. Weather Bureau Station at Hartford, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Figure 41

CHLORIDE CONCENTRATION IN THE RUBICON AND OCONOMOWOC RIVERS, AND IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK

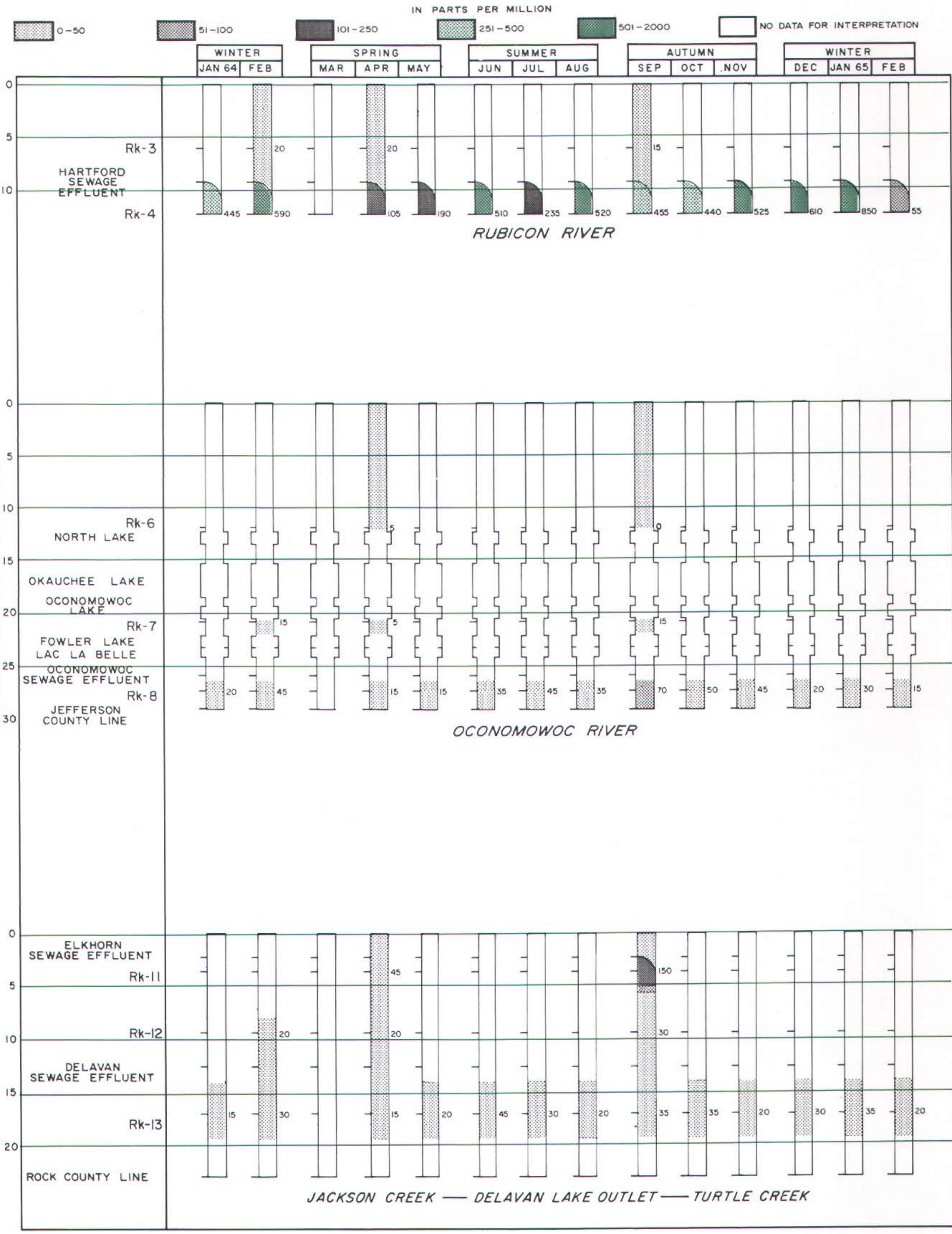


Figure 42

DISSOLVED SOLIDS CONCENTRATIONS IN THE RUBICON AND OCONOMOWOC RIVERS, AND IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK

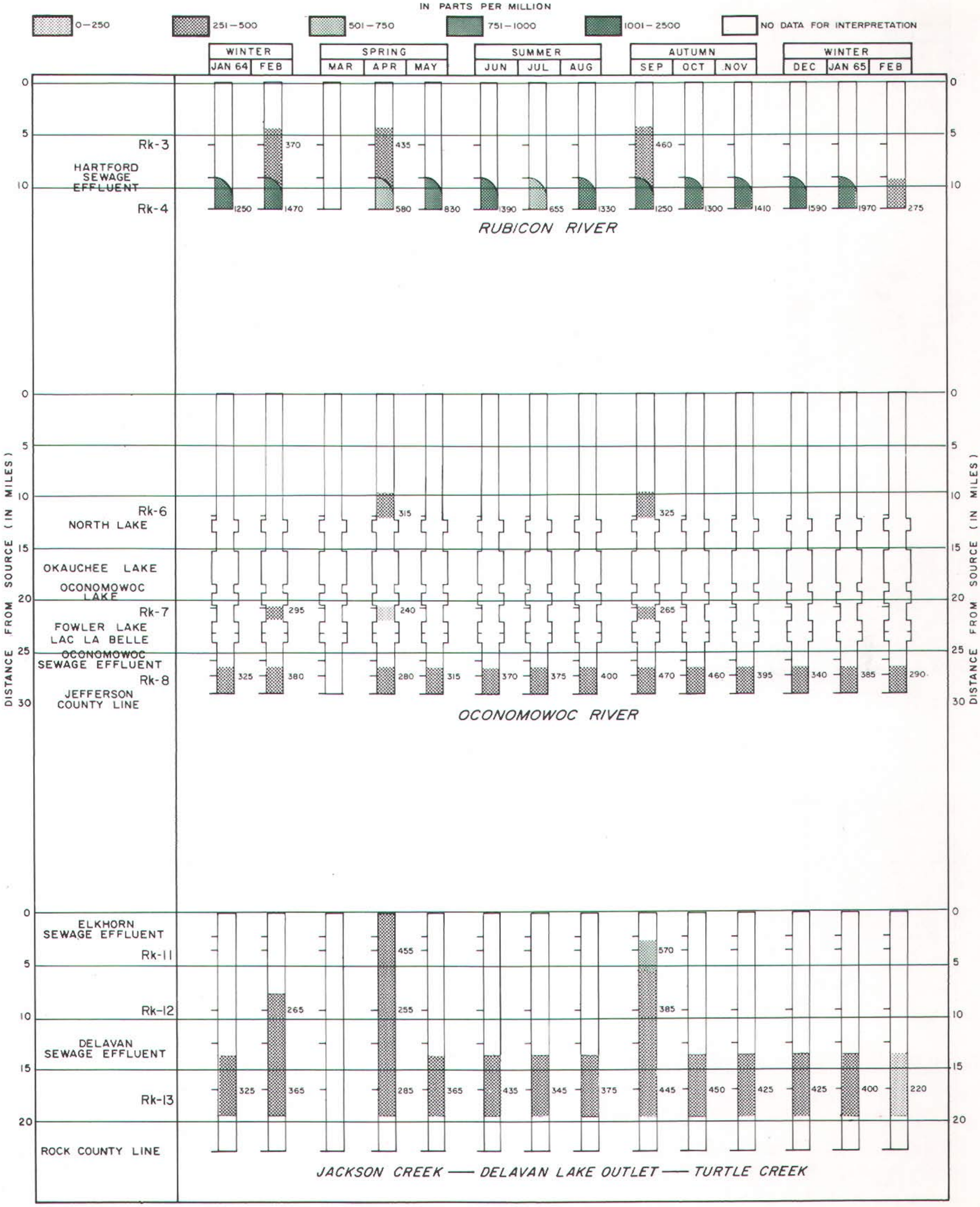


Figure 44

DISSOLVED OXYGEN CONCENTRATION IN THE RUBICON AND OCONOMOWOC RIVERS, AND IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK

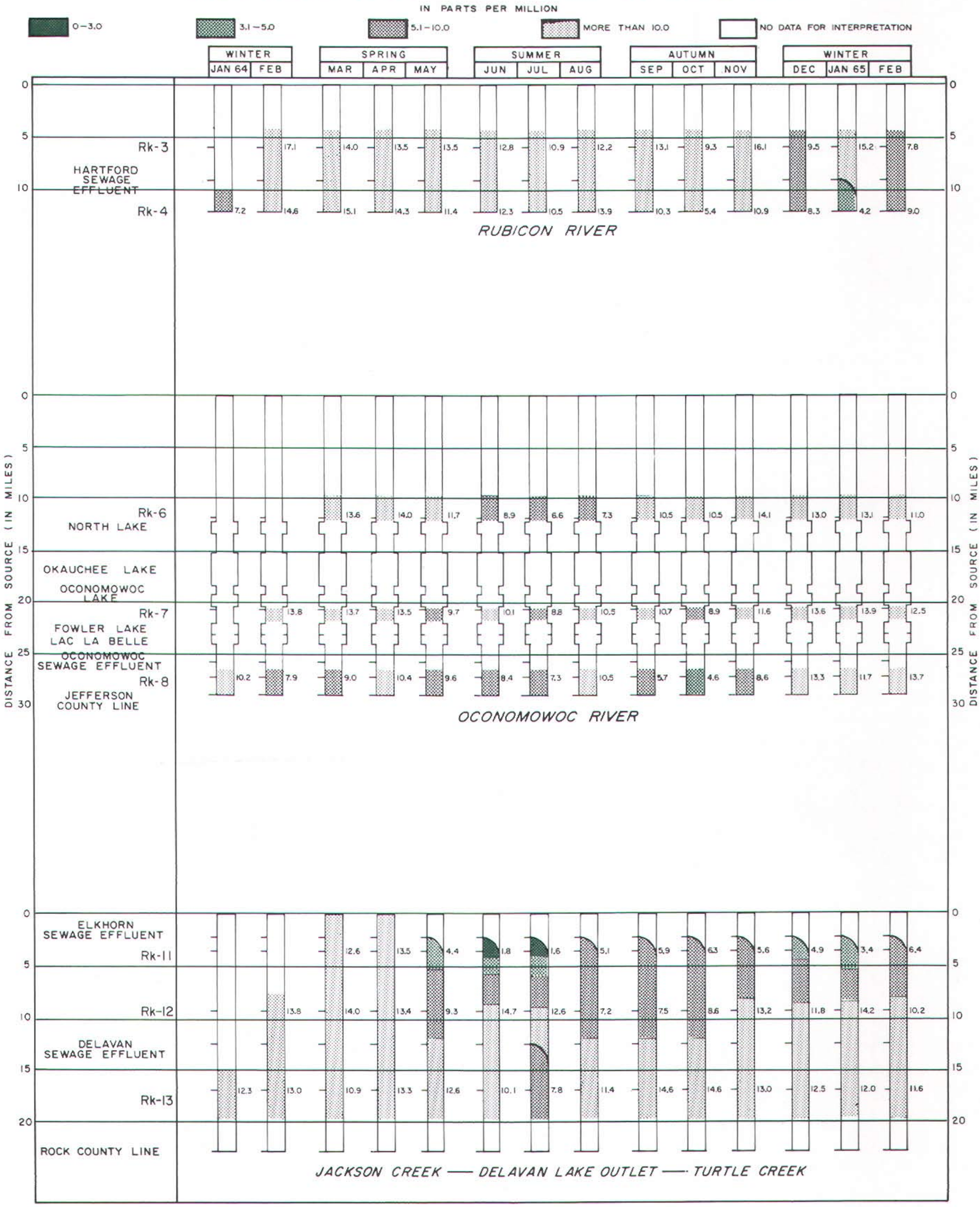


Figure 43

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN THE RUBICON RIVER

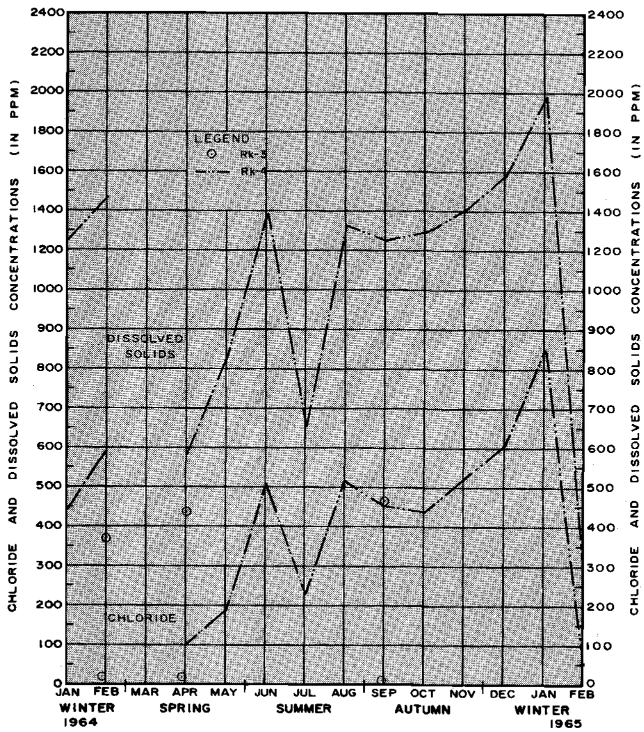
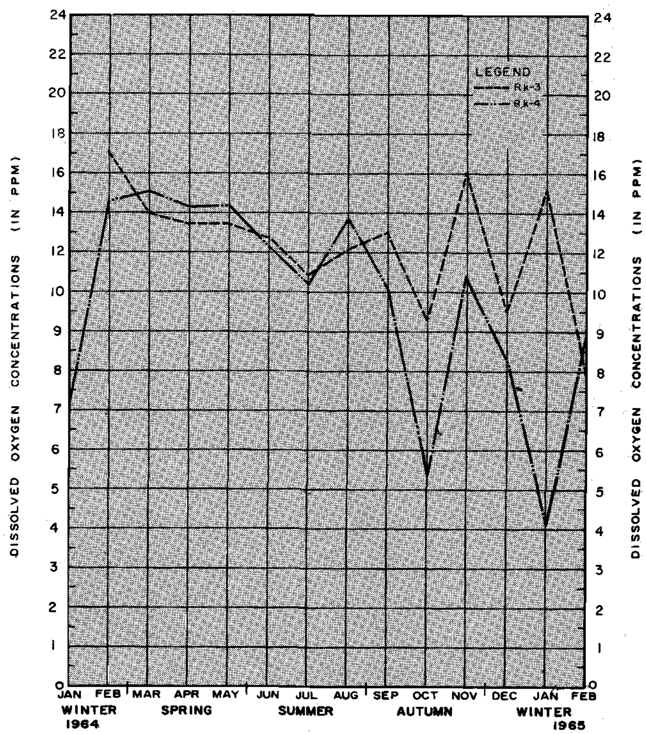


Figure 45

DISSOLVED OXYGEN CONCENTRATIONS IN THE RUBICON RIVER



Forecast Quality of the Rubicon River for the Year 1990: Population and land use studies by the SEWRPC indicate that a significant increase in urban population may be expected in the sub-watershed of the Rubicon River by the year 1990. Most of this increase will center about the City of Hartford and Village of Slinger, which are estimated to have had populations of 6,000 and 1,200 people, respectively, in 1963. Table 232 lists the estimated future population of these municipalities by the year 1990 according to each of the three regional alternative land use plans prepared by the SEWRPC. This table also lists the estimated average daily sewage flow rates and the estimated low flow of the Rubicon River at sampling station Rk-4 under each regional alternative land use plan.

Table 233 indicates the forecast quality of the Rubicon River for the year 1990. The Rubicon River has an exceptionally high chloride concentration due to the wastes entering the stream from industrial sources of pollution. For this reason future quality conditions with respect to chloride and dissolved solids is listed as indeterminate.

Ashippun River

Present Stream Quality: One sampling station, Rk-5, was established by the SEWRPC on the Ashippun River at a point approximately 9.4 miles downstream from the river source. No sewage treatment plants are located in the sub-watershed of the Ashippun River.

The Ashippun River is a calcium bicarbonate stream of relatively constant total mineralization. In the three complete chemical analyses run on stream samples collected from the Ashippun River, calcium was the predominant cation at concentrations ranging from 65 ppm to 58 ppm at station Rk-5 in February and September 1964. Bicarbonate was predominant at concentrations ranging from 390 ppm to 255 ppm at station Rk-5 in February and April 1964. Maximum nitrate concentration was 4.6 ppm. Total phosphorus at station Rk-5 was 0.24 ppm on September 14, 1964. Selected water analyses of the Ashippun River at station Rk-5 are listed in Table 234. Water quality conditions of the river are indicated in Table 235.

Figure 46

COLIFORM COUNT IN THE RUBICON AND OCONOMOWOC RIVERS, AND IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK

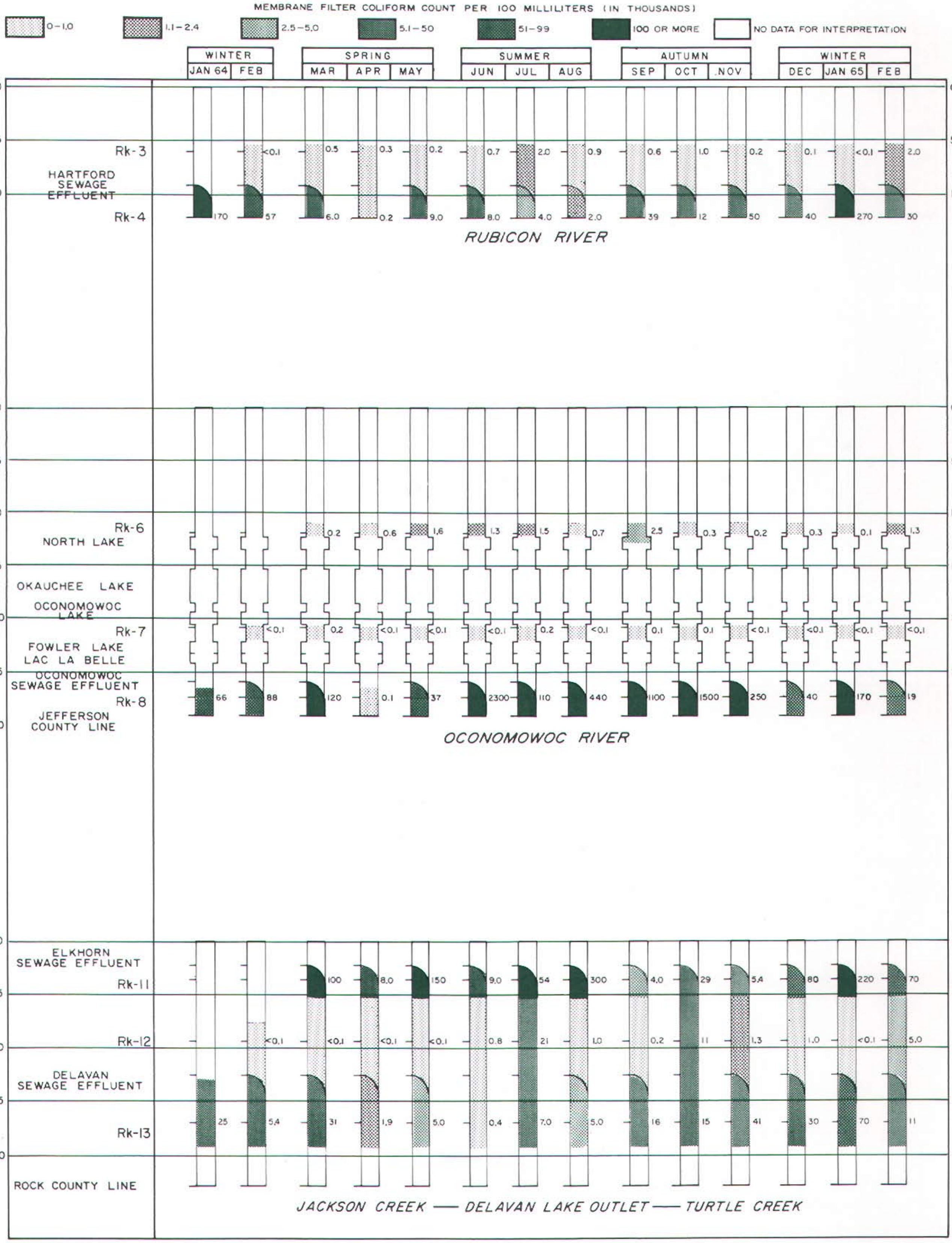


Table 232

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE SLINGER AND HARTFORD SEWAGE TREATMENT PLANTS: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Slinger.	1,200	3,200	7,400	5,700
City of Hartford. .	6,000	9,600	13,100	20,800
	Estimated Average Daily Sewage Flow Rate			
Village of Slinger.	150,000[a] 0.2[b]	400,000 0.6	750,000 1.2	1,050,000 1.6
City of Hartford. .	700,000[a] 1.1[b]	1,150,000 1.8	2,350,000 3.6	3,750,000 5.8
	Estimated Low Flow of the Rubicon River at Sampling Station Rk-4			
	3.4	4.3	6.2	8.3

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 233

FORECAST QUALITY OF THE RUBICON RIVER AT SAMPLING STATION RK-4: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Rubicon River	Rk-4	Chloride (in ppm)	455[a]	Indeterminate		
		Dissolved Solids (in ppm)	1,250[a]	Indeterminate		
		Dissolved Oxygen (in ppm)	11.7[b]	More than 8.0		
		Coliform Count (in MFCC/ 100 ml)	13,200[b]	20,000	27,000	42,000

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Table 234

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-5 ON THE ASHIPPUN RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	4	4-2-64	8	9-14-64
Iron	0.01	"	0.08	"
Manganese.	--	--	0.00	"
Chromium	--	--	<0.005	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	63	4-2-64	65	"
Magnesium.	36	"	40	"
Sodium (and Potassium) . . .	10	"	20	"
Bicarbonate.	255	"	330	"
Carbonate.	30	"	20	"
Sulfate.	49	"	56	"
Chloride	5	"	5	"
Fluoride	--	--	<0.3	"
Nitrite.	0.0	4-2-64	0.0	"
Nitrate.	--	--	0.8	"
Phosphorus	--	--	0.24	"
Cyanide.	--	--	--	--
Oil.	--	--	<1	9-14-64
Detergents	0.2	4-2-64	0.0	"
Dissolved Solids	320	"	375	"
Hardness	305	"	329	"
Noncarbonate Hardness. . . .	45	"	25	"
Calcium Hardness	158	"	163	"
Magnesium Hardness	147	"	166	"
Alkalinity P	15	"	10	"
Alkalinity M	240	"	290	"
Specific Conductance	512	"	568	"
pH	8.2	"	8.0	"
Color.	20	"	20	"
Turbidity.	3	"	5	"
Biochemical Oxygen Demand. .	1.6	"	1.9	"
Dissolved Oxygen	13.3	"	10.8	"
Coliform Count	100	"	2,000	"
Temperature (^{o}F)	39	"	56	"

Source: *SEWRPC*.

Table 235

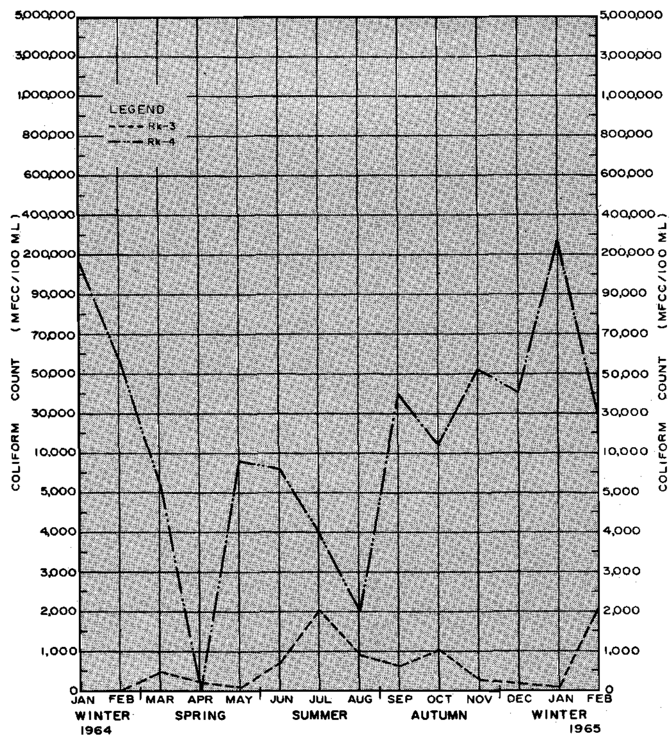
WATER QUALITY CONDITIONS OF THE ASHIPPUN RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	20	10	5	3
Dissolved Solids (ppm)	440	380	320	3
Dissolved Oxygen (ppm)	15.9	10.3	5.0	12
Coliform Count (MFCC/100 ml) .	10,000	2,500	100	12
Temperature (^{o}F)	77	50	32	12

Source: *SEWRPC*.

Figure 47

COLIFORM COUNT IN THE RUBICON RIVER



The chloride concentrations in the Ashippun River varied from 20 ppm in February 1964 to 5 ppm in April and September 1964 at sampling station Rk-5. Assuming a "background" chloride concentration of 5 ppm, the chloride impact upon the Ashippun River was as much as 15 ppm from human sources.

The dissolved solids concentrations in the Ashippun River varied from 440 ppm in February to 320 ppm in April 1964 at sampling station Rk-5. The presumed "background" dissolved solids concentration is 375 ppm.

The dissolved oxygen concentrations in the Ashippun River varied from 15.9 ppm in November to 5.0 in July 1964. The maximum, average, and minimum dissolved oxygen concentrations during the period June through September 1964 were 10.8, 8.7, and 5.0 ppm, respectively.

The coliform counts in the Ashippun River varied from 10,000 MFCC/100 ml in August to 100 MFCC/100 ml in April 1964 at sampling station Rk-5. The maximum, average, and minimum counts for the period June through September 1964 were 10,000, 4,700, and 1,100 MFCC/100 ml.

The maximum temperature of the Ashippun River was 77°F in August 1964. The maximum, average, and minimum temperatures for the period June through September 1964 were 77°, 69°, and 56°F, respectively.

Streamflow and Precipitation: Throughout much of the year, the Ashippun River is a shallow stream occupying a narrow meandering channel. At sampling station Rk-5, a distance approximately 9.4 miles downstream from the river source, the Ashippun River had a maximum depth of 0.3 foot and a width of 16 feet when measured under low-flow conditions in September 1964.

The SEWRPC measured the flow of the Ashippun River under conditions of relatively high and low flow in April and September 1964, as indicated in Table 236. Daily precipitation for the period January 1964 through February 1965 is listed in Table 237.

Forecast Quality of the Ashippun River for the Year 1990: Population and land use studies by the SEWRPC indicate that no significant increase is expected by the year 1990 in the population of the sub-watershed of the Ashippun River. The forecast quality of the Ashippun River for the year 1990 is indicated in Table 238.

Table 236

STREAMFLOW MEASUREMENTS OF THE ASHIPPUN RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Rk-5	4- 4-64 9-15-64	45 2.1	0.52 0.07

[a] *Measured at U. S. Weather Bureau Station at Oconomowoc, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 237

PRECIPITATION[a] AT OCONOMOWOC, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.21	0.03	0.19	--	--	--	--	--	--	0.16
2	--	--	--	0.27	0.65	0.09	0.12	--	0.04	0.01	0.33	0.07	0.28	--
3	--	--	--	0.25	--	0.04	--	--	--	--	0.12	--	--	--
4	--	--	--	--	--	--	--	--	0.03	--	0.06	0.05	--	--
5	--	--	1.25	0.56	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	0.02	0.01	0.02	--	--	--
7	--	--	--	0.65	--	--	0.18	--	--	--	--	0.06	--	0.03
8	--	--	0.27	--	0.32	--	0.17	--	--	0.13	--	--	0.03	0.06
9	--	--	--	--	0.06	--	--	--	0.03	--	--	--	--	0.03
10	--	--	--	--	--	--	--	0.06	0.06	--	--	--	--	0.06
11	--	--	--	--	--	--	--	0.13	--	--	--	0.07	--	--
12	0.01	0.05	--	--	--	--	--	--	--	--	0.14	0.03	--	0.26
13	--	0.10	--	0.11	0.37	--	0.16	--	--	--	--	0.09	--	--
14	--	--	0.12	--	--	--	0.24	--	0.07	--	--	--	--	--
15	--	--	--	--	--	0.30	--	--	0.05	--	0.61	--	0.03	--
16	0.02	--	--	--	0.55	--	--	0.13	--	--	--	--	--	--
17	--	--	--	--	--	0.17	--	--	--	--	--	--	--	--
18	--	--	--	0.51	0.01	--	2.12	--	0.37	--	--	--	--	--
19	--	--	--	--	--	0.35	--	--	--	--	--	--	--	--
20	0.11	--	0.05	--	--	--	0.78	--	0.04	--	0.03	0.02	--	--
21	--	--	0.20	0.47	--	1.03	--	1.27	0.03	--	--	--	--	--
22	--	--	--	--	--	0.76	0.07	0.53	--	--	--	--	0.45	--
23	--	--	--	--	--	--	--	0.01	0.07	--	--	0.03	0.12	--
24	0.39	--	--	--	0.35	--	--	--	0.04	--	--	0.02	0.40	0.21
25	0.19	--	--	--	--	--	0.30	--	--	--	--	--	--	--
26	--	--	0.25	--	--	--	--	--	0.32	--	--	0.02	0.14	--
27	--	--	0.06	0.17	--	--	--	--	--	--	--	--	--	--
28	--	--	0.03	0.05	--	--	--	--	--	--	1.05	--	--	--
29	--	--	--	0.23	--	--	0.01	--	--	--	--	--	--	--
30	--	--	--	0.06	--	--	0.05	0.32	--	--	--	--	--	--
31	--	--	--	--	0.02	--	--	--	--	--	--	--	--	--
Total	0.72	0.15	2.23	3.33	2.54	3.04	4.39	2.45	1.17	0.15	2.36	0.46	1.45	0.81

[a] *Precipitation measured in inches. Trace quantities not included.*

Source: U. S. Weather Bureau.

Oconomowoc River

Present Stream Quality: Three sampling stations, Rk-6, Rk-7, and Rk-8, were established by the SEWRPC on the Oconomowoc River at distances of 11.9, 20.6, and 27.2 miles downstream from the river source. This stream receives effluent from the sewage treatment plant at the City of Oconomowoc.

The Oconomowoc River is predominantly a calcium bicarbonate stream of relatively constant total mineralization. In the 19 complete chemical analyses run on stream samples collected from the Oconomowoc River, calcium and sodium were predominant cations. Calcium was predominant in 17 analyses at concentrations ranging from 69 ppm at station Rk-8 in October 1964 to 30 ppm at station Rk-7 in September 1964. Sodium was the predominant anion in two samples at concentrations of 55 and 65 ppm in August and

Table 238

FORECAST QUALITY OF THE ASHIPPUN RIVER AT SAMPLING STATION RK-5: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Ashippun River	Rk-5	Chloride (in ppm)	5[a]	Less than 10		
		Dissolved Solids (in ppm)	375[a]	Less than 400		
		Dissolved Oxygen (in ppm)	8.7[b]	More than 8.0		
		Coliform Count (in MFCC/ 100 ml)	4,700[b]	Approximately 5,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

September 1964, respectively, at station Rk-8. Bicarbonate was the predominant anion in all 19 complete chemical analyses at concentrations ranging from 400 ppm in October 1964 at station Rk-8 to 200 ppm in April 1964 at station Rk-7. Maximum nitrate concentration was 3.6 ppm. Total phosphorus concentrations at sampling stations Rk-6 and Rk-8 were 0.12 and 5.3 ppm on September 14, 1964. Selected water analyses of the Oconomowoc River at station Rk-6 and Rk-8 are listed in Tables 239 and 240. Water quality conditions of the river are indicated in Table 241.

The chloride concentrations in the Oconomowoc River varied from 70 ppm in September 1964 at station Rk-8 to 0 ppm in September 1964 at sampling station Rk-6. Assuming a "background" chloride concentration of 5 ppm, the chloride impact upon the Oconomowoc River was as much as 65 ppm from human sources.

The dissolved solids concentrations varied from 470 ppm in September 1964 at station Rk-8 to 240 ppm in April 1964 at station Rk-7. Assuming a "background" dissolved solids concentration of about 370 ppm at station Rk-8, the dissolved solids impact upon the Oconomowoc River was as much as 100 ppm. The variations in the dissolved solids concentrations in the Oconomowoc River are shown in a series of 14 interpretive stream quality graphs in Figure 42. Figure 48 shows the variations in the chloride and dissolved solids concentrations at stations Rk-6, Rk-7, and Rk-8.

The dissolved oxygen concentrations in the Oconomowoc River varied from 14.1 ppm in November 1964 at station Rk-6 to 4.6 ppm in October 1964 at station Rk-8. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 10.5, 8.3, and 6.6 ppm, respec-

Figure 48

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN THE OCONOMOWOC RIVER

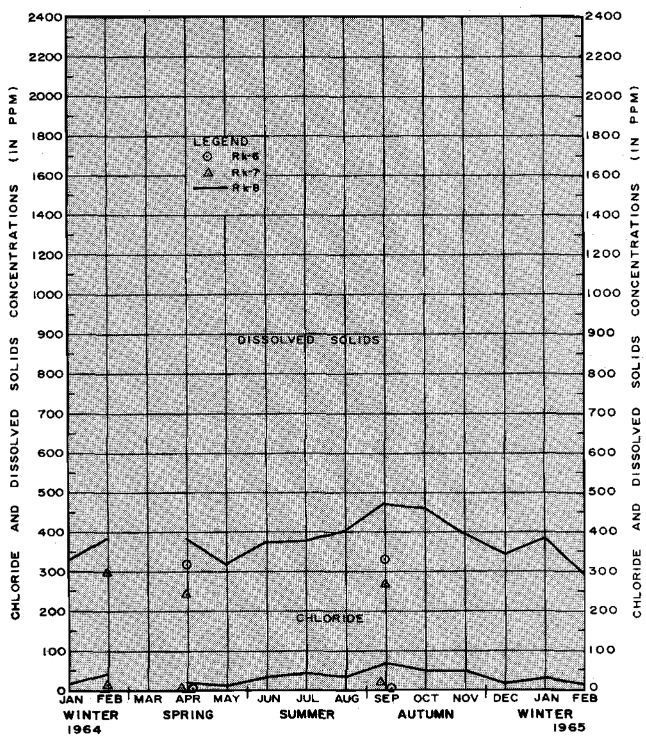
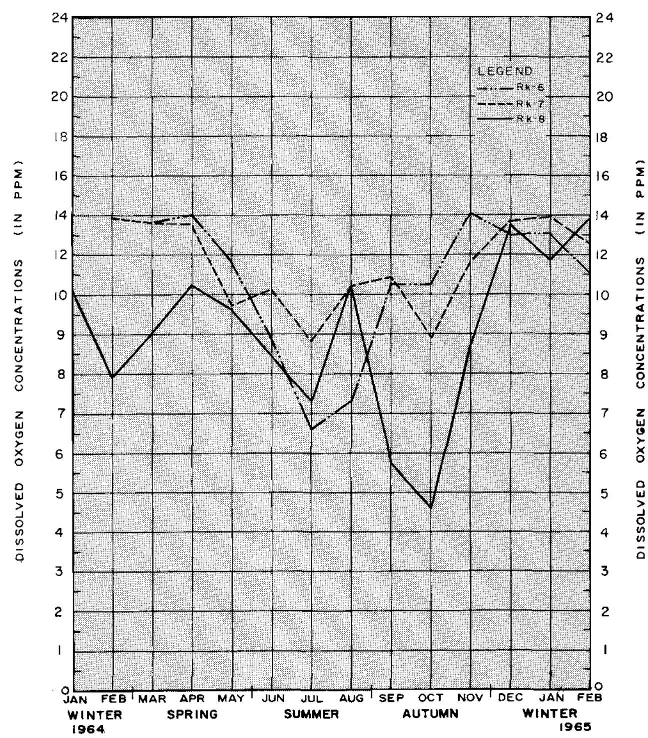


Figure 49

DISSOLVED OXYGEN CONCENTRATIONS IN THE OCONOMOWOC RIVER



tively, at station Rk-6; 10.7, 10.0, and 8.8 ppm, respectively, at station Rk-7; and 10.5, 8.0, and 5.7 ppm, respectively, at station Rk-8. A series of 14 interpretive stream quality graphs in Figure 35 shows the variations in dissolved oxygen concentrations in the Oconomowoc River. Figure 49 shows the variations in dissolved oxygen at sampling stations Rk-6, Rk-7, and Rk-8.

The coliform counts in the Oconomowoc River varied from 2,300,000 MFCC/100 ml in June 1964 at sampling station Rk-8 to less than 100 MFCC/100 ml in 9 of 13 months of sampling at station Rk-7. The maximum, average, and minimum coliform counts for the period June through September 1964 were 2,500, 1,500, and 700 MFCC/100 ml, respectively, at station Rk-6; 200, 100, and less than 100 MFCC/100 ml, respectively, at station Rk-7; and 2,300,000, 900,000, and 110,000 MFCC/100 ml, respectively, at station Rk-8. Figure 46 presents a series of 14 interpretive stream quality graphs showing the variations in coliform count in the Oconomowoc River. Figure 50 shows the variations in coliform counts at sampling stations Rk-6, Rk-7, and Rk-8.

The maximum temperatures of the Oconomowoc River occurred in August 1964 and were 77^{o}, 80^{o}, and $79^{o}F$ at stations Rk-6, Rk-7, and Rk-8, respectively. The maximum, average, and minimum stream temperatures at stations Rk-6, Rk-7, and Rk-8 for the period June through September 1964 were 77^{o}, 69^{o}, and $59^{o}F$; 80^{o}, 72^{o}, and $64^{o}F$; and 79^{o}, 71^{o}, and $59^{o}F$, respectively. The variations in the temperatures of the Oconomowoc River at station Rk-8 are shown in Figure 51.

Streamflow and Precipitation: Throughout much of the year, the Oconomowoc River is a shallow stream occupying a relatively wide meandering channel that flows through six major lakes in the Region. At sampling station Rk-6 and Rk-8, the stream had maximum depths of 0.5 foot and 0.7 foot and widths of 15 and 17 feet when measured under low-flow conditions in September 1964.

The SEWRPC measured the flow of the Oconomowoc River under conditions of relatively high and low flow in April and September 1964, as indicated in Table 242. Daily precipitation data for the period January 1964 through February 1965 are listed in Table 237. The lake levels and the flow of the Oconomowoc River are

Table 239

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-6 ON THE OCONOMOWOC RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-2-64	2	9-14-64
Iron	0.02	"	0.05	"
Manganese	--	--	0.00	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	55	4-2-64	53	"
Magnesium	33	"	34	"
Sodium (and Potassium)	20	"	20	"
Bicarbonate	245	"	280	"
Carbonate	40	"	10	"
Sulfate	38	"	65	"
Chloride	5	"	0	"
Fluoride	--	--	<0.35	"
Nitrite	0.0	4-2-64	0.0	"
Nitrate	--	--	0.0	"
Phosphorus	--	--	0.12	"
Cyanide	--	--	--	--
Oil	--	--	<1	9-14-64
Detergents	0.2	4-2-64	0.0	"
Dissolved Solids	315	"	325	"
Hardness	274	"	274	"
Noncarbonate Hardness	5	"	25	"
Calcium Hardness	137	"	133	"
Magnesium Hardness	137	"	141	"
Alkalinity P	20	"	5	"
Alkalinity M	240	"	240	"
Specific Conductance	480	"	490	"
pH	8.4	"	8.0	"
Color	20	"	25	"
Turbidity	2	"	2	"
Biochemical Oxygen Demand	3.9	"	1.1	"
Dissolved Oxygen	14.0	"	10.5	"
Coliform Count	600	"	2,500	"
Temperature (^{o}F)	39	"	59	"

Source: SEWRPC

regulated by water control structures, and the flow of this stream is not necessarily directly related to rainfall or ice and snowmelt.

Forecast Quality of the Oconomowoc River for the Year 1990: Population and land use studies by the SEWRPC indicate that a significant increase in population may be expected in the sub-watershed of the Oconomowoc River in and near the City of Oconomowoc by the year 1990. In contrast, the remaining area of the sub-watershed is not expected to experience significant population growth by 1990. Population forecasts for the watershed under the three regional alternative land use plans are indicated in Table 243, together with the estimated average daily sewage flow rates and the estimated low flow of the Oconomowoc River at sampling station Rk-8 under each regional alternative land use plan. The forecast quality of the Oconomowoc River at sampling station Rk-8 for the year 1990 is indicated in Table 244.

Bark River

Present Stream Quality: One sampling station, Rk-9, was established by the SEWRPC on the Bark River at a point 29 miles downstream from the river source. This stream receives effluent from sewage treatment plants at the villages of Hartland and Dousman.

Table 240

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-8 ON THE OCONOMOWOC RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-2-64	15	9-14-64
Iron	0.05	"	0.07	"
Manganese	--	--	0.00	"
Chromium	--	--	<0.02	"
Hexavalent Chromium	--	--	0.00	"
Calcium	45	4-2-64	58	"
Magnesium	37	"	39	"
Sodium (and Potassium)	10	"	65	"
Bicarbonate	260	"	365	"
Carbonate	10	"	10	"
Sulfate	31	"	31	"
Chloride	15	"	70	"
Fluoride	--	--	<1.5	"
Nitrite	0.0	4-2-64	0.1	"
Nitrate	--	--	2.9	"
Phosphorus	--	--	5.3	"
Cyanide	--	--	<0.01	11-19-64
Oil	--	--	<1	9-14-64
Detergents	0.1	4-2-64	0.4	"
Dissolved Solids	280	"	470	"
Hardness	267	"	306	"
Noncarbonate Hardness	35	"	0	"
Calcium Hardness	113	"	145	"
Magnesium Hardness	154	"	161	"
Alkalinity P	5	"	5	"
Alkalinity M	225	"	310	"
Specific Conductance	470	"	782	"
pH	8.0	"	7.6	"
Color	10	"	10	"
Turbidity	2	"	3	"
Biochemical Oxygen Demand	3.7	"	5.4	"
Dissolved Oxygen	10.4	"	5.7	"
Coliform Count	100	"	1,100,000	"
Temperature (°F)	41	"	59	"

Source: SEWRPC.

The Bark River apparently is a calcium bicarbonate stream of relatively constant total mineralization. In the two complete chemical analyses run on stream samples collected from the Bark River, the predominant cation was calcium at concentrations of 45 and 47 ppm when sampled in April and September 1964. The predominant anion was bicarbonate at concentrations of 260 and 275 ppm in April and September 1964. Maximum nitrate concentration was 1.3 ppm. No total phosphorus determination was made on water sampled by the SEWRPC from the Bark River during the study. Selected water analyses of the Bark River at station Rk-9 are listed in Table 245. Water quality conditions of the stream are indicated in Table 246.

The chloride concentrations in the Bark River were 5 ppm when sampled in April and September 1964 at sampling station Rk-9. Assuming a "background" chloride concentration of 5 ppm, the chloride impact upon the Bark River was negligible from human sources.

The dissolved solids concentrations were 300 and 255 ppm when sampled in September and in April 1964 at station Rk-9. Assuming a minimum "background" dissolved solids concentration of about 300 ppm, the dissolved solids impact upon the Bark River was also negligible from human sources.

Figure 50

COLIFORM COUNT IN THE OCONOMOWOC RIVER

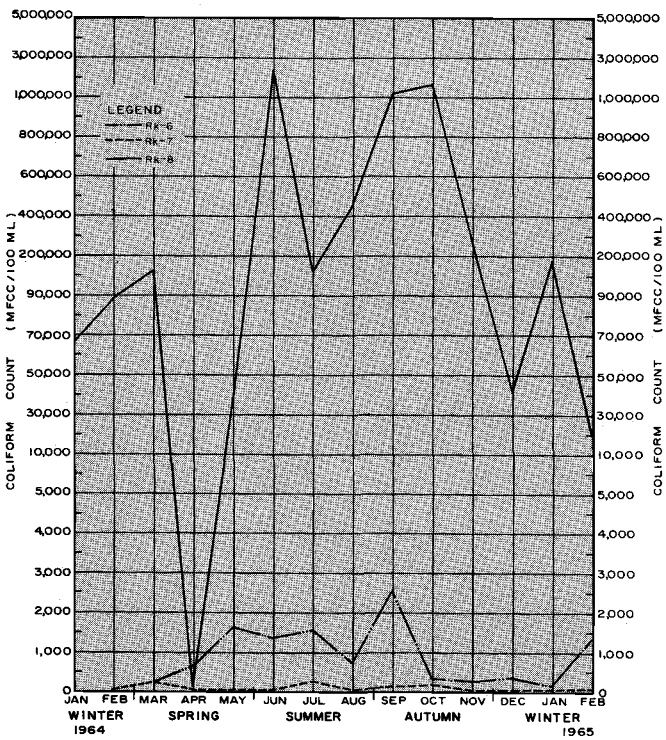


Figure 51

TEMPERATURE OF THE RUBICON RIVER, THE OCONOMOWOC RIVER, AND TURTLE CREEK

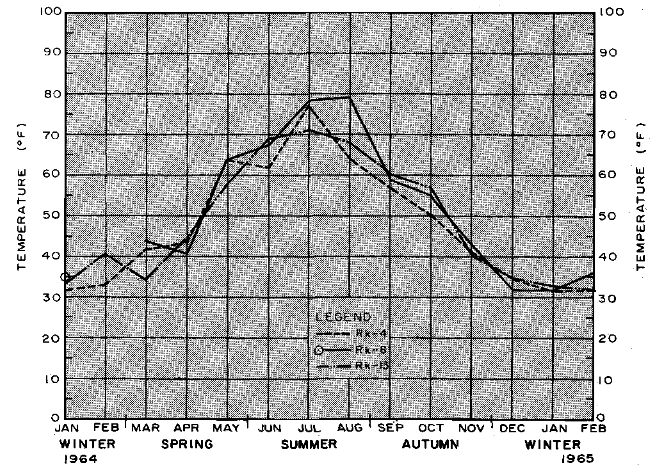


Table 241

WATER QUALITY CONDITIONS OF THE OCONOMOWOC RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	70	15	0	18
Dissolved Solids (ppm)	470	320	240	18
Dissolved Oxygen (ppm)	14.1	10.8	4.6	39
Coliform Count (MFCC/100 ml) .	2,300,000	128,000	100	39
Temperature (°F)	80	51	32	39

Source: SEWRPC.

Table 242

STREAMFLOW MEASUREMENTS OF THE OCONOMOWOC RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Rk-6	4- 4-64	22	0.52
	9-15-64	7.5	0.07
Rk-8	3-12-64	10	0
	4- 4-64	58	0.52
	9-15-64	3.8	0.07

[a] *Measured at U. S. Weather Bureau Station at Oconomowoc, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 243

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE OCONOMOWOC SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
City of Oconomowoc	7,600	20,600	26,100	46,000
	Estimated Average Daily Sewage Flow Rate			
	1,400,000 2.2	3,700,000 5.7	4,700,000 7.3	8,300,000 12.8
	Estimated Low Flow of the Oconomowoc River at Sampling Station Rk-8			
	5.6	8.4	9.6	14.0

Source: SEWRPC.

Table 244

FORECAST QUALITY OF THE OCONOMOWOC RIVER AT SAMPLING STATION RK-8: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Oconomowoc River	Rk-8	Chloride (in ppm)	70[a]	160	170	170
		Dissolved Solids (in ppm)	470[a]	650	700	700
		Dissolved Oxygen (in ppm)	8.0[b]	Less than 5.0		
		Coliform Count (in MFCC/ 100 ml)	1,000,000[b]	More than 1,000,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Table 245

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-9 ON THE BARK RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-2-64	4	9-14-64
Iron	0.05	"	0.07	"
Manganese.	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium.	--	--	--	--
Calcium.	45	4-2-64	47	9-14-64
Magnesium.	35	"	36	"
Sodium (and Potassium) . . .	5	"	15	"
Bicarbonate.	260	"	275	"
Carbonate.	10	"	10	"
Sulfate.	25	"	47	"
Chloride	5	"	5	"
Fluoride	--	--	--	--
Nitrite.	0.0	4-2-64	0.0	9-14-64
Nitrate.	--	--	1.3	"
Phosphorus	--	--	--	--
Cyanide.	--	--	--	--
Oil.	--	--	--	--
Detergents	0.2	4-2-64	0.0	9-14-64
Dissolved Solids	255	"	300	"
Hardness	257	"	264	"
Noncarbonate Hardness. . . .	25	"	20	"
Calcium Hardness	113	"	117	"
Magnesium Hardness	144	"	147	"
Alkalinity P	5	"	5	"
Alkalinity M	225	"	235	"
Specific Conductance	448	"	488	"
pH	8.0	"	7.9	"
Color.	5	"	0	"
Turbidity.	3	"	2	"
Biochemical Oxygen Demand. .	2.3	"	1.9	"
Dissolved Oxygen	10.9	"	10.8	"
Coliform Count	23,000	"	9,000	"
Temperature (^{o}F)	42	"	60	"

Source: SEWRPC.

Table 246

WATER QUALITY CONDITIONS OF THE BARK RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	5	5	5	2
Dissolved Solids (ppm)	300	280	255	2
Dissolved Oxygen (ppm)	13.5	11.2	9.2	12
Coliform Count (MFCC/100 ml) .	100,000	14,700	300	12
Temperature (^{o}F)	76	51	32	12

Source: SEWRPC.

The dissolved oxygen concentrations in the Bark River varied from 13.5 ppm in February 1965 to 9.2 ppm in July 1964 at station Rk-9. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 11.8, 10.3, and 9.2 ppm, respectively.

The coliform counts in the Bark River varied from 100,000 MFCC/100 ml in December to 300 MFCC/100 ml in May 1964 at station Rk-9. The maximum, average, and minimum coliform counts for the period June through September 1964 were 9,000, 3,300, and 800 MFCC/100 ml, respectively.

The maximum temperature of the Bark River was $76^{\circ}F$ in July 1964. The maximum, average, and minimum stream temperatures for the period June through September 1964 were 76°, 69°, and $60^{\circ}F$.

Streamflow and Precipitation: Throughout much of the year, the Bark River is a shallow stream occupying a relatively narrow meandering channel. It flows through three major lakes in the Region. At sampling station Rk-9, the stream had a maximum depth of 1.4 feet and a width of 20 feet when measured under low-flow conditions in September 1964.

The SEWRPC measured the flow of the Bark River under conditions of relatively high and low flow in April and September 1964, as indicated in Table 247. Daily precipitation data for the period January 1964 through February 1965 are listed in Table 237. The lake levels and the flow of the Bark River are regulated by water control structures, and the flow of this stream is not necessarily directly related to rainfall or ice and snowmelt.

Forecast Quality of the Bark River for the Year 1990: Population and land use studies by the SEWRPC indicate that a significant increase in the population of the sub-watershed of the Bark River may be expected in the vicinity of the villages of Hartland and Dousman by the year 1990. The estimated connected populations of these two villages for 1963 were 2,250 and 700 people, respectively. Table 248 lists the expected future population of Dousman by the year 1990, according to each of three regional alternative land use plans. This table also lists the estimated average daily sewage flow rates and the estimated low flow of the Bark River at sampling station Rk-9 under each alternative regional land use plan. The forecast quality of the Bark River at sampling station Rk-9 is indicated in Table 249.

Whitewater Creek

Present Stream Quality: One sampling station, Rk-10, was established by SEWRPC on Whitewater Creek at a point 9 miles downstream from the river source. This stream receives effluent from the sewage treatment plant at the City of Whitewater.

Whitewater Creek apparently is a calcium bicarbonate stream of relatively constant total mineralization. In the two complete chemical analyses run on stream samples collected from Whitewater Creek, the predominant cation was calcium at concentrations of 100 and 42 ppm when sampled in April and September 1964. The predominant anion was bicarbonate at concentrations of 245 and 295 ppm in April and September 1964. Maximum nitrate concentration was 4.4 ppm. No total phosphorus determination was made on water sampled by the SEWRPC from Whitewater Creek during the present study. Selected water analyses of Whitewater Creek at station Rk-10 are listed in Table 250. Water quality conditions of the stream are indicated in Table 251.

Table 247

STREAMFLOW MEASUREMENTS OF THE BARK RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Rk-9	4- 4-64	30	0.52
	9-15-64	6.2	0.07

[a] *Measured at U. S. Weather Bureau Station at Oconomowoc, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 248

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE VILLAGE OF DOUSMAN SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Village of Dousman	700	2,300	2,300	2,300
	Estimated Average Daily Sewage Flow Rate			
	70,000 0.1	280,000 0.4	280,000 0.4	280,000 0.4
	Estimated Low Flow of the Bark River at Sampling Station Rk-9			
	5	5	5	5

Source: SEWRPC.

Table 249

FORECAST QUALITY OF THE BARK RIVER AT SAMPLING STATION RK-9: 1990 ALTERNATIVE LAND USE PLAN

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Bark River	Rk-9	Chloride (in ppm)	5[a]	20	20	20
		Dissolved Solids (in ppm)	300[a]	350	350	350
		Dissolved Oxygen (in ppm)	10.3[b]	More than 8.0		
		Coliform Count (in MFCC/100 ml)	3,300[b]	More than 5,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Table 250

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-10 ON WHITEWATER CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	10	4-9-64	6	9-14-64
Iron	0.05	"	0.06	"
Manganese	--	--	0.01	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	100	4-9-64	42	9-14-64
Magnesium	43	"	35	"
Sodium (and Potassium)	5	"	20	"
Bicarbonate	245	"	295	"
Carbonate	30	"	0	"
Sulfate	155	"	34	"
Chloride	20	"	15	"
Fluoride	--	--	--	--
Nitrite	0.0	4-9-64	0.1	9-14-64
Nitrate	--	--	2.5	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.0	4-9-64	0.2	9-14-64
Dissolved Solids	485	"	300	"
Hardness	428	"	250	"
Noncarbonate Hardness	180	"	10	"
Calcium Hardness	250	"	104	"
Magnesium Hardness	178	"	146	"
Alkalinity P	15	"	0	"
Alkalinity M	230	"	240	"
Specific Conductance	756	"	500	"
pH	8.4	"	8.2	"
Color	40	"	5	"
Turbidity	15	"	15	"
Biochemical Oxygen Demand	6.1	"	4.3	"
Dissolved Oxygen	11.4	"	10.4	"
Coliform Count	42,000	"	140,000	"
Temperature (^{o}F)	48	"	66	"

Source: SEWRPC.

Table 251

WATER QUALITY CONDITIONS OF WHITEWATER CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	20	20	15	2
Dissolved Solids (ppm)	485	395	300	2
Dissolved Oxygen (ppm)	11.4	8.7	5.6	11
Coliform Count (MFCC/100 ml)	1,000,000	196,000	17,000	11
Temperature (^{o}F)	80	56	35	11

Source: SEWRPC.

The chloride concentrations in Whitewater Creek varied from 20 ppm in April to 15 ppm in September 1964 at sampling station Rk-10. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon Whitewater Creek was as much as 10 ppm from human sources.

The dissolved solids concentrations were 485 and 300 ppm when sampled in April and in September 1964 at station Rk-10. Assuming maximum and minimum "background" dissolved solids concentrations of about 460 and 285 ppm, the dissolved solids impact upon Whitewater Creek was at least 15 ppm from human sources.

The dissolved oxygen concentrations of Whitewater Creek varied from 11.4 ppm in April 1965 to 5.6 ppm in June 1964 at station Rk-10. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 11.3, 8.3, and 5.6 ppm, respectively.

The coliform counts in Whitewater Creek varied from 1,000,000 MFCC/100 ml in October to 17,000 MFCC/100 ml in July 1964 at station Rk-10. The maximum, average, and minimum coliform counts for the period June through September 1964 were 140,000, 61,000, and 17,000 MFCC/100 ml, respectively.

The maximum temperature of Whitewater Creek was 80°F in July 1964. The maximum, average, and minimum stream temperatures for the period June through September 1964 were 80°, 73°, and 66°F.

Streamflow and Precipitation: Throughout much of the year, Whitewater Creek is a shallow stream occupying a relatively narrow meandering channel. It flows through two major lakes in the Region. At sampling station Rk-10, the stream had a maximum depth of 1.3 feet and a width of 39 feet when measured under low-flow conditions in September 1964.

The SEWRPC measured the flow of Whitewater Creek under conditions of relatively high and low flow in April and September 1964, as indicated in Table 252. Daily precipitation data for the period January 1964 through February 1965 are listed in Table 237. The lake levels and the flow of Whitewater Creek are regulated by water control structures, and the flow of this stream is not necessarily directly related to rainfall or ice and snowmelt.

Forecast Quality of Whitewater Creek for the Year 1990: Population and land use studies by the SEWRPC indicate that a significant increase in the population of the sub-watershed of Whitewater Creek may be expected in the vicinity of the City of Whitewater by the year 1990. The estimated connected population of this city for 1963 was 6,700. Table 253 lists the expected future population of Whitewater by the year 1990, according to each of three SEWRPC alternative regional land use plans. This table also lists the estimated average daily sewage flow rates and the estimated low flow of Whitewater Creek at sampling station Rk-10 under each alternative regional land use plan. The forecast quality of Whitewater Creek at sampling station Rk-10 is indicated in Table 254.

Jackson Creek

Present Stream Quality: One sampling station, Rk-11, was established by the SEWRPC on Jackson Creek at a distance 1.4 miles downstream from the source. Jackson Creek receives the effluent from the City of Elkhorn sewage treatment plant.

Table 252

STREAMFLOW MEASUREMENTS OF WHITEWATER CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Rk-10	4-25-64 9-17-64	30 19	0.47 0.12

[a] *Measured at U. S. Weather Bureau Station at Oconomowoc, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 253

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE CITY OF WHITEWATER SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
City of Whitewater	6,700	12,800	15,600	25,800
	Estimated Average Daily Sewage Flow Rate			
	1,200,000 1.9	2,300,000 3.6	2,800,000 4.3	4,600,000 7.1
	Estimated Low Flow of Whitewater Creek at Sampling Station Rk-10			
	<19	<20	<21	<23

Source: SEWRPC.

Table 254

FORECAST QUALITY OF WHITEWATER CREEK AT SAMPLING STATION RK-10: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Whitewater Creek	Rk-10	Chloride (in ppm)	15[a]	20	30	40
		Dissolved Solids (in ppm)	300[a]	300	350	350
		Dissolved Oxygen (in ppm)	8.3[b]	More than 5.0	Less than 5.0	
		Coliform Count (in MFCC/ 100 ml)	61,000[b]	More than 100,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Figure 52

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK

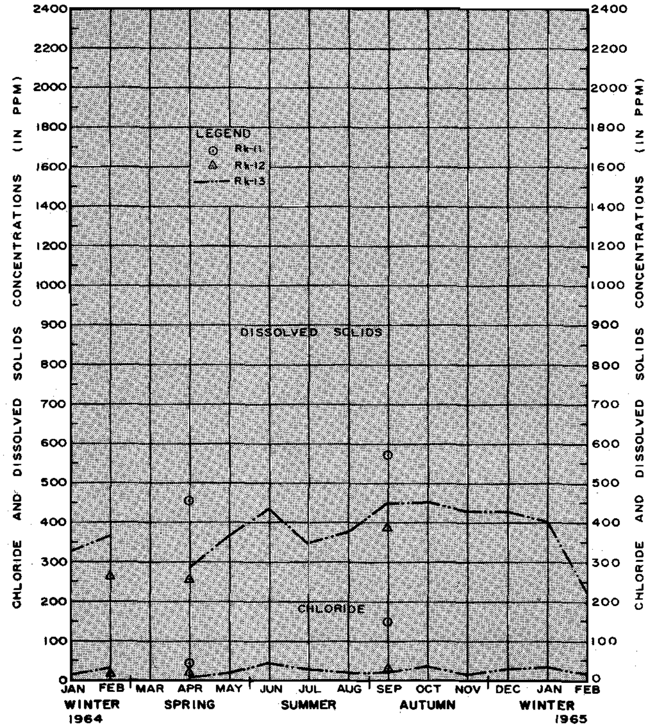
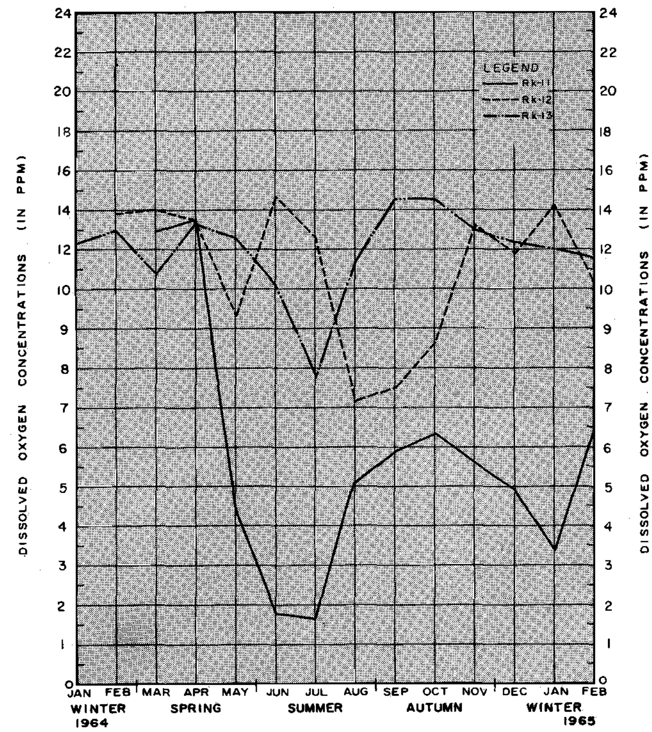


Figure 53

DISSOLVED OXYGEN CONCENTRATIONS IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK



Jackson Creek apparently has a relatively constant total mineralization. In the two complete chemical analyses run on samples collected from the stream, calcium and sodium were predominant cations. Calcium was predominant in one analysis at a concentration of 86 ppm at station Rk-11 in April 1964. Sodium was the predominant cation in one sample at a concentration of 115 ppm in September 1964 at station Rk-11. Bicarbonate was the predominant anion in the two complete chemical analyses at concentrations of 295 ppm in September and 280 ppm in April 1964 at station Rk-11. Maximum nitrate concentration was 16.9 ppm. No total phosphorus determination was made on water samples from Jackson Creek during the present study. Selected water analyses at station Rk-11 are listed in Table 255. Water quality conditions of the river are indicated in Table 256.

The chloride concentrations in Jackson Creek were 150 ppm in September and 45 ppm in April 1964 at sampling station Rk-11. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon Jackson Creek was as much as 140 ppm from human sources. Figure 52 shows the chloride and dissolved solids concentrations in Jackson Creek at sampling station Rk-11.

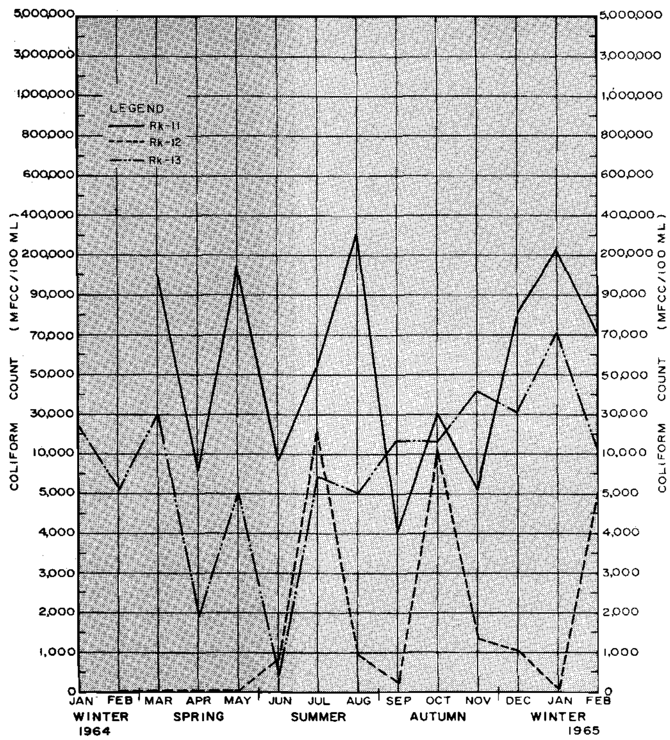
The dissolved solids concentrations in Jackson Creek were 570 ppm in September and 455 ppm in April 1964 at station Rk-11. Assuming a "background" dissolved solids concentration of 330 ppm, the dissolved solids impact upon Jackson Creek was as much as 240 ppm from human sources.

The dissolved oxygen concentrations in Jackson Creek varied from 13.5 ppm in April to 1.6 ppm in July 1964 at station Rk-11. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 5.9, 3.6, and 1.6 ppm, respectively, at station Rk-11. Figure 53 indicates the dissolved oxygen concentrations in Jackson Creek at sampling station Rk-11.

The coliform counts in Jackson Creek varied from 300,000 MFCC/100 ml in August to 4,000 MFCC/100 ml in September 1964 at station Rk-11. The maximum, average, and minimum coliform counts for the period June through September 1964 were 300,000, 92,000, and 4,000 MFCC/100 ml, respectively. Figure 54 indicates the coliform counts in Jackson Creek at sampling station Rk-11.

Figure 54

COLIFORM COUNT IN JACKSON CREEK, DELAVAN LAKE OUTLET, AND TURTLE CREEK



The maximum temperature of Jackson Creek was 74°F at sampling station Rk-11. The maximum, average, and minimum temperatures for the period June through September 1964 were 74°, 67°, and 59°F, respectively.

Streamflow and Precipitation: Throughout much of the year, Jackson Creek is a relatively shallow stream occupying a narrow meandering channel. At sampling station Rk-11, which is located near the point where the stream enters Delavan Lake, Jackson Creek had a maximum depth of 4 feet and a width of 38 feet when surveyed in February 1964.

No measurements were made by the SEWRPC of the flow of Jackson Creek during the study. The stream is sluggish and during periods of low flow may discharge less than 2 cfs, of which about 1/2 cfs is effluent from the City of Elkhorn sewage treatment plant.

Forecast Quality of Jackson Creek for the Year 1990: SEWRPC population studies indicate that the City of Elkhorn had a connected population of approximately 4,000 persons in 1963. SEWRPC population forecasts for the City of Elkhorn under the three regional alternative land use plans are indicated in Table 257, together with the estimated average daily sewage flow rates. It should be noted that the low flow figures indicated at station Rk-11 are estimated figures and are not based on direct field measurements. The forecast quality of Jackson Creek at station Rk-11 is indicated in Table 258.

Delavan Lake Outlet

Present Stream Quality: One sampling station Rk-12 was established by the SEWRPC on the Delavan Lake Outlet at a distance 2.3 miles downstream from the point where Delavan Lake discharges into the outlet stream. Little urban development has occurred along the outlet between Delavan Lake and station Rk-12, and no sewage treatment plants or industries discharge wastes upstream from station Rk-12.

The Delavan Lake Outlet apparently is a calcium bicarbonate stream of relatively constant total mineralization. In the three complete chemical analyses run on samples collected from the stream, calcium was

Table 255

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-11 ON JACKSON CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-9-64	6	9-16-64
Iron	0.04	"	0.09	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	86	4-9-64	52	9-16-64
Magnesium	39	"	33	"
Sodium (and Potassium)	25	"	115	"
Bicarbonate	280	"	295	"
Carbonate	40	"	5	"
Sulfate	72	"	44	"
Chloride	45	"	150	"
Fluoride	--	--	--	--
Nitrite	0.0	4-9-64	0.2	9-16-64
Nitrate	--	--	16.9	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.1	4-9-64	0.8	9-16-64
Dissolved Solids	455	"	570	"
Hardness	377	"	269	"
Noncarbonate Hardness	80	"	20	"
Calcium Hardness	216	"	131	"
Magnesium Hardness	161	"	138	"
Alkalinity P	20	"	2.5	"
Alkalinity M	270	"	245	"
Specific Conductance	696	"	1,010	"
pH	8.8	"	7.6	"
Color	15	"	20	"
Turbidity	5	"	4	"
Biochemical Oxygen Demand	5.6	"	3.2	"
Dissolved Oxygen	13.5	"	5.9	"
Coliform Count	8,000	"	4,000	"
Temperature (°F)	45	"	59	"

Source: SEWRPC.

Table 256

WATER QUALITY CONDITIONS OF JACKSON CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	150	95	45	2
Dissolved Solids (ppm)	570	510	455	2
Dissolved Oxygen (ppm)	13.5	6.0	1.6	12
Coliform Count (MFCC/100 ml)	300,000	86,000	4,000	12
Temperature (°F)	74	50	32	12

Source: SEWRPC.

Table 257

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE ELKHORN SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
City of Elkhorn	4,000	10,000	16,100	16,200
	Estimated Average Daily Sewage Flow Rate			
	480,000[a] 0.7[b]	1,800,000 2.8	2,900,000 4.5	2,900,000 4.5
	Estimated Low Flow of Jackson Creek at Sampling Station Rk-11			
	Approx. 1[b]	Approx. 3	Approx. 5	Approx. 5

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

Table 258

FORECAST QUALITY OF JACKSON CREEK AT SAMPLING STATION RK-11: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Jackson Creek	Rk-11	Chloride (in ppm)	150[a]	170	170	170
		Dissolved Solids (in ppm)	570[a]	600	600	600
		Dissolved Oxygen (in ppm)	3.6[b]	Critical concentration of less than 2.0 can be frequently expected.		
		Coliform Count (in MFCC/ 100 ml)	92,000[b]	Approximately 100,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

the predominant cation at concentrations ranging from 57 to 34 ppm at station Rk-12 in September and April 1964. Calcium and magnesium were equal in concentration at 34 ppm in February 1964 at station Rk-12. Bicarbonate was the predominant anion at concentrations ranging from 295 ppm in September to 245 ppm in February 1964 at station Rk-12. Maximum nitrate concentration was 1.9 ppm. No total phosphorus determination was made on water samples from the Delavan Lake Outlet during the present study. Selected water analyses at station Rk-12 are listed in Table 259. Water quality conditions of the river are indicated in Table 260.

The chloride concentrations in the Delavan Lake Outlet were 30 ppm in September and 20 ppm in February and April 1964 at sampling station Rk-12. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon this stream was as much as 20 ppm from human sources. Figure 52 shows the chloride and dissolved solids concentrations in the Delavan Lake Outlet at sampling station Rk-12.

The dissolved solids concentrations in the Delavan Lake Outlet were 385 ppm in September and 255 ppm in April 1964 at station Rk-12. Assuming a "background" dissolved solids concentration of 350 ppm, the dissolved solids impact upon the Delavan Lake Outlet was no more than 35 ppm from human sources.

Table 259

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-12 ON DELAVAN LAKE OUTLET: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	2	4-9-64	2	9-16-64
Iron	0.02	"	0.06	"
Manganese	--	--	0.01	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	47	4-9-64	57	9-16-64
Magnesium	27	"	38	"
Sodium (and Potassium)	15	"	35	"
Bicarbonate	255	"	295	"
Carbonate	0	"	30	"
Sulfate	19	"	46	"
Chloride	20	"	30	"
Fluoride	--	--	--	--
Nitrite	0.0	4-9-64	0.1	9-16-64
Nitrate	--	--	1.9	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.1	4-9-64	0.1	9-16-64
Dissolved Solids	255	"	385	"
Hardness	226	"	300	"
Noncarbonate Hardness	15	"	10	"
Calcium Hardness	116	"	142	"
Magnesium Hardness	110	"	158	"
Alkalinity P	0	"	15	"
Alkalinity M	210	"	270	"
Specific Conductance	440	"	580	"
pH	8.1	"	7.6	"
Color	10	"	20	"
Turbidity	4	"	10	"
Biochemical Oxygen Demand	4.4	"	2.1	"
Dissolved Oxygen	13.4	"	7.5	"
Coliform Count	<100	"	200	"
Temperature (°F)	43	"	59	"

Source: SEWRPC.

The dissolved oxygen concentrations in the Delavan Lake Outlet varied from 14.7 ppm in June to 7.2 ppm in August 1964 at station Rk-12. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 14.7, 10.5, and 7.2 ppm, respectively. Figure 52 indicates the dissolved solids concentrations in the Delavan Lake Outlet at sampling station Rk-12.

The coliform counts in the Delavan Lake Outlet varied from 21,000 MFCC/100 ml in July to less than 100 MFCC/100 ml in February, March, April, and May 1964 at station Rk-12. The maximum, average, and minimum coliform counts for the period June through September 1964 were 21,000, 5,700, and 800 MFCC/100 ml, respectively. Figure 54 indicates the coliform counts in the Delavan Lake Outlet at sampling station Rk-12.

The maximum temperature of the Delavan Lake Outlet was 75°F at sampling station Rk-12. The maximum, average, and minimum temperatures for the period June through September 1964 were 75°, 66°, and 59°F, respectively.

Streamflow and Precipitation: Throughout much of the year, the Delavan Lake Outlet is a relatively shallow stream occupying a narrow channel. At sampling station Rk-12, the Delavan Lake Outlet had a maximum depth of 1 foot and a width of 21.5 feet when measured in September 1964 under low-flow conditions.

The SEWRPC measured the flow of the Delavan Lake Outlet in April and September 1964 during periods of relatively high and low flow. Table 261 lists the flow determinations at sampling station Rk-12. The daily precipitation recorded at the U. S. Weather Bureau Station at Fontana, Wisconsin, for the period of January 1964 through February 1965 is listed in Table 262.

Forecast Quality of the Delavan Lake Outlet for the Year 1990: The quality of the Delavan Lake Outlet at sampling station Rk-12 is dependent almost exclusively upon the quality of Delavan Lake at and near the outlet channel. The quality of Delavan Lake may be expected to deteriorate markedly under the impact of increasing pollution from Jackson Creek and from lakeside dwellings. Forecast quality of Delavan Lake Outlet at station Rk-12 is indicated in Table 263.

Turtle Creek

Present Stream Quality: One sampling station, Rk-13, was established by the SEWRPC on Turtle Creek at a point 13.4 miles downstream from the source. This stream receives the effluent from the City of Delavan sewage treatment plant.

Turtle Creek is a calcium bicarbonate stream of relatively constant total mineralization. In the 13 complete chemical analyses run on stream samples collected from Turtle Creek, the predominant cation was calcium at concentrations ranging from 74 ppm in December 1964 to 33 ppm in February 1965 at station Rk-13. The predominant anion was bicarbonate at concentrations of 365 ppm in June 1964 to 185 ppm in February 1965 at station Rk-13. Maximum nitrate concentration was 3.4 ppm. Total phosphorus con-

Table 260

WATER QUALITY CONDITIONS OF DELAVAN LAKE OUTLET (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	30	25	20	3
Dissolved Solids (ppm)	385	300	255	3
Dissolved Oxygen (ppm)	14.2	11.6	7.2	13
Coliform Count (MFCC/100 ml) .	21,000	3,200	100	13
Temperature (°F)	75	48	32	13

Source: SEWRPC.

Table 261

STREAMFLOW MEASUREMENTS OF THE DELAVAN LAKE OUTLET: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Rk-12	4-26-64 9-18-64	17 0	0 0

[a] *Measured at U. S. Weather Bureau Station at Fontana, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 262

PRECIPITATION[a] AT FONTANA, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	--	--	--	--	0.15	--	0.03	--	--	--	--	--	--	0.13
2	--	--	--	--	0.30	--	--	--	--	--	0.31	0.13	0.35	--
3	--	--	--	1.22	--	--	--	--	--	--	0.18	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	0.24	--	--
5	--	--	0.90	0.71	--	--	--	--	--	--	--	0.02	--	--
6	--	--	0.41	0.37	--	--	--	--	--	--	--	--	--	--
7	--	--	0.22	--	--	--	0.37	--	--	--	--	0.01	--	--
8	--	--	--	0.23	0.59	--	--	--	--	0.27	--	--	0.08	--
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	0.48	--	--	--	--	--	--
11	--	--	--	--	--	--	--	0.11	--	--	--	0.03	--	--
12	--	--	--	--	--	0.15	--	--	--	--	--	--	--	0.03
13	--	0.33	--	--	0.41	--	0.08	--	--	--	--	0.07	--	--
14	--	--	--	--	--	--	0.25	--	--	--	--	--	--	--
15	--	0.05	--	--	--	1.23	--	--	--	--	1.00	--	0.13	--
16	--	--	--	--	0.55	--	--	--	--	--	--	--	--	--
17	--	--	0.10	--	--	0.07	--	--	--	--	--	--	0.17	--
18	--	--	--	0.12	--	--	1.34	--	0.28	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	0.09	--	0.43	0.32	--	0.04	--	--	--	--	0.20[b]	--	--	--
21	--	--	--	0.63	--	0.06	--	1.28	0.59	--	--	--	--	--
22	--	--	--	--	--	1.47	--	0.12	--	--	--	--	0.22	--
23	--	--	--	--	--	--	--	--	0.62	--	--	--	0.51	0.05
24	1.16	--	0.07	--	--	--	--	--	--	--	--	--	0.31	0.25
25	--	--	--	--	--	--	0.60	0.05	--	--	--	--	--	--
26	--	--	--	--	0.78	--	--	--	0.63	--	--	0.03	0.17	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28	--	--	--	0.27	--	--	0.57	--	--	--	1.12	--	--	--
29	--	--	0.05[b]	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	0.22	--	--	--	0.15	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	1.25	0.38	2.18[b]	4.09	2.78	3.02	3.24	2.19	2.12	0.27	2.81[b]	0.53+	1.94	0.46

[a] *Precipitation measured in inches. Trace quantities not included.*

[b] *Water equivalent of snowfall wholly or partly estimated using a ratio of 1 inch water equivalent to every 10 inches of new snowfall.*

Source: U. S. Weather Bureau.

centration at station Rk-13 was 0.64 ppm on September 16, 1964. Selected water analyses of Turtle Creek at station Rk-13 are listed in Table 264. Water quality conditions of the stream are indicated in Table 265.

The chloride concentrations in Turtle Creek varied from 45 ppm in June to 15 ppm in January and April 1964 at sampling station Rk-13. Assuming a "background" chloride concentration of 10 ppm, the chloride impact upon Turtle Creek was as much as 35 ppm from human sources. Figure 52 indicates the chloride and dissolved solids concentrations in Turtle Creek at sampling station Rk-13.

The dissolved solids concentrations in Turtle Creek varied from 450 ppm in October to 220 ppm in February 1965 at station Rk-13. Assuming a "background" concentration of 390 ppm, the maximum dissolved solids impact upon Turtle Creek was about 60 ppm from human sources.

Table 263

FORECAST QUALITY OF DELAVAN LAKE OUTLET AT SAMPLING STATION RK-12: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Delavan Lake Outlet	Rk-12	Chloride (in ppm)	30	50	70	70
		Dissolved Solids (in ppm)	385	450	450	450
		Dissolved Oxygen (in ppm)	10.5	Widely varying concentrations possibly ranging from less than 3.0 to more than 5.0		
		Coliform Count (in MFCC/ 100 ml)	5,700	Approximately 6,000		

Source: SEWRPC.

The dissolved oxygen concentrations in Turtle Creek varied from 14.6 ppm in September and October 1964 to 7.8 ppm in July 1964 at station Rk-13. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 were 14.6, 11.0, and 7.8 ppm, respectively. Figure 53 indicates the dissolved oxygen concentrations in Turtle Creek at sampling station Rk-13.

The coliform counts in Turtle Creek varied from 70,000 MFCC/100 ml in January 1965 to 400 MFCC/100 ml in June 1964 at station Rk-13. The maximum, average, and minimum coliform counts for the period June through September 1964 were 16,000, 7,100, and 400 MFCC/100 ml. Figure 46 indicates the coliform counts in Turtle Creek at sampling station Rk-13.

The maximum temperature of Turtle Creek was 71°F in July 1964. The maximum, average, and minimum temperature for the period June through September 1964 were 71°, 67°, and 60°F, respectively.

Streamflow and Precipitation: Throughout much of the year, Turtle Creek is a relatively shallow stream occupying a narrow meandering channel. At sampling station Rk-13, Turtle Creek had a maximum depth of 1.2 feet and a width of 50 feet when measured in September 1964 under low-flow conditions.

The SEWRPC measured the flow of Turtle Creek in April and September 1964 during periods of relatively high and low flow. Table 266 lists the flow determinations at sampling station Rk-13. The daily precipitation recorded at the U. S. Weather Bureau Station at Fontana, Wisconsin, for the period January 1964 through February 1965 is listed in Table 262.

Forecast Quality of Turtle Creek for the Year 1990: SEWRPC population studies indicate that the City of Delavan had a connected population of approximately 5,200 persons in 1963. SEWRPC population forecasts

Table 264

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RK-13 ON TURTLE CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-9-64	12	9-16-64
Iron	0.03	"	0.05	"
Manganese	--	--	0.00	"
Chromium	--	--	< 0.02	"
Hexavalent Chromium	--	--	0.00	"
Calcium	59	4-9-64	68	"
Magnesium	26	"	40	"
Sodium (and Potassium)	10	"	45	"
Bicarbonate	205	"	330	"
Carbonate	30	"	40	"
Sulfate	38	"	43	"
Chloride	15	"	35	"
Fluoride	--	--	< 0.4	"
Nitrite	0.0	4-9-64	0.2	"
Nitrate	--	--	3.4	"
Phosphorus	--	--	0.64	"
Cyanide	--	--	< 0.01	11-19-64
Oil	--	--	< 1	9-16-64
Detergents	0.1	4-9-64	0.2	"
Dissolved Solids	285	"	445	"
Hardness	253	"	334	"
Noncarbonate Hardness	35	"	0	"
Calcium Hardness	147	"	170	"
Magnesium Hardness	106	"	164	"
Alkalinity P	15	"	20	"
Alkalinity M	200	"	310	"
Specific Conductance	472	"	656	"
pH	8.4	"	8.0	"
Color	30	"	5	"
Turbidity	10	"	2	"
Biochemical Oxygen Demand	5.1	"	2.6	"
Dissolved Oxygen	13.3	"	14.6	"
Coliform Count	1,900	"	16,000	"
Temperature (°F)	45	"	60	"

Source: SEWRPC.

Table 265

WATER QUALITY CONDITIONS OF TURTLE CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	45	25	15	13
Dissolved Solids (ppm)	450	375	220	13
Dissolved Oxygen (ppm)	14.6	12.1	7.8	14
Coliform Count (MFCC/100 ml)	70,000	18,800	400	14
Temperature (°F)	71	48	32	14

Source: SEWRPC.

for the City of Delavan under three regional alternative land use plans are indicated in Table 267, together with the estimated average daily sewage flow rates and the estimated low flow of Turtle Creek. The forecast quality of Turtle Creek at sampling station Rk-13 for the year 1990 is indicated in Table 268.

Table 266

STREAMFLOW MEASUREMENTS OF TURTLE CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Rk-13	4-26-64 9-18-64	45 10	0 0

[a] *Measured at U. S. Weather Bureau Station at Fontana, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 267

ESTIMATED CONNECTED POPULATION AND AVERAGE DAILY SEWAGE FLOW RATES FOR THE DELAVAN SEWAGE TREATMENT PLANT: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location of Sewage Treatment Plant	Estimated Connected Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
City of Delavan	5,200	10,200	15,200	15,200
	Estimated Average Daily Sewage Flow Rate			
	940,000[a] 1.4[b]	1,800,000 2.8	2,700,000 4.2	2,700,000 4.2
	Estimated Low Flow of Turtle Creek at Sampling Station Rk-13			
	1[b]	2	4	4

[a] *Gallons per day.*

[b] *Cubic feet per second.*

Source: SEWRPC.

ROOT RIVER WATERSHED

The Root River watershed ranks sixth in population and fourth in size as compared to the other 11 watersheds of the Region. An estimated 134,200[11] persons reside in this watershed, which has a total area of 197.9 square miles and an average population density of 678 people per square mile. The principal land use is agriculture, which comprises 66.2 percent of the watershed. The areas within the watershed devoted to each of eight major land use categories are listed in Table 269.

Two streams were studied by the SEWRPC in the Root River watershed: the Root River proper and the Root River Canal. The Root River rises in the City of West Allis near Greenfield Park and flows 42.2 miles south, east, and southeasterly to Lake Michigan at the City of Racine. The Root River Canal originates at the confluence of the East and West Branches of the Root River Canal and flows 5.5 miles northward to where it joins the Root River.

The Root River watershed is largely developed upon a glacial terrane comprising a series of broad end moraines that parallel Lake Michigan and upon ground moraine formed by the Lake Michigan glacier. In

[11] *Based on SEWRPC estimate for 1963.*

Table 268

FORECAST QUALITY OF TURTLE CREEK AT SAMPLING STATION RK-13: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Turtle Creek	Rk-13	Chloride (in ppm)	35[a]	60	80	80
		Dissolved Solids (in ppm)	445[a]	500	500	500
		Dissolved Oxygen (in ppm)	11.0[b]	More than 8.0		
		Coliform Count (in MFCC/ 100 ml)	7,000[b]	Approximately 10,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for period June through September 1964.*

Source: SEWRPC.

Table 269

EXISTING LAND USE IN THE ROOT RIVER WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agriculture	131.1	83,890	66.3
Woodland, Wetland, and Unused Land.	22.2	14,212	11.2
Residential	20.2	12,945	10.2
Transportation-Communication. . . .	14.9	9,512	7.5
Park and Recreational	5.1	3,265	2.6
Governmental-Institutional.	1.8	1,164	0.9
Industrial.	1.7	1,069	0.8
Commercial.	0.9	584	0.5
Total	197.9	126,641	100.0

Source: SEWRPC.

Table 270

DISTANCES OF SELECTED POINTS OF REFERENCE ON THE ROOT RIVER FROM THE RIVER SOURCE AND BETWEEN CONSECUTIVE POINTS OF REFERENCE

Point of Reference	Distance from River Source (in miles)	Distance between Points of Reference (in miles)
River Source	---	---
Rt-1	4.6	4.6
Hales Corners Tributary. . . .	5.9	1.3
Greendale STPO[a].	7.6	1.7
Franklin Creek	11.3	3.7
House of Correction STPO . . .	13.2	1.9
Rt-2	13.6	0.4
Root River Canal	15.8	2.2
Rt-4	17.6	1.8
Franksville Tributary.	22.2	4.6
Caddy Vista STPO	23.4	1.2
Rt-5	24.0	0.6
Hoods Creek.	30.3	6.3
Rt-6	36.1	5.8
Lake Michigan.	42.2	6.1

[a] *STPO - Sewage treatment plant outfall.*

Source: SEWRPC.

a narrow belt adjacent to Lake Michigan, the Root River cuts through sands and gravels deposited along the shores of glacial Lake Chicago. Marsh deposits occur at many locations in the intermorainal valleys.

Root River

Present Stream Quality: Five sampling stations, Rt-1, Rt-2, Rt-4, Rt-5, and Rt-6, were established by the SEWRPC on the Root River. Significant points of reference on the Root River are listed in Table 270 in terms of their distances downstream from the river source and the distances between consecutive points of reference.

The Root River is predominantly a calcium bicarbonate stream that is subject to small changes in total mineralization. In the 37 complete chemical analyses of stream samples collected from the Root River, calcium or sodium were the predominant cations. Calcium was the predominant cation in 20 analyses at concentrations ranging from 136 ppm in August 1964 at station Rt-1 to 71 ppm in January 1965 at station Rt-6. Sodium occurred as the predominant cation in 16 samples at concentrations ranging from 175 ppm in February 1964 at station Rt-6 to 55 ppm in July 1964 at station Rt-1. In December 1964 at station Rt-4, the calcium and sodium concentrations were equal at 100 ppm. Bicarbonate and sulfate were the predominant anions. Bicarbonate was the predominant anion in 34 analyses at concentrations ranging from 435 ppm in August and September 1964 at stations Rt-1 and Rt-2, respectively, to 195 ppm in January 1964 at station Rt-6. Sulfate was predominant in three analyses at concentrations ranging from 282 to 224 ppm in April 1964 at stations Rt-4, Rt-5, and Rt-6. Maximum nitrate concentration was 14.4 ppm. Total phosphorus was 1.3 ppm on September 11, 1964, at station Rt-5 (the only station on the Root River at which a sample was collected for total phosphorus determination). Selected water analyses of the Root River at stations Rt-1, Rt-4, and Rt-6 are listed in Tables 271, 272, and 273. Water quality conditions of the river are indicated in Table 274.

The chloride concentrations of the Root River varied from 240 ppm in February and March 1964 at stations Rt-2 and Rt-1, respectively, to 30 ppm in April 1964 at station Rt-1. Assuming a "background" chloride concentration of 10 ppm, the Root River has a chloride impact of 20 to 230 ppm from human sources. The variations in the chloride concentration are shown by a series of 14 interpretive stream quality graphs in

Table 271

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION Rt-1 ON THE ROOT RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-8-64	4	9-11-64
Iron	0.07	"	0.16	"
Manganese.	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium.	--	--	--	--
Calcium.	107	4-8-64	82	9-11-64
Magnesium.	51	"	52	"
Sodium (and Potassium) . . .	0	"	80	"
Bicarbonate.	255	"	365	"
Carbonate.	10	"	0	"
Sulfate.	155	"	168	"
Chloride	30	"	85	"
Fluoride	--	--	--	--
Nitrite.	0.0	4-8-64	0.0	9-11-64
Nitrate.	--	--	1.3	"
Phosphorus	--	--	--	--
Cyanide.	--	--	--	--
Oil.	--	--	--	--
Detergents	0.1	4-8-64	0.0	9-11-64
Dissolved Solids	485	"	650	"
Hardness	476	"	419	"
Noncarbonate Hardness. . . .	250	"	120	"
Calcium Hardness	267	"	204	"
Magnesium Hardness	209	"	215	"
Alkalinity P	5	"	0	"
Alkalinity M	220	"	300	"
Specific Conductance	930	"	960	"
pH	8.4	"	7.6	"
Color.	30	"	20	"
Turbidity.	20	"	25	"
Biochemical Oxygen Demand. .	2.9	"	3.7	"
Dissolved Oxygen	10.4	"	4.4	"
Coliform Count	20,000	"	3,000	"
Temperature (^{o}F)	38	"	63	"

Source: SEWRPC.

Figure 55. The chloride concentrations of the Root River were relatively high throughout the 14-month period of field study and throughout the 32-mile reach studied by the SEWRPC.

The dissolved solids concentrations of the Root River varied from 955 ppm in February 1964 at station Rt-6 to 390 ppm in July 1964 at station Rt-1. The assumed "background" dissolved solids concentration is 540 ppm. The principal ions that contributed to the highest concentration were chloride, sodium, sulfate, and bicarbonate. The variations in the dissolved solids concentrations are shown by a series of 14 interpretive stream quality graphs in Figure 56. The dissolved solids concentrations of the Root River were relatively high throughout the 14-month period of field study and throughout the 32-mile reach studied by the SEWRPC.

The dissolved oxygen concentrations of the Root River varied from 14.6 ppm in March 1964 at station Rt-6 to 0 ppm in February 1964 at station Rt-5. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 at stations Rt-1, Rt-5, and Rt-6 were 6.2, 5.4, and 4.4 ppm; 14.1, 9.7, and 6.3 ppm; and 8.1, 7.9, and 7.5 ppm, respectively. Variations in the dissolved

Figure 55

CHLORIDE CONCENTRATION IN THE ROOT RIVER

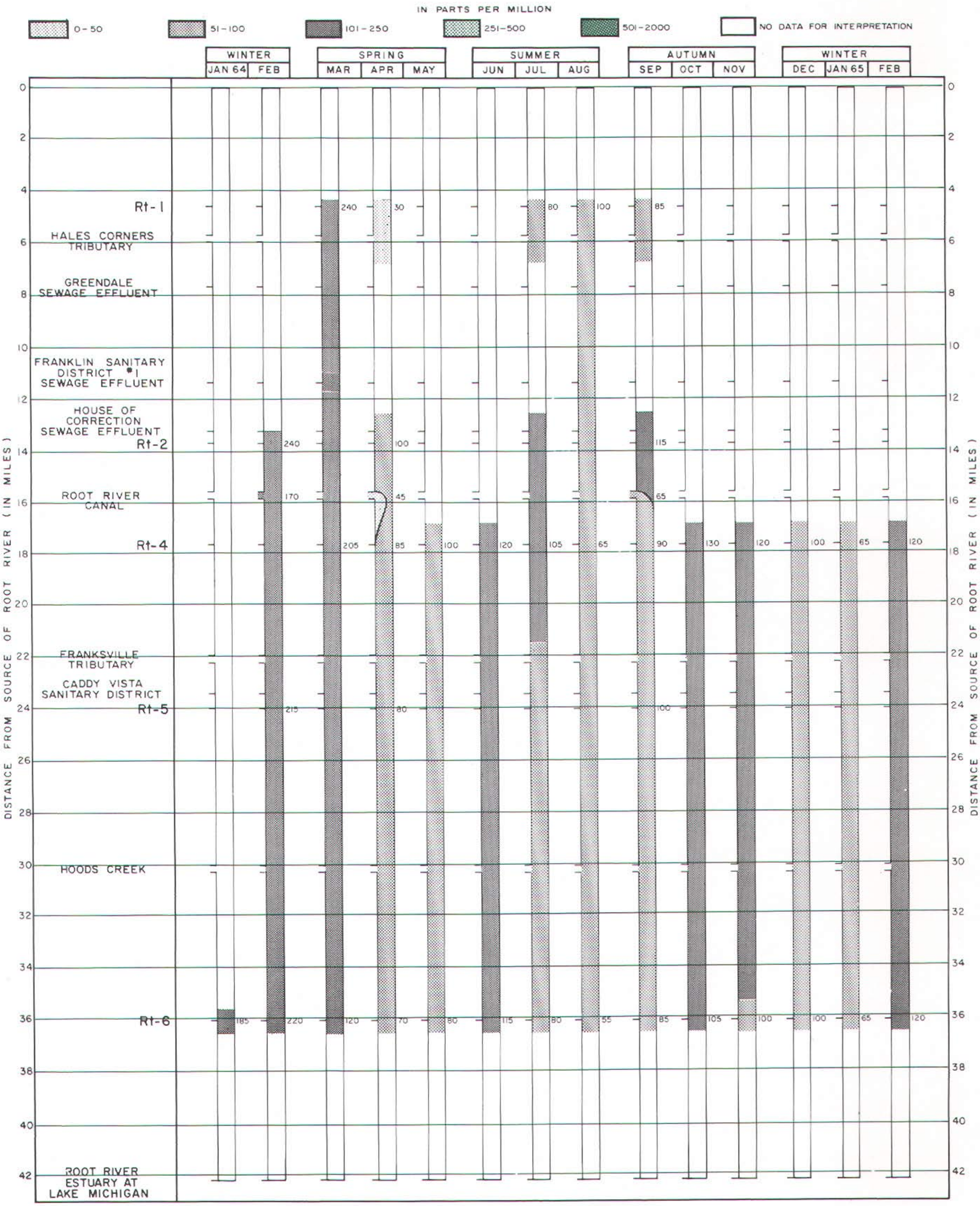


Figure 56

DISSOLVED SOLIDS CONCENTRATION IN THE ROOT RIVER

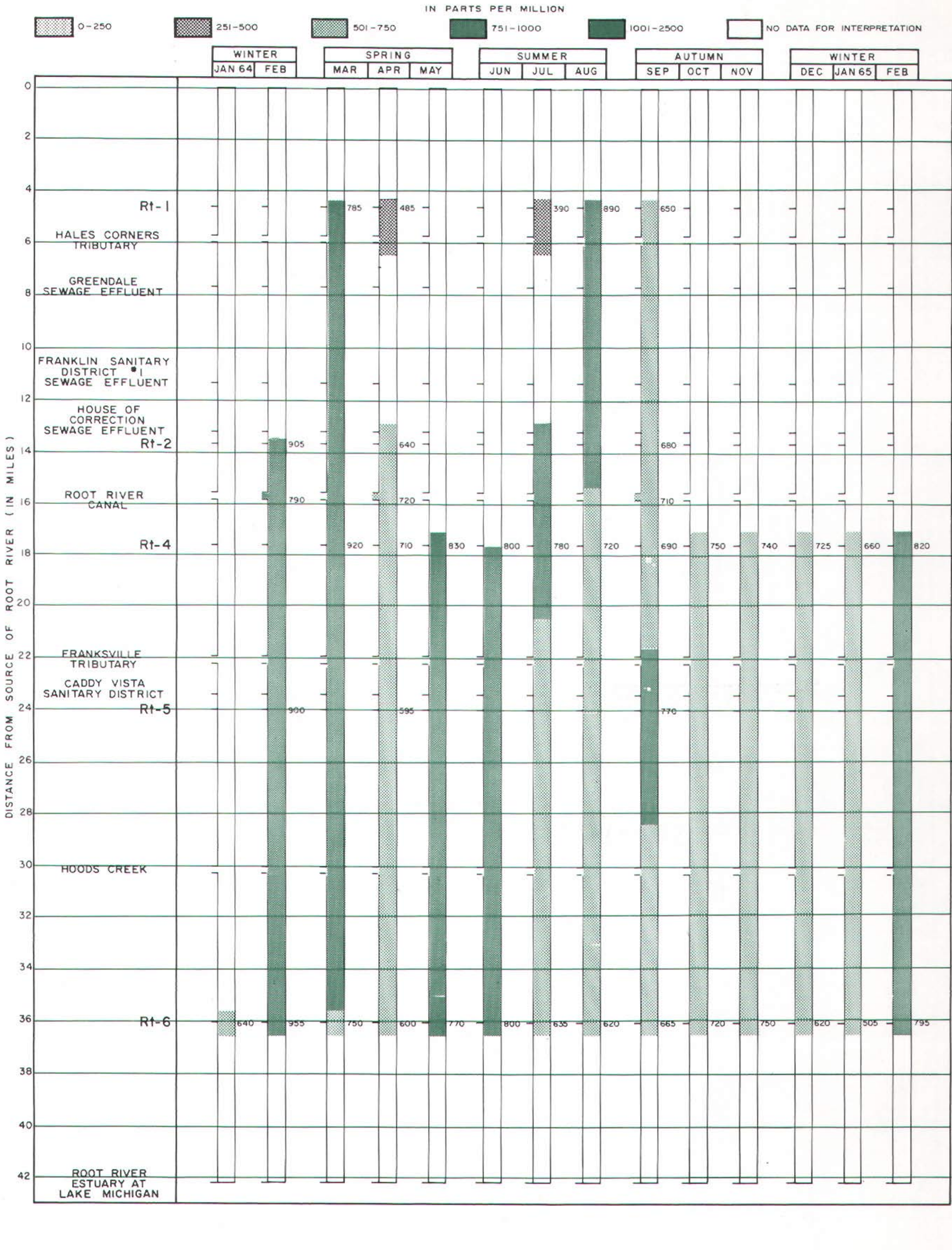


Table 272

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION Rt-4 ON THE ROOT RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-8-64	2	9-11-64
Iron	0.04	"	0.24	"
Manganese	--	--	0.04	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	97	4-8-64	92	9-11-64
Magnesium	47	"	45	"
Sodium (and Potassium)	80	"	100	"
Bicarbonate	195	"	330	"
Carbonate	20	"	30	"
Sulfate	282	"	168	"
Chloride	85	"	90	"
Floride	--	--	--	--
Nitrite	0.0	4-8-64	0.1	9-11-64
Nitrate	--	--	3.9	"
Phosphorus	--	--	--	--
Cyanide	--	--	< 0.03	11- 5-64
Oil	--	--	--	--
Detergents	0.1	4-8-64	0.5	9-11-64
Dissolved Solids	710	"	690	"
Hardness	438	"	414	"
Noncarbonate Hardness	245	"	95	"
Calcium Hardness	243	"	230	"
Magnesium Hardness	195	"	184	"
Alkalinity P	10	"	15	"
Alkalinity M	180	"	300	"
Specific Conductance	920	"	1,030	"
pH	8.1	"	7.8	"
Color	30	"	25	"
Turbidity	7	"	55	"
Biochemical Oxygen Demand	3.9	"	3.3	"
Dissolved Oxygen	9.5	"	5.0	"
Coliform Count	47,000	"	7,000	"
Temperature (^{o}F)	39	"	68	"

Source: SEWRPC.

oxygen concentrations in the Root River are shown by a series of 14 interpretive stream quality graphs in Figure 57. Conspicuous features of these graphs are the extremely adverse conditions that existed in February 1964 and in February 1965 when the dissolved oxygen concentrations were 0 to 1.6 ppm over much of the middle reaches of the river. In October 1964 critical concentrations (3.0 ppm or less) occurred over a 9-mile reach from station Rt-1 to Rt-2.

The coliform counts in the Root River varied from 1,100,000 MFCC/100 ml in February 1964 at station Rt-2 to 100 MFCC/100 ml in June at station Rt-4. The maximum, average, and minimum counts for the period June through September at stations Rt-1, Rt-5, and Rt-6 were 3,000, 2,000, and 800 MFCC/100 ml; 390,000, 150,000, and 2,000 MFCC/100 ml; 26,000, 9,100, and 1,500 MFCC/100 ml, respectively. Variations in the coliform counts in the Root River are shown by a series of 14 interpretive stream quality graphs in Figure 58. Conspicuous features of the graphs are the extremely high coliform counts (100,000 MFCC/100 ml or more) that occurred in February 1964 and in the winter of 1964-1965 over a distance of about 17 miles in the middle reaches of the Root River. Between station Rt-1 and Rt-2, where the effluent from three sewage treatment plants enters the Root River, the Root River is subject to severe pollution. The Caddy Vista sanitary district treatment plant is thought to contribute much to the very high coliform counts in the Root River at station Rt-5.

Table 273

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RT-6 ON THE ROOT RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	8	4-8-64	1	9-11-64
Iron	0.02	"	0.52	"
Manganese	--	--	0.03	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	91	4-8-64	96	9-11-64
Magnesium	42	"	50	"
Sodium (and Potassium)	55	"	70	"
Bicarbonate	220	"	340	"
Carbonate	0	"	0	"
Sulfate	224	"	191	"
Chloride	70	"	85	"
Fluoride	--	--	--	--
Nitrite	0.0	4-8-64	0.0	9-11-64
Nitrate	--	--	1.9	--
Phosphorus	--	--	--	--
Cyanide	--	--	< 0.03	11- 5-64
Oil	--	--	--	--
Detergents	0.1	4-8-64	0.3	9-11-64
Dissolved Solids	600	"	665	"
Hardness	397	"	447	"
Noncarbonate Hardness	215	"	165	"
Calcium Hardness	226	"	240	"
Magnesium Hardness	171	"	207	"
Alkalinity P	0	"	0	"
Alkalinity M	180	"	280	"
Specific Conductance	856	"	1,020	"
pH	7.1	"	8.3	"
Color	30	"	30	"
Turbidity	10	"	45	"
Biochemical Oxygen Demand	5.7	"	6.3	"
Dissolved Oxygen	12.3	"	8.1	"
Coliform Count	21,000	"	26,000	"
Temperature (^{o}F)	41	"	67	"

Source: SEWRPC.

Table 274

WATER QUALITY CONDITIONS OF THE ROOT RIVER (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride(ppm)	240	115	30	37
Dissolved Solids (ppm)	955	715	390	37
Dissolved Oxygen (ppm)	14.6	7.2	0	64
Coliform Count (MFCC/100 ml)	1,100,000	71,000	100	64
Temperature (^{o}F)	78	52	32	64

Source: SEWRPC.

Figure 57

DISSOLVED OXYGEN CONCENTRATION IN THE ROOT RIVER

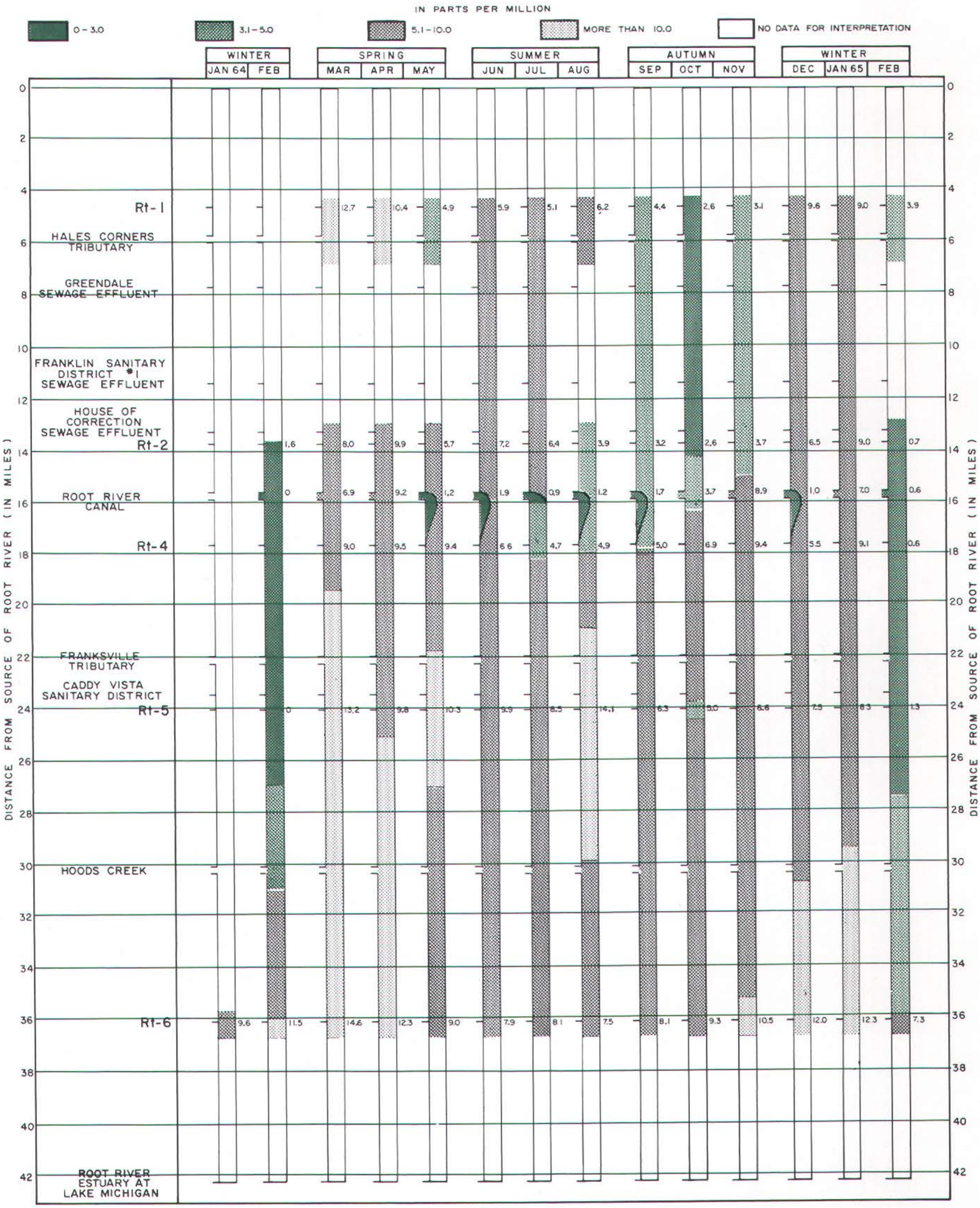
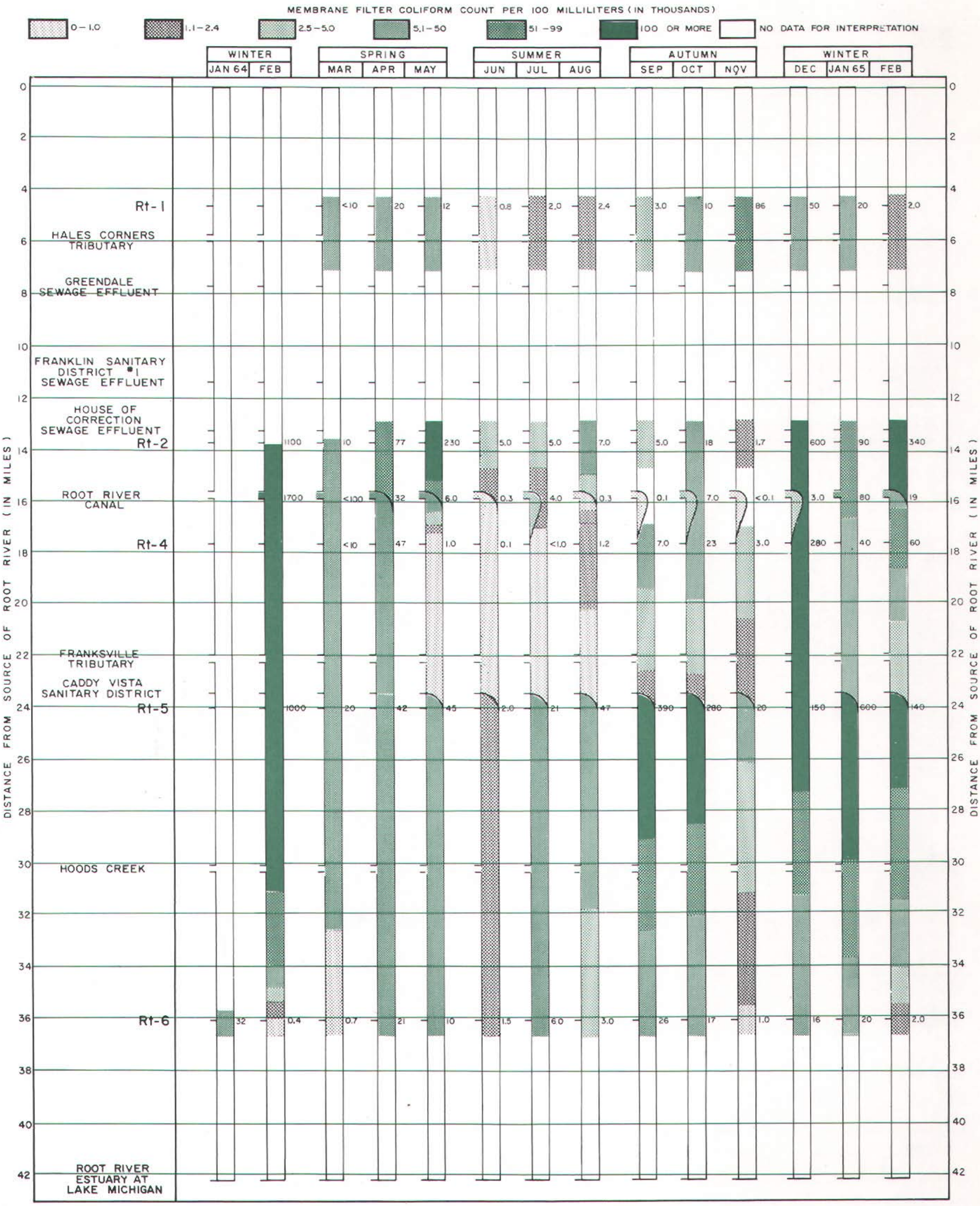


Figure 58
COLIFORM COUNT IN THE ROOT RIVER



The maximum temperature of the Root River was 78°F in July 1964 at sampling station Rt-2. For the period June through September 1964, the maximum, average, and minimum stream temperatures were 74°, 67°, and 59°F at station Rt-1; 77°, 72°, and 66°F at station Rt-5; and 77°, 72°, and 67°F at station Rt-6. Figure 59 shows the monthly variations in the temperature of the Root River at sampling stations Rt-1 and Rt-6.

Streamflow and Precipitation: The Root River is a shallow meandering stream, which, throughout much of the year, occupies a relatively narrow channel. At stations Rt-1 and Rt-6, which are 4.6 and 36.1 miles downstream from the river source, the stream had maximum depths of 1.4 feet and 1.0 foot and widths of 27 feet and 58 feet, respectively, when surveyed in January and March 1964.

The U. S. Geological Survey, in cooperation with the SEWRPC, established two water-stage recorders on the Root River at or near locations designated in this study as sampling stations Rt-2 and Rt-6. Tables 275 and 276 list the mean daily discharge at these two stations computed from the water-stage records covering the period January 1964 through February 1965. Table 210 lists the daily precipitation for the same period as recorded at the U. S. Weather Bureau Station at Racine, Wisconsin.

Forecast Quality of the Root River for the Year 1990: There are seven sewage treatment plants in the Root River watershed that discharge treated wastes into the Root River or its tributaries. These seven sewage treatment plants serve the villages of Hales Corners, Greendale, and Union Grove; the City of Franklin (Sewerage District #1); the Milwaukee County House of Correction; the community of Caddy Vista; and the State of Wisconsin Southern Colony and Training School, with a combined total connected population of approximately 21,300 persons in 1963. By the year 1990, all the sewage treatment plants except the two that serve the Village of Union Grove and the State of Wisconsin Southern Colony and Training School are expected to be connected to the Milwaukee metropolitan sewerage system. The treated wastes from the sewage treatment plants at the Village of Union Grove and at the Southern Colony may be expected to continue to be discharged into the West Branch of the Root River Canal through 1990. A food processing plant that presently discharges treated wastes to Hoods Creek is expected to be connected to the City of Racine

Figure 59

TEMPERATURE OF THE ROOT RIVER

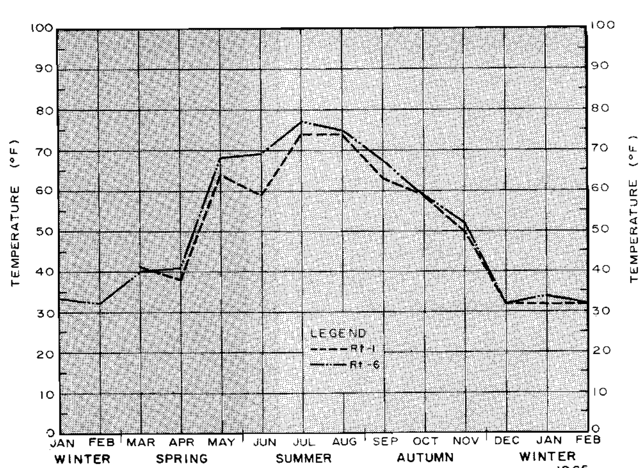


Table 275

DISCHARGE OF THE ROOT RIVER NEAR FRANKLIN, WISCONSIN:
JANUARY 1964 THROUGH FEBRUARY 1965
STREAMFLOW (in CFS)

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	1.6	4.3	3.5	10	30	2.9	4.5	14	6.4	4.2	3.2	6.0	9.0	7.2
2	2.0	4.4	4.5	16	38	2.9	8.0	13	6.8	4.2	3.4	5.0	120	6.4
3	2.6	4.5	6.5	82	34	3.6	9.6	11	7.6	2.4	7.8	4.5	60	5.8
4	4.0	4.5	5.8	38	26	2.7	6.0	11	8.0	2.4	6.4	4.1	26	5.4
5	2.4	4.5	5.0	34	24	3.0	3.4	10	6.4	2.6	4.5	3.8	18	5.0
6	5.0	4.8	8.0	154	22	2.8	2.3	12	5.1	2.8	3.8	3.6	15	10
7	3.0	5.0	20	105	22	2.6	2.6	11	4.8	2.9	3.8	3.4	12	60
8	2.6	4.5	67	53	165	2.4	3.0	8.8	4.8	2.9	3.8	3.2	25	230
9	2.3	3.8	38	35	57	2.2	2.8	9.2	3.3	3.1	4.2	3.1	32	200
10	2.0	3.1	28	29	28	2.1	2.5	9.6	3.9	2.9	7.2	3.1	16	160
11	1.9	3.1	20	24	22	2.0	2.2	14	3.0	2.8	7.2	4.5	8.0	320
12	1.8	3.2	38	21	18	1.9	2.0	18	2.7	2.9	7.2	11	5.0	180
13	1.7	3.5	81	20	24	1.9	3.6	8.0	2.6	2.8	6.1	12	4.0	100
14	1.6	3.5	143	18	28	3.5	4.5	5.7	2.4	2.8	6.1	10	3.4	60
15	1.6	3.5	49	14	20	15	3.2	3.9	2.0	2.9	9.5	8.0	3.2	30
16	1.5	3.5	28	14	63	11	2.8	3.0	2.6	3.1	22	6.4	3.0	40
17	1.5	3.5	20	14	42	5.7	25	4.5	2.4	3.2	10	5.4	2.9	50
18	1.5	3.6	13	16	21	2.3	318	5.1	2.9	2.9	4.9	4.5	2.9	30
19	1.5	3.6	11	14	14	2.1	680	4.2	10	3.2	3.8	3.8	2.8	20
20	6.0	3.6	10	14	9.2	1.9	232	3.6	5.1	3.2	3.3	3.5	2.8	40
21	20	3.6	10	67	7.8	3.0	88	60	3.6	2.9	3.0	3.3	3.0	24
22	16	3.5	11	79	6.8	35	47	50	2.6	3.1	3.0	3.2	30	18
23	14	3.4	12	32	5.8	30	59	16	5.7	3.2	3.2	3.1	80	14
24	16	3.2	13	24	5.0	15	30	10	6.0	3.1	3.4	3.5	60	12
25	30	3.2	11	20	8.0	7.0	97	6.4	3.6	3.1	3.4	3.5	40	11
26	12	3.1	10	18	6.0	4.0	245	5.7	2.9	3.1	3.2	3.1	30	10
27	8.0	3.1	9.4	28	4.2	3.0	50	5.4	3.3	3.1	3.4	2.8	24	11
28	5.4	3.1	8.8	36	3.0	2.4	28	5.7	3.3	2.9	55	2.8	18	20
29	4.5	3.2	8.2	33	3.0	2.1	20	6.0	2.9	3.1	25	3.7	14	---
30	4.4	---	8.2	31	2.6	2.5	18	6.8	2.7	3.1	14	5.8	11	---
31	4.3	---	8.4	---	2.6	---	16	8.8	---	3.1	---	8.0	8.4	---

Source: U. S. Geological Survey

sanitary sewerage system. The other major source of industrial wastes within the watershed is a food processing plant located on the West Branch of the Root River Canal in the Town of Raymond. This industry is expected to continue to discharge its treated wastes into the Canal but after improved treatment. Table 277 forecasts the quality of the Root River for the year 1990 at sampling stations Rt-2, Rt-5, and Rt-6.

Root River Canal

Present Stream Quality: One sampling station, Rt-3, was established by the SEWRPC on the Root River Canal at a point 3.5 miles upstream from where the Canal joins the Root River. The Root River Canal has its origin two miles upstream from station Rt-3 at the junction of the East and West Branches of the Root River Canal. The City of Union Grove, Southern Colony, and one major industry discharge wastes into the West Branch of the Root River Canal.

The Root River Canal is predominantly a calcium bicarbonate stream of relatively constant total mineralization. In the three complete chemical analyses of stream samples collected from the Root River Canal, calcium and sodium were the predominant cations. Calcium was predominant in two analyses at concentrations of 130 ppm in April and 100 ppm in September 1964. Sodium was the predominant cation in February at a concentration of 170 ppm. Bicarbonate and sulfate were the predominant anions. Bicarbonate was predominant in February and September 1964 at respective concentrations of 435 and 355 ppm. In April 1964 sulfate was predominant at 364 ppm. Maximum nitrate concentration was 14.4 ppm. No total phosphorus determination was made on water samples from the Root River Canal during the present study. Selected water analyses at station Rt-3 are listed in Table 278. Water quality conditions of the stream are indicated in Table 279.

Table 276

DISCHARGE OF THE ROOT RIVER AT RACINE, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965
STREAMFLOW (in CFS)

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	1.3	6.7	5.9	21	89	11	8.4	33	6.4	17	5.7	35	11	30
2	1.3	6.7	7.0	27	100	11	15	27	6.7	11	6.2	22	80	24
3	1.4	6.3	8.4	62	106	11	15	22	6.4	7.7	6.7	15	150	20
4	1.8	6.0	10	156	100	9.3	11	17	5.7	7.3	6.7	10	120	17
5	1.7	7.0	16	113	85	8.8	15	12	5.2	7.7	10	8.0	84	15
6	2.0	7.3	14	216	77	8.8	9.8	10	5.0	7.3	11	7.2	62	14
7	2.2	7.3	25	316	71	9.8	8.0	9.8	5.2	6.4	8.8	6.8	50	50
8	2.7	6.7	43	260	83	10	7.3	8.4	5.5	5.9	7.3	6.6	38	100
9	2.5	6.7	66	146	219	8.8	7.3	7.3	5.2	5.5	7.0	6.6	70	210
10	2.3	6.7	69	98	159	8.0	6.7	7.0	5.2	5.2	6.7	6.5	60	600
11	2.1	6.2	58	77	91	7.7	5.9	7.0	5.0	4.8	6.4	7.0	50	719
12	1.8	5.9	55	62	64	8.0	5.5	6.7	5.2	5.0	7.0	9.0	40	758
13	1.6	5.9	67	51	53	8.0	5.7	11	5.2	5.2	7.7	12	32	706
14	1.5	5.9	159	43	53	7.3	5.9	9.8	5.2	5.2	7.3	20	24	554
15	1.4	5.7	212	36	69	9.3	5.7	7.7	5.2	5.2	9.3	18	20	407
16	1.4	5.9	106	30	79	8.8	5.2	6.7	5.0	5.2	11	13	17	322
17	1.4	5.9	64	26	143	8.8	6.2	6.2	5.0	4.8	15	10	14	261
18	1.4	5.9	42	27	129	11	137	5.7	5.7	5.0	21	8.4	12	261
19	1.4	5.9	32	26	85	16	524	5.7	6.4	4.5	13	7.6	11	233
20	5.0	5.9	27	26	60	13	830	6.2	6.4	4.3	10	7.0	10	210
21	5.4	5.7	25	27	51	12	893	8.0	12	4.7	8.4	6.6	10	180
22	5.8	5.7	23	82	45	11	604	42	12	4.7	7.3	6.5	14	140
23	12	5.5	24	116	43	14	375	71	8.8	4.7	7.0	6.4	50	100
24	25	5.5	27	62	39	57	223	36	5.0	4.8	6.7	6.8	60	70
25	18	5.5	32	43	30	62	146	20	6.7	4.7	6.7	7.6	130	50
26	12	5.5	33	45	24	31	165	14	8.8	5.0	6.7	8.6	110	40
27	45	5.2	30	42	21	18	252	10	9.3	5.2	7.0	8.0	90	35
28	30	5.2	24	57	16	12	149	8.8	8.8	5.2	17	7.2	70	40
29	19	5.2	22	79	13	11	75	7.7	8.4	5.5	39	6.8	56	---
30	12	---	20	85	12	8.8	51	8.4	8.0	6.2	67	6.8	46	---
31	8.5	---	20	---	11	---	40	6.7	---	5.9	---	8.2	36	---

Source: U. S. Geological Service.

The chloride concentrations in the Root River Canal varied from 170 ppm in February to 45 ppm in April 1964 at sampling station Rt-3. Assuming a "background" concentration of 10 ppm, the maximum chloride impact upon the Root River Canal was 160 ppm from human sources.

The dissolved solids concentrations of the Root River Canal varied from 710 ppm in February to 390 ppm in September 1964 at station Rt-3. Assuming that the maximum and minimum "background" dissolved solids concentrations were 650 and 525 ppm, respectively, the dissolved solids impact upon the Root River Canal was as much as 185 ppm.

The dissolved oxygen concentrations in the Root River Canal varied from 9.2 in April to 0.0 ppm in February 1964 at station Rt-3. The maximum, average, and minimum dissolved oxygen concentrations in the Root River Canal for the period June through September 1964 were 1.9, 1.4, and 0.9 ppm, respectively.

The coliform counts in the Root River Canal varied from 1,700,000 MFCC/100 ml in February to less than 100 MFCC/100 ml in November 1964 at station Rt-3. The maximum, average, and minimum coliform counts for the period June through September were 4,000, 1,100, and 100 MFCC/100 ml.

The maximum temperature of the Root River Canal was 72°F in August 1964. The maximum, average, and minimum temperatures for the period June through September were 72°, 67°, and 63°F.

Streamflow and Precipitation: Throughout most of the year, the Root River Canal is a shallow stream occupying a relatively narrow channel, which has been straightened, widened, and deepened in its upper reaches. At station Rt-3, the Root River Canal had a maximum depth of 1.5 feet and a width of 47 feet when surveyed in January 1964.

Table 277

FORECAST QUALITY OF THE ROOT RIVER AT SAMPLING STATIONS RT-2, RT-5, AND RT-6: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Root River	Rt-2 Rt-5 Rt-6	Chloride (in ppm)	115[a] 100[a] 85[a]	30 40 30	30 40 30	30 40 30
	Rt-2 Rt-5 Rt-6	Dissolved Solids (in ppm)	680[a] 770[a] 665[a]	550 700 600	550 700 600	550 700 600
	Rt-2 Rt-5 Rt-6	Dissolved Oxygen (in ppm)	5.2[b] 9.7[b] 7.9[b]	More than 6.0 More than 8.0 More than 8.0		
	Rt-2 Rt-5 Rt-6	Coliform Count (in MFCC/ 100 ml)	5,500[b] 115,000[b] 9,100[b]	Less than 5,000		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

The U. S. Geological Survey, in cooperation with the SEWRPC, established a water-stage recorder on the Root River Canal at a location designated in the study as sampling station Rt-3. Table 280 lists the mean daily discharge at this station computed from the water-stage records covering the period January 1964 through February 1965. Table 210 lists the daily precipitation for the same period recorded at the U. S. Weather Bureau Station at Racine, Wisconsin.

Forecast Quality of the Root River Canal for the Year 1990: There are two sewage treatment plants that discharge effluent to the West Branch of the Root River Canal: one at the Village of Union Grove and one at the State of Wisconsin Southern Colony and Training School, with a combined estimated connected population of 4,000 persons in 1963. The treated wastes from these two sewage treatment plants will continue to be discharged to the West Branch of the Root River Canal through 1990. One major industry that discharges its wastes into the West Branch of the Root River Canal presumably will continue to do so in coming years. Table 281 forecasts the quality of the Root River Canal for the year 1990 at sampling station Rt-3.

SAUK CREEK WATERSHED

The Sauk Creek watershed ranks eleventh in population and ninth in size as compared to the other 11 watersheds of the Region. An estimated 5,400[12] persons reside within this watershed, which has a total area of 34.47 square miles and an average population density of 156 people per square mile. The principal land use is agriculture, which comprises 84.2 percent of the area of the watershed. The areas within the watershed devoted to each of eight major land use categories are listed in Table 282.

[12] *Based on SEWRPC estimate for 1963.*

Table 278

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION RT-3 ON THE ROOT RIVER CANAL: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-8-64	11	9-11-64
Iron	0.01	"	0.14	"
Manganese	--	--	0.00	"
Chromium	--	--	--	--
Hexavalent Chromium	--	--	--	--
Calcium	130	4-8-64	100	9-11-64
Magnesium	60	"	47	"
Sodium (and Potassium)	15	"	85	"
Bicarbonate	190	"	355	"
Carbonate	5	"	30	"
Sulfate	364	"	182	"
Chloride	45	"	65	"
Fluoride	--	--	--	--
Nitrite	0.0	4-8-64	0.2	9-11-64
Nitrate	--	"	14.4	"
Phosphorus	--	--	--	--
Cyanide	--	--	--	--
Oil	--	--	--	--
Detergents	0.1	4-8-64	0.4	9-11-64
Dissolved Solids	720	"	710	"
Hardness	572	"	445	"
Noncarbonate Hardness	410	"	105	"
Calcium Hardness	325	"	250	"
Magnesium Hardness	247	"	195	"
Alkalinity P	2.5[a]	"	15	"
Alkalinity M	160	"	320	"
Specific Conductance	1,040	"	1,050	"
pH	7.6	"	7.6	"
Color	40	"	25	"
Turbidity	2	"	7	"
Biochemical Oxygen Demand	1.9	"	2.8	"
Dissolved Oxygen	9.2	"	1.7	"
Coliform Count	32,000	"	100	"
Temperature (°F)	39	"	66	"

[a] *Estimated.*

Source: SEWRPC.

Table 279

WATER QUALITY CONDITIONS OF THE ROOT RIVER CANAL (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	170	95	45	3
Dissolved Solids (ppm)	790	740	710	3
Dissolved Oxygen (ppm)	9.2	3.4	0.0	13
Coliform Count (MFCC/100 ml)	1,700,000	150,000	<100	13
Temperature (°F)	72	50	32	13

Source: SEWRPC.

Table 280

DISCHARGE OF THE ROOT RIVER CANAL NEAR FRANKLIN, WISCONSIN: JANUARY 1964 THROUGH FEBRUARY 1965

STREAMFLOW (in CFS)

Day	1964												1965	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	0.3	1.1	1.3	4.9	26	2.2	1.7	7.5	2.2	1.8	1.7	6.0	7.0	5.8
2	0.3	1.1	1.5	8.3	23	2.9	3.2	6.1	2.1	1.8	1.6	3.0	70	5.4
3	0.3	1.1	2.0	22	19	5.1	2.4	5.0	2.4	1.7	1.6	2.7	60	5.2
4	0.4	1.2	2.5	23	16	4.9	2.4	4.0	2.5	1.6	1.7	2.4	35	5.1
5	0.5	1.3	2.9	21	13	3.8	1.7	3.4	2.4	1.5	2.4	2.2	19	5.0
6	0.6	1.4	2.1	81	12	3.4	1.0	3.0	2.1	1.4	2.4	2.1	13	5.8
7	0.8	1.4	7.0	67	9.9	3.2	1.0	2.9	2.0	1.4	2.2	2.0	11	40
8	1.0	1.3	15	42	15	2.5	1.0	2.5	1.7	1.8	2.7	2.0	18	190
9	0.8	1.2	13	26	14	2.1	1.0	2.4	1.6	2.0	1.8	1.9	25	180
10	0.6	1.1	12	19	9.1	2.2	1.0	2.4	1.8	1.8	1.5	1.9	14	200
11	0.4	1.1	9.9	15	7.7	2.0	1.0	2.4	2.1	1.8	1.5	2.5	9.4	300
12	0.3	1.1	11	12	7.0	2.0	1.0	2.5	2.2	1.6	1.8	6.0	6.6	200
13	0.3	1.2	16	12	8.5	2.6	1.0	2.7	1.8	1.4	2.2	7.0	5.0	130
14	0.3	1.3	26	10	10	1.6	1.0	2.6	1.6	1.2	2.4	6.0	3.8	90
15	0.3	1.2	19	8.5	7.9	2.6	0.9	2.2	1.5	1.4	3.0	5.0	3.4	64
16	0.3	1.2	11	7.7	25	6.0	0.6	2.2	1.6	1.5	7.5	4.2	3.0	80
17	0.3	1.3	7.0	7.2	36	5.3	0.3	2.2	1.7	1.6	8.5	3.4	2.7	90
18	0.3	1.3	5.0	7.2	21	4.4	171	2.2	2.0	1.6	6.3	2.8	2.5	64
19	0.3	1.3	4.5	6.4	15	3.8	289	2.6	2.6	1.4	5.0	2.3	2.4	46
20	1.5	1.3	4.0	5.7	10	2.9	200	2.5	2.2	1.3	3.6	2.1	2.3	36
21	2.5	1.3	4.0	8.8	8.1	2.8	137	4.1	2.1	1.3	2.8	2.0	2.3	28
22	4.0	1.2	4.0	13	6.8	9.9	91	[illegible]	2.9	1.5	2.4	2.2	14	24
23	2.9	1.2	4.0	9.4	5.7	61	81	4.[illegible]	7.3	1.6	2.1	2.5	50	22
24	3.5	1.2	4.6	7.9	5.5	41	55	5.0	5.5	2.0	2.5	2.8	40	21
25	4.4	1.2	5.4	7.0	4.9	21	39	3.2	3.4	2.0	3.0	2.4	30	20
26	3.0	1.2	4.6	6.2	4.4	13	27	2.9	2.2	1.8	3.2	2.2	22	20
27	2.0	1.2	4.0	6.8	4.8	8.3	19	2.8	2.6	1.4	3.4	2.0	16	23
28	1.5	1.2	3.8	12	4.8	4.8	16	2.9	2.5	1.3	19	1.9	12	60
29	1.2	1.2	3.7	16	4.1	2.9	12	2.8	1.8	1.5	24	2.4	9.0	---
30	1.1	---	3.7	22	3.5	1.7	9.8	2.6	1.6	1.6	14	4.0	7.2	---
31	1.0	---	3.9	---	2.7	---	8.7	2.4	---	1.6	---	5.0	6.2	---

Source: U. S. Geological Service.

One stream was studied by the SEWRPC in the Sauk Creek watershed—Sauk Creek proper. This stream rises within the Region about 2 miles northeast of the Village of Fredonia in north central Ozaukee County and flows northeast, east, and south to Lake Michigan in the harbor area of the City of Port Washington.

The Sauk Creek watershed is in an area almost exclusively underlain by end moraines and ground moraine of red glacial drift. The end moraines parallel Lake Michigan and form broad ridges and intermorainal valleys. Sauk Creek flows northeasterly off the eastern slope of an end moraine, cuts along the southern edge of extensive ground moraine, and proceeds southerly through a relatively broad intermorainal valley to Lake Michigan.

Sauk Creek

Present Stream Quality: Two sampling stations, Sk-1 and Sk-2, were established on Sauk Creek. Station Sk-1 is located 5.9 miles downstream from the source of Sauk Creek and 6.7 miles upstream from station Sk-2. Station Sk-2 is 0.3 mile from where Sauk Creek flows into Lake Michigan.

Sauk Creek is predominantly a calcium bicarbonate stream that is subject to medium changes in total mineralization. Of 15 complete chemical analyses run on stream samples collected from Sauk Creek, calcium was the predominant cation in all but one analysis at concentrations ranging from 124 ppm in October 1964 at station Sk-1 to 26 ppm in February 1965 at station Sk-2. Sodium occurred as the predominant cation in the sample collected at station Sk-2 in February 1965 and had a concentration of 35 ppm. Bicarbonate was the predominant anion in all 15 analyses at concentrations ranging from 550 ppm in October 1964 at station Sk-1 to 120 ppm in February 1965 at station Sk-2. Maximum nitrate concentration was 3.4 ppm. Total phosphorus was 1.92 at Sk-1 and 0.26 at Sk-2 on October 15, 1964. Selected water analyses of Sauk Creek at sampling station Sk-1 and Sk-2 are indicated in Tables 283 and 284. Water quality conditions of Sauk Creek are indicated in Table 285.

Table 281

FORECAST QUALITY OF THE ROOT RIVER CANAL AT SAMPLING STATION RT-3: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Root River Canal	Rt-3	Chloride (in ppm)	65[a]	Less than 30		
		Dissolved Solids (in ppm)	710[a]	Approximately 600		
		Dissolved Oxygen (in ppm)	1.4[b]	Less than 3.0		
		Coliform Count (in MFCC/ 100 ml)	1,200[b]	Less than 1,500		

[a] *Based on analysis for September 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

Table 282

EXISTING LAND USE IN THE SAUK CREEK WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	29.0	18,572	84.2
Woodland, Wetland, and Unused Land	2.5	1,587	7.2
Transportation-Communication . . .	1.7	1,098	5.0
Residential.	0.9	594	2.7
Industrial	0.2	102	0.5
Governmental-Institutional	0.1	58	0.2
Park and Recreational.	0.1	29	0.1
Commercial	0.0	19	0.1
Total	34.5	22,059	100.0

Source: SEWRPC.

Table 283

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION SK-1 ON SAUK CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	1	4-16-64	8	10-15-64
Iron	0.01	"	0.60	"
Manganese	--	--	0.01	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	107	4-16-64	124	"
Magnesium	44	"	59	"
Sodium (and Potassium)	40	"	80	"
Bicarbonate	280	"	550	"
Carbonate	0	"	20	"
Sulfate	250	"	150	"
Chloride	30	"	55	"
Fluoride	--	--	<0.70	"
Nitrite	0.0	4-16-64	0.0	"
Nitrate	--	--	3.2	"
Phosphorus	--	--	1.92	"
Cyanide	--	--	--	--
Oil	--	--	<2	10-15-64
Detergents	0.1	4-16-64	0.0	"
Dissolved Solids	610	"	770	"
Hardness	449	"	551	"
Noncarbonate Hardness	220	"	70	"
Calcium Hardness	267	"	310	"
Magnesium Hardness	182	"	241	"
Alkalinity P	0	"	10	"
Alkalinity M	230	"	470	"
Specific Conductance	740	"	992	"
pH	8.3	"	7.4	"
Color	50	"	70	"
Turbidity	2	"	10	"
Biochemical Oxygen Demand	4.5	"	19.0	"
Dissolved Oxygen	14.2	"	0.1	"
Coliform Count	16,000	"	7,000	"
Temperature (°F)	52	"	58	"

Source: SEWRPC.

The chloride concentrations in Sauk Creek ranged from 55 ppm in October 1964 at station Sk-1 to 20 ppm in January, February, September, and November 1964. Assuming a "background" chloride concentration of 10 ppm, the maximum chloride impact upon Sauk Creek was 45 ppm from human sources. Figure 60 shows the chloride concentrations in Sauk Creek at stations Sk-1 and Sk-2.

The dissolved solids concentrations varied from 770 ppm at station Sk-1 in October 1964 to 200 ppm at station Sk-2 in February 1965. The low concentration in February involved marked decreases in the concentrations of all parameters except chloride, sodium, and nitrate. Figure 60 shows the dissolved solids concentrations in Sauk Creek at stations Sk-1 and Sk-2.

The dissolved oxygen concentrations in Sauk Creek varied from 17.0 ppm at station Sk-2 in April to 0.1 ppm at station Sk-1 in October 1964. The maximum, average, and minimum dissolved oxygen concentrations for the period June through September 1964 at Sk-1 and Sk-2 were 14.7, 8.8, and 3.4 ppm and 12.1, 11.3, and 10.9 ppm, respectively. Figure 61 shows the dissolved oxygen concentrations at stations Sk-1 and Sk-2.

Table 284

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION SK-2 ON SAUK CREEK: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	1	4-16-64	1	10-15-64
Iron	0.01	"	0.03	"
Manganese.	--	--	0.03	"
Chromium	--	--	<0.005	"
Hexavalent Chromium.	--	--	0.00	"
Calcium.	93	4-16-64	79	"
Magnesium.	47	"	50	"
Sodium (and Potassium)	40	"	45	"
Bicarbonate.	270	"	355	"
Carbonate.	0	"	10	"
Sulfate.	236	"	150	"
Chloride	35	"	30	"
Fluoride	--	--	0.6	"
Nitrite.	0.0	4-16-64	0.0	"
Nitrate.	--	--	0.4	"
Phosphorus	--	--	0.26	"
Cyanide.	--	--	<0.01	11-13-64
Oil.	--	--	<0.5	10-15-64
Detergents	0.1	4-16-64	0.1	"
Dissolved Solids	580	"	540	"
Hardness	425	"	401	"
Noncarbonate Hardness.	205	"	95	"
Calcium Hardness	233	"	196	"
Magnesium Hardness	192	"	205	"
Alkalinity P	0	"	5	"
Alkalinity M	220	"	300	"
Specific Conductance	720	"	680	"
pH	8.2	"	8.6	"
Color.	40	"	15	"
Turbidity.	2	"	8	"
Biochemical Oxygen Demand. . . .	2.0	"	1.6	"
Dissolved Oxygen	17.0	"	16.1	"
Coliform Count	400	"	2,500	"
Temperature (°F)	53	"	56	"

Source: SEWRPC.

Table 285

WATER QUALITY CONDITIONS OF SAUK CREEK (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	55	40	20	15
Dissolved Solids (ppm)	770	605	200	15
Dissolved Oxygen (ppm)	19.3	10.6	0.1	25
Coliform Count (MFCC/100 ml) . .	200,000	20,000	400	25
Temperature (°F)	86	51	32	24

Source: SEWRPC.

Figure 60

CHLORIDE AND DISSOLVED SOLIDS CONCENTRATIONS IN SAUK CREEK

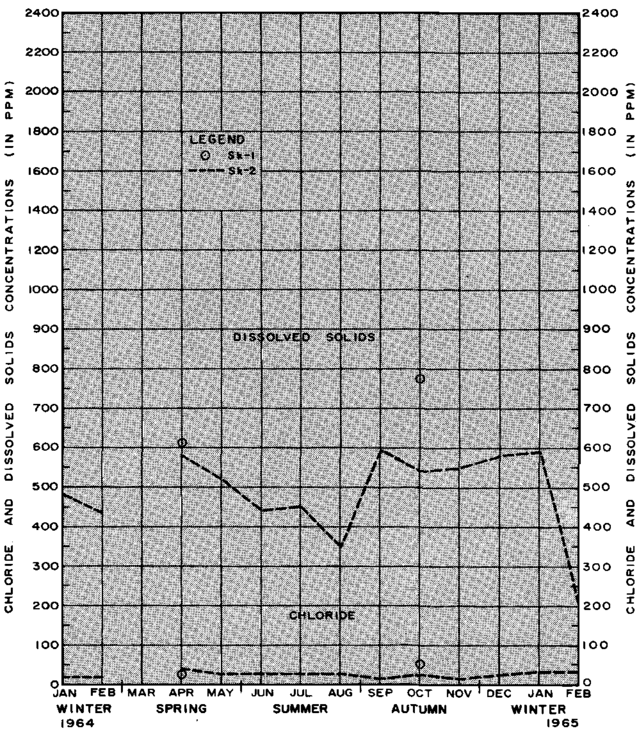
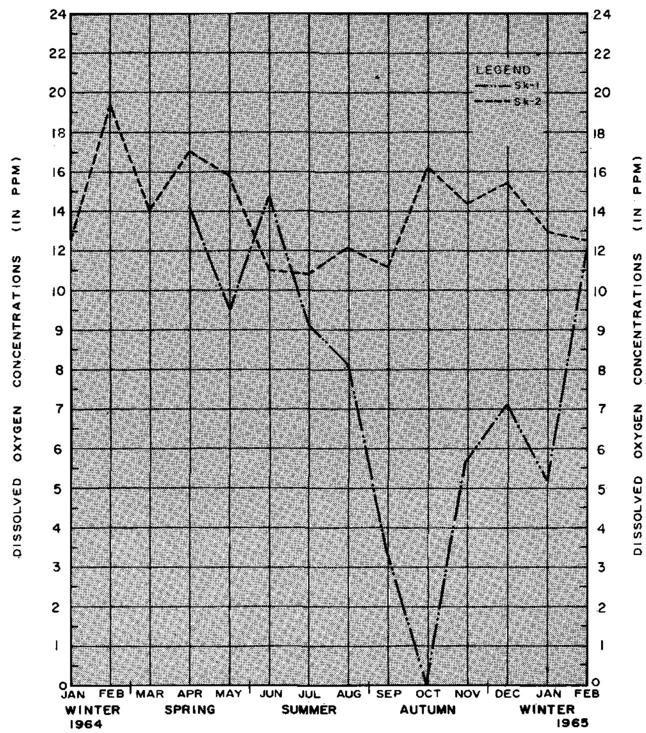


Figure 61

DISSOLVED OXYGEN CONCENTRATIONS IN SAUK CREEK



The coliform counts in Sauk Creek varied from 220,000 MFCC/100 ml at station Sk-1 in September 1964 to 200 MFCC/100 ml at the same station in June 1964. The concentrations varied greatly in the upper reaches of Sauk Creek at station Sk-1 in a manner typical of intermittent discharges reaching a stream from a source or sources of wastes high in coliform count. The coliform counts at station Sk-2 were generally low. Eight of 14 analyses were less than 2,400 MFCC/100 ml. Twelve of 14 analyses were less than 5,000 MFCC/100 ml. The maximum, average, and minimum coliform counts for the period June through September 1964 were 200,000, 60,000, and 200 MFCC/100 ml and 4,400, 2,300, and 1,200 MFCC/100 ml, respectively. No sewage treatment plants presently discharge treated sewage into Sauk Creek. Figure 62 shows the variations in the coliform counts at stations Sk-1 and Sk-2.

The maximum temperature of Sauk Creek was 86°F in June 1964 and for the period June through September 1964 averaged 67° and 62°F at stations Sk-1 and Sk-2, respectively. Figure 63 shows the temperature at Sauk Creek at stations Sk-1 and Sk-2.

Streamflow and Precipitation: Sauk Creek is a relatively shallow stream occupying a relatively wide channel during much of the year. At sampling station Sk-2, a distance 12.6 miles from the source, the stream had a maximum depth of 0.8 foot and a width of 13.5 feet when measured under low-flow conditions in October 1964.

The flow of Sauk Creek was measured by the SEWRPC in the spring and autumn of 1964 during periods of relatively high and low flow. The streamflow data are listed in Table 286. Table 186 indicates the daily precipitation at Port Washington, Wisconsin.

Forecast Quality of Sauk Creek for the Year 1990: Population estimates by the SEWRPC indicate that in 1963 there were 5,400 people living in the Sauk Creek watershed. Table 287 indicates the estimated population of the watershed under the three alternative regional land use plans for the year 1990. The large increases in population within the watershed by 1990 under two of the alternatives would be located about the City of Port Washington and to a much lesser extent about the villages of Belgium and Fredonia. The area about Port Washington would be served by Port Washington sanitary sewerage facilities. A negligible

Figure 62

COLIFORM COUNT IN SAUK CREEK

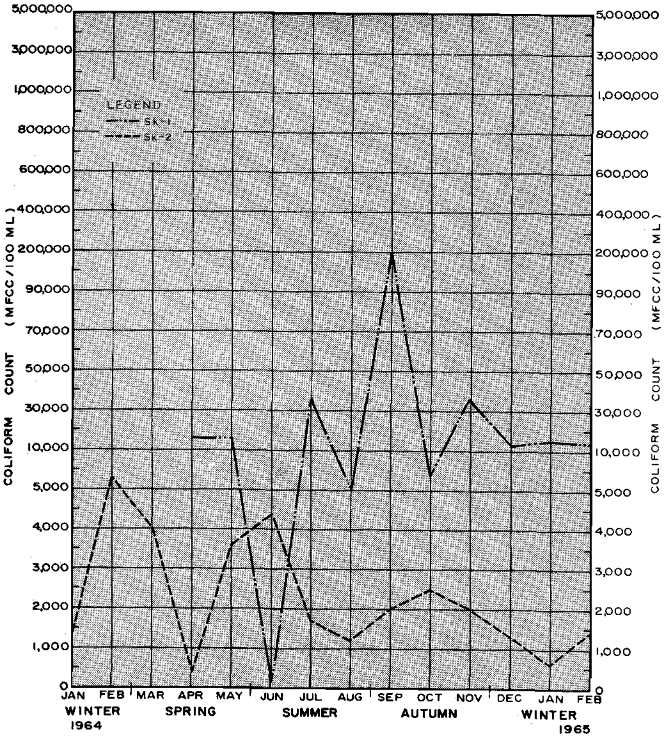


Figure 63

TEMPERATURE OF SAUK CREEK

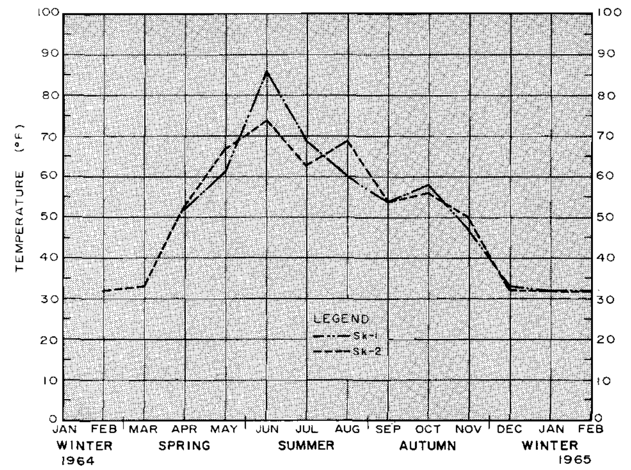


Table 286

STREAMFLOW MEASUREMENTS OF SAUK CREEK: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 4-Day Rainfall (in inches)[a]
Sk-2	4-25-64 10-15-64	13 1.9	1.25 0

Source: SEWRPC.

Table 287

ESTIMATED POPULATION OF THE SAUK CREEK WATERSHED: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sauk Creek Watershed	5,400	8,000	20,000	38,000

Source: SEWRPC.

increase in population is expected to occur in the rural areas of the watershed. Table 288 presents forecasts of future quality of Sauk Creek.

SHEBOYGAN RIVER WATERSHED

The Sheboygan River watershed ranks twelfth in population and twelfth in size as compared to the other 11 watersheds of the Region. An estimated 1,000[13] persons reside within this watershed, which has a total area of 10.3 square miles and an average population density of 98 people per square mile. The principal land use is agriculture, which comprises 82.7 percent of the watershed. The areas within the watershed devoted to each of eight major land use categories are listed in Table 289.

One stream was studied in the part of the Sheboygan River watershed that extends into southeastern Wisconsin. This stream rises near the Village of Belgium in northeastern Ozaukee County and is an unnamed tributary of Onion River, which flows into Sheboygan River at the City of Sheboygan Falls.

The Sheboygan River watershed in southeastern Wisconsin occurs in an area underlain by red glacial drift. The eastern boundary of the watershed parallels Lake Michigan and is located along an end moraine about two miles from the lake. The northern part of the western boundary roughly coincides with the end moraine that defines the western limit of the area of red drift. The southern part of the western boundary extends across a red ground moraine and marsh land that occupies the area between the end moraines discussed.

Tributary of Sheboygan River

Present Stream Quality: One sampling station, Sb-1, was established by the SEWRPC on an unnamed tributary of Onion River, a first-rank tributary of the Sheboygan River, at a point about one-half mile downstream from where the unnamed tributary of the Sheboygan River becomes perennial. This stream supposedly does not receive wastes from the Village of Belgium sewage treatment plant.

[13] *Based on SEWRPC estimate for 1963.*

Table 288

FORECAST QUALITY OF SAUK CREEK AT SAMPLING STATION SK-2: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sauk Creek	Sk-2	Chloride (in ppm)	30	30	30	30
		Dissolved Solids (in ppm)	540	540	540	540
		Dissolved Oxygen (in ppm)	11.3	More than 10		
		Coliform Count (in MFCC/ 100 ml)	2,300	Less than 5,000		

Source: SEWRPC.

Table 289

EXISTING LAND USE IN THE SHEBOYGAN RIVER WATERSHED: 1963

Land Use	Area		Percent of Total Watershed
	Square Miles	Acres	
Agricultural	8.5	5,455	82.7
Woodland, Wetland, and Unused Land	1.2	784	11.9
Transportation-Communication	0.3	205	3.1
Residential	0.2	118	1.8
Industrial	<0.1	15	0.2
Governmental-Institutional	<0.1	14	0.2
Park and Recreational	<0.1	4	0.1
Commercial	<0.1	3	0.0
Total	10.3	6,598	100.0

Source: SEWRPC.

The unnamed tributary is apparently a predominantly calcium bicarbonate stream of relatively constant total mineralization. In two complete analyses run on stream samples from the unnamed tributary, calcium was the predominant cation at concentrations of 108 and 104 ppm in October and April 1964, respectively. Bicarbonate was the predominant anion in October 1964 at 410 ppm. Sulfate occurred as the predominant anion at 300 ppm in April 1964. Sulfate concentrations decreased from 300 ppm in April to 168 ppm in October, whereas the bicarbonate concentration increased from 275 ppm to 410 ppm in the same time span. Maximum nitrate concentration was 2.1 ppm. Total phosphorus was 0.52 ppm at station Sb-1 on October 15, 1964. Selected water analyses of the unnamed tributary at sampling station Sb-1 are indicated in Table 290. Stream quality conditions of the unnamed tributary of the Sheboygan River are indicated in Table 291.

The chloride concentrations of the unnamed tributary were 30 ppm in April and 20 ppm in October 1964. No chemical analyses are available of ground water from the glacial drift or from the shallow bedrock units. Assuming that the "background" chloride concentration was as high as 15 ppm, the maximum chloride impact was 15 ppm from human sources.

The dissolved solids concentrations of the unnamed tributary were relatively high as compared to that of other streams and watercourses of the Region. The maximum and minimum "background" concentrations may be 650 and 570 ppm, respectively. The decrease in dissolved solids between the samples collected in April and October 1964 from 675 ppm to 590 ppm was largely due to the net difference between increased bicarbonate and decreased sulfate concentrations.

The dissolved oxygen concentrations in the unnamed tributary at station Sb-1 varied from 16.5 ppm in June to 1.0 in September 1964. The maximum, average, and minimum for the period June through September 1964 were 16.5, 10.0, and 1.0 ppm, respectively. It would appear that this unnamed tributary is subject to sporadic heavy pollutional loads that lower the dissolved oxygen to temporary critical levels (3.0 ppm or less) for the preservation of fish life. Variations in the dissolved oxygen concentrations in the unnamed tributary are shown in Figure 64.

The variations in the coliform counts in the unnamed tributary are shown in Figure 65. At the time of sampling in September 1964, the coliform count was 200,000 MFCC/100 ml. The maximum, average, and minimum concentrations for the period June through September were 200,000, 54,000, and 2,000 MFCC/100 ml. It would appear that this stream is subject to sporadic, heavy pollutional loads that increase the coliform counts to levels normally associated only with discharges of treated wastes from sewage treatment plants.

The temperature variations of the unnamed tributary are shown in Figure 66. The maximum temperature of $87^{o}F$ occurred in June 1964. The average stream temperature for the period June through September 1964 was $68^{o}F$.

Table 290

SELECTED CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL ANALYSES OF STREAM SAMPLES COLLECTED AT SAMPLING STATION SB-1 ON AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER: 1964

Parameter	Analysis	Date of Collection	Analysis	Date of Collection
Silica	6	4-16-64	8	10-15-64
Iron	0.05	"	0.14	"
Manganese	--	--	0.00	"
Chromium	--	--	<0.005	"
Hexavalent Chromium	--	--	0.00	"
Calcium	104	4-16-64	108	"
Magnesium	51	"	45	"
Sodium (and Potassium)	50	"	40	"
Bicarbonate	275	"	410	"
Carbonate	0	"	0	"
Sulfate	300	"	168	"
Chloride	30	"	20	"
Fluoride	--	--	<0.65	"
Nitrite	0.0	4-16-64	0.1	"
Nitrate	--	--	1.9	"
Phosphorus	--	--	0.52	"
Cyanide	--	--	--	--
Oil	--	--	<2	10-15-64
Detergents	0.0	4-16-64	0.1	"
Dissolved Solids	675	"	590	"
Hardness	469	"	457	"
Noncarbonate Hardness	245	"	120	"
Calcium Hardness	260	"	270	"
Magnesium Hardness	209	"	187	"
Alkalinity P	0	"	0	"
Alkalinity M	225	"	335	"
Specific Conductance	756	"	800	"
pH	8.3	"	7.5	"
Color	110	"	45	"
Turbidity	3	"	7	"
Biochemical Oxygen Demand	2.9	"	2.0	"
Dissolved Oxygen	7.6	"	10.5	"
Coliform Count	3,400	"	7,000	"
Temperature (°F)	49	"	55	"

Source: SEWRPC.

Table 291

WATER QUALITY CONDITIONS OF AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER: (1964-1965)

Parameter	Numerical Value			Number of Analyses
	Maximum	Average	Minimum	
Chloride (ppm)	30	25	20	2
Dissolved Solids (ppm)	675	635	590	2
Dissolved Oxygen (ppm)	16.5	9.7	1.0	11
Coliform Count (MFCC/100 ml)	200,000	24,000	2,000	11
Temperature (°F)	87	53	32	11

Source: SEWRPC.

Figure 64

DISSOLVED OXYGEN CONCENTRATIONS IN AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER

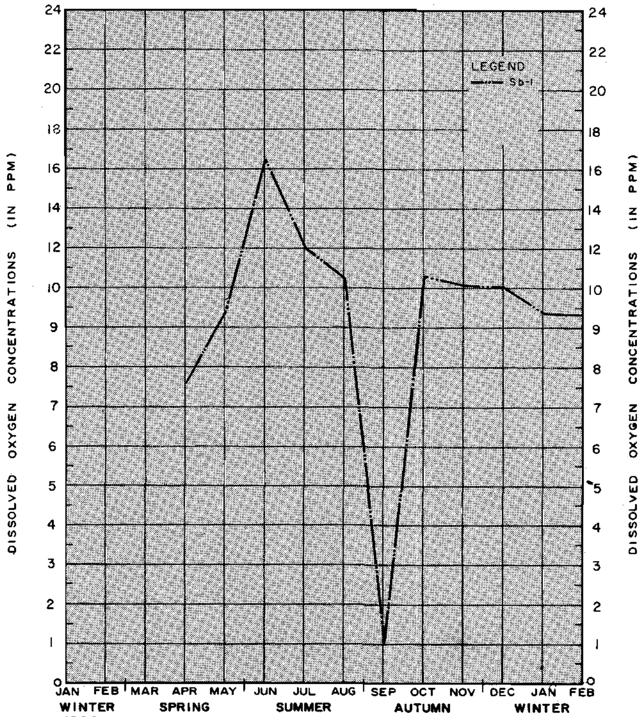


Figure 65

COLIFORM COUNT IN AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER

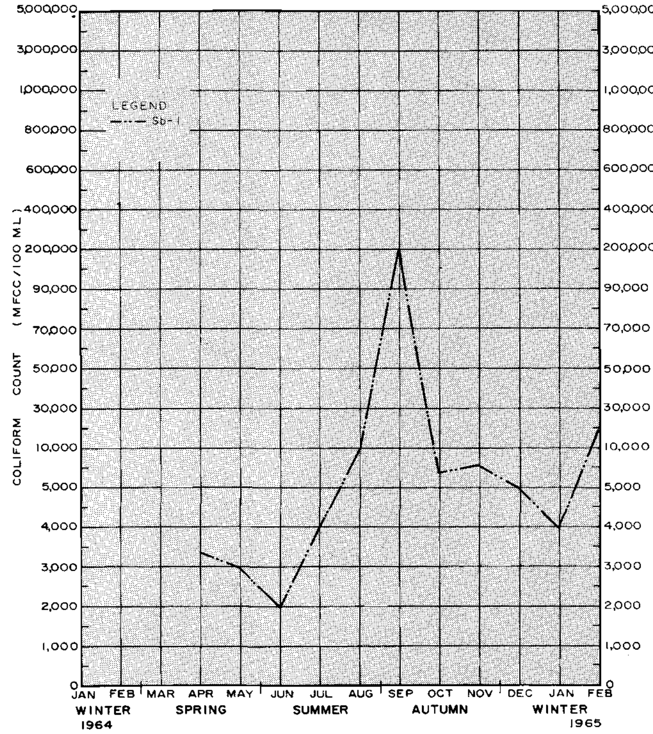
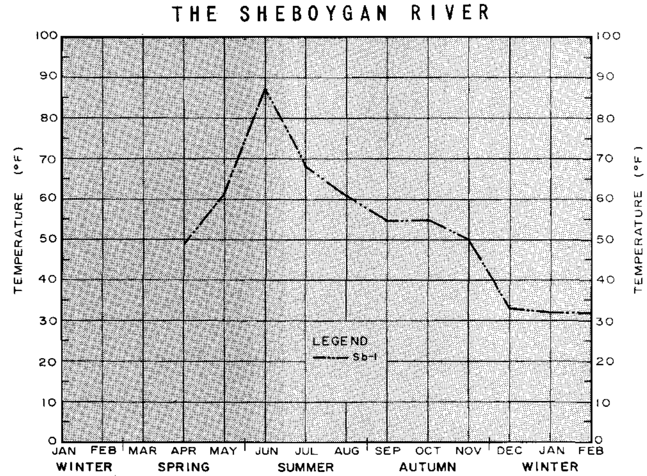


Figure 66

TEMPERATURE OF AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER



Streamflow and Precipitation: The unnamed tributary of the Sheboygan River has a relatively narrow, artificially deepened, and straightened channel. Although this stream at sampling station Sb-1 drains no more than 10.31 square miles, the ground water discharge during the period of study was sufficient to sustain the perennial flow of the stream. At sampling station Sb-1, a distance of about one-half mile from the source, the stream had a maximum depth of 0.8 foot and a width of 3.5 feet when measured under low-flow conditions in October 1964.

During the present study, the flow of the unnamed tributary was measured by the SEWRPC at sampling station Sb-1 in April and October 1964. These measurements are listed in Table 292.

Table 167 indicates the daily precipitation at West Bend, Wisconsin, from January 1964 through February 1965. The precipitation data at this weather station is presumed to represent precipitation in the Sheboygan River watershed in the Region.

Table 292

STREAMFLOW MEASUREMENTS OF AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER: SPRING AND AUTUMN 1964

Sampling Station	Date	Streamflow (cfs)	Previous 7-Day Rainfall (in inches)[a]
Sb-1	4-25-64 10-15-64	3.5 0.5	0.76 0.21

[a] *Measured at U. S. Weather Bureau Station at West Bend, Wisconsin.*

Source: U. S. Weather Bureau and SEWRPC.

Table 293

ESTIMATED POPULATION OF THE SHEBOYGAN RIVER WATERSHED IN SOUTHEASTERN WISCONSIN: 1963 AND 1990 ALTERNATIVE LAND USE PLANS

Location	Estimated Population			
	Existing 1963	1990		
		Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Sheboygan River Watershed	1,000	2,000	4,000	2,000

Source: SEWRPC.

Forecast Quality of a Tributary of the Sheboygan River for the Year 1990: Population studies by the SEWRPC indicate that in 1963 there were about 1,000 people living in the Sheboygan River watershed in the Region. Table 293 indicates the estimated population of the watershed under the three alternative regional land use plans for the year 1990. According to these same plans, the sewage treatment plant at the Village of Belgium will have a connected population ranging from 1,500 to 4,100 people. The treated wastes from this plant will continue to be discharged into a watercourse approximately one mile east of the unnamed tributary. The increase in population within the watershed by 1990 will be centralized about the Village of Belgium and to a lesser extent about the Village of Fredonia. A negligible increase in population is expected to occur in the rural areas of the watershed. Table 294 presents forecasts of future quality of the unnamed tributary of the Sheboygan River.

Table 294

FORECAST QUALITY OF AN UNNAMED TRIBUTARY OF THE SHEBOYGAN RIVER: 1990 ALTERNATIVE LAND USE PLANS

Stream	Sampling Station	Parameter	Stream Quality in 1964	Forecast Quality for 1990		
				Controlled Existing Trend Plan	Corridor Plan	Satellite City Plan
Unnamed Tributary of the Sheboygan River	Sb-1	Chloride (in ppm)	20[a]	20	20	20
		Dissolved Solids (in ppm)	590[a]	590	590	590
		Dissolved Oxygen (in ppm)	10[b]	10	10	10
		Coliform Count (in MFCC/ 100 ml)	54,000[b]	55,000	55,000	55,000

[a] *Based on water analysis for October 1964.*

[b] *Based on average for the period June through September 1964.*

Source: SEWRPC.

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Chapter VI

SUMMARY AND CONCLUSIONS

INTRODUCTION

The previously stated purpose of the present study indicated that for regional planning application the study of stream quality and streamflow must be designed to permit: 1) assessment of the present condition of stream quality in relation to existing major sources of pollution, to existing levels of population, and to land use; 2) assessment of the effects of stream quality on various water uses and concomitant effects on land use patterns; and 3) forecast of future stream quality in major watersheds under alternative long-range regional development plans.

ASSESSMENT OF THE PRESENT CONDITIONS OF STREAM QUALITY

The assessment of the present conditions of stream quality within the Region involved an intensive stream quality sampling program extending over a period of 14 months, during which 3,933 water samples were collected at 87 sampling stations established on 43 streams and watercourses. These samples were analyzed for over 30 chemical, physical, biochemical, and bacteriological water quality parameters. Attention was particularly focused on those conditions of stream quality which would obviate water uses; that is, the condition known as pollution. Efforts to map and appraise regional stream quality for comprehensive planning purposes required stream quality to be evaluated in terms of water quality standards for major water uses rather than in terms of effluent standards for sources of pollution. To meet this requirement, water quality standards were adopted by the SEWRPC for 10 major water uses: municipal (public) water supply, industrial water supply, cooling, waste assimilation, livestock and wildlife watering, irrigation, preservation and enhancement of aquatic life, recreation, navigation, and aesthetic use (see Table 4). The procedures for, and the detailed results of, the stream quality study have been described in ~~detail~~ in preceding chapters of this report. To summarize important aspects of the findings, the 43 streams were comparatively rated in terms of four selected water quality parameters and then ranked in order of decreasing quality. The rank order of each stream in the tabular sequence thus provides a comparative stream quality rating for that stream with respect to the water quality parameter under consideration.

The four water quality parameters selected for the comparative stream quality rating were: chloride, dissolved solids, dissolved oxygen, and coliform count. Chloride was selected because it occurs in stream waters within the Region generally in higher than background concentrations of approximately 10 ppm, primarily as a result of the discharge of treated and untreated sewage and industrial wastes. It is also an inorganic substance that does not decompose, is not chemically changed or physically removed by natural processes, and is one which may adversely affect several water uses when concentrations exceed quality standards, as, for example, use for municipal water supply when concentrations exceed 250 ppm, use for the preservation of fish life when concentrations exceed 500 ppm, and use for livestock and wildlife watering when concentrations exceed 1,500 ppm. Dissolved solids provides a good measure of the mineralization and gross quality of surface waters. Dissolved solids also affects several water uses when concentrations exceed quality standards, as, for example, use for municipal water supply when concentrations exceed 500 ppm and use for irrigation when concentrations exceed 2,000 ppm. Dissolved oxygen provides an excellent measure of stream quality in relation to the preservation and enhancement of aquatic life, concentrations of less than 3.0 ppm being critical for the preservation of aquatic life. Finally, the coliform bacterial count was selected as one of the four parameters for the comparative stream quality rating because it occurs in stream water in high counts, primarily as a result of the discharge of treated and untreated domestic sewage. It also adversely affects a number of water uses when concentrations exceed quality standards, as, for example, use for partial-body contact recreation when concentrations exceed 5,000 ppm and use for whole-body contact recreation when concentrations exceed 2,400 ppm.

Finally, the coliform bacterial count was selected as one of the four parameters for the comparative stream quality rating because it occurs in stream water in high counts, primarily as a result of the discharge of treated and untreated domestic sewage. It also adversely affects a number of water uses when concentrations exceed quality standards, as, for example, use for partial-body contact recreation when concentrations exceed 5,000 ppm and use for whole-body contact recreation when concentrations exceed 2,400 ppm.

Tables 295 through 298 set forth the comparative water quality ratings of the 43 streams and watercourses studied within the Region, together with the three water quality criteria upon which the ratings are based. Also listed are the number of samples upon which the averages were based and the number of sampling stations located on each stream. Data pertaining to sampling station Ml-12 in the Milwaukee River estuary are omitted in calculations of the quality ratings of the Milwaukee River because these data are not considered representative of quality conditions in the estuary.

Table 295

COMPARATIVE STREAM QUALITY RATINGS BASED UPON WEIGHTED AVERAGE CHLORIDE CONCENTRATIONS IN 43 STREAMS OF SOUTHEASTERN WISCONSIN

Comparative Stream Quality Rating	Stream	Watershed	Chloride Concentration (in ppm)			Number of Stream Samples	Number of Sampling Stations
			Maximum	Weighted Average	Minimum		
1	Bark River	Rk	5	5	5	2	1
2	Mukwonago River	Fx	15	5	0	13	1
3	Como Creek	Fx	15	10	5	2	1
4	Kohlsville River	Rk	15	10	5	2	1
5	Ashippun River	Rk	20	10	5	3	1
6	Honey Creek	Fx	15	15	15	6	2
7	East Branch Rock River	Rk	30	15	0	12	1
8	Oconomowoc River	Rk	70	15	0	18	3
9	North Branch Milwaukee River	Ml	20	20	15	3	1
10	Whitewater Creek	Fx	20	20	15	2	1
11	Brighton Creek	DP	30	25	15	2	1
12	Delavan Lake Outlet	Rk	30	25	20	3	1
13	White River	Fx	55	25	5	6	2
14	Sugar Creek	Fx	30	25	20	2	1
15	Nippersink Creek	Fx	30	25	20	2	1
16	Tributary of Sheboygan River	Sb	30	25	20	2	1
17	Turtle Creek	Rk	45	25	15	13	1
18	Cedar Creek	Ml	130	25	15	16	2
19	Sucker Creek	Mh	30	30	30	2	1
20	Milwaukee River	Ml	170	30	0	56[a]	8[b]
21	Poplar Creek	Fx	50	35	20	3	1
22	Wind Lake Drainage Canal	Fx	35	35	30	2	1
23	Muskego Canal	Fx	35	35	35	2	1
24	Barnes Creek	Mh	45	40	30	2	1
25	Sauk Creek	Sk	55	40	20	15	2
26	Bassett Creek	Fx	90	50	20	4	2
27	Des Plaines River	DP	105	50	20	16	2
28	Fox River	Fx	445	50	5	123	12
29	Sussex Creek	Fx	70	60	40	3	1
30	Pike River	Pk	90	65	35	17	2
31	Pike Creek	Pk	90	65	35	15	2
32	Little Menomonee River	Mn	100	65	30	4	1
33	Kinnickinnic River	Kk	115	65	20	2	1
34	Pewaukee River	Fx	120	65	30	17	2
35	Oak Creek	Ok	135	80	30	16	2
36	Jackson Creek	Rk	150	95	45	2	1
37	Root River Canal	Rt	170	95	45	3	1
38	Menomonee River	Mn	425	100	15	51	9
39	Root River	Rt	240	115	30	37	5
40	Pike Creek	Mh	285	130	20	7	1
41	Rubicon River	Rk	850	195	15	16	2
42	Underwood Creek	Mn	340	210	80	4	1
43	Honey Creek	Mn	1270	370	50	10	1
Total						538[a]	86[b]

[a] *Data pertaining to sampling station Ml-12 are omitted.*
[b] *Sampling station Ml-12 is not included.*

Source: SEWRPC.

The four parameters used in the comparative stream quality ratings are expressed as the maximum, weighted average, and minimum concentrations. With respect to chloride, dissolved solids, and coliform count, the sequential order, and thus the comparative stream quality rating, is based upon increasing weighted average concentrations. Where streams have identical weighted averages, the sequence within this group is determined by the maximum concentrations, lower maximums preceding higher maximums. In rating streams according to dissolved oxygen concentration levels, the sequential order, and thus the comparative stream quality rating, is based upon decreasing minimum dissolved oxygen concentrations. Where streams have identical minimum concentrations, the sequence within this group is determined by the weighted average concentrations, higher weighted averages preceding lower weighted averages.

Table 296

COMPARATIVE STREAM QUALITY RATINGS BASED UPON WEIGHTED AVERAGE DISSOLVED SOLIDS CONCENTRATIONS IN 43 STREAMS OF SOUTHEASTERN WISCONSIN

Comparative Stream Quality Rating	Stream	Watershed	Dissolved Solids Concentration (in ppm)			Number of Stream Samples	Number of Sampling Stations
			Maximum	Weighted Average	Minimum		
1	Bark River	Rk	300	280	255	2	1
2	Mukwonago River	Fx	400	285	240	13	1
3	Delavan Lake Outlet	Rk	385	300	255	3	1
4	Oconomowoc River	Rk	470	320	240	18	3
5	Turtle Creek	Kk	450	375	220	13	1
6	Ashippun River	Rk	440	380	320	3	1
7	White River	Fx	560	390	265	6	2
8	Whitewater Creek	Rk	485	395	300	2	1
9	Como Creek	Fx	430	410	390	2	1
10	Milwaukee River	Ml	620	415	245	55[a]	8[b]
11	Honey Creek	Fx	455	420	340	6	2
12	North Branch Milwaukee River	Ml	525	440	400	3	1
13	East Branch Rock River	Rk	570	440	195	12	1
14	Sugar Creek	Fx	450	445	440	2	1
15	Nippersink Creek	Fx	455	455	450	2	1
16	Kohlsville River	Rk	490	480	470	2	1
17	Kinnickinnic River	Kk	680	485	290	2	1
18	Cedar Creek	Ml	730	505	330	16	2
19	Jackson Creek	Rk	570	510	455	2	1
20	Fox River	Fx	1210	510	295	123	12
21	Pike Creek	Mh	780	515	260	7	1
22	Pewaukee River	Fx	755	520	350	17	2
23	Brighton Creek	DP	615	540	460	2	1
24	Wind Lake Drainage Canal	Fx	635	565	495	2	1
25	Bassett Creek	Fx	655	575	530	4	2
26	Barnes Creek	Mh	585	575	560	2	1
27	Sussex Creek	Fx	650	590	535	3	1
28	Pike River	Pk	905	600	380	17	2
29	Sauk Creek	Sk	770	605	200	15	2
30	Oak Creek	Ok	755	605	375	16	2
31	Poplar Creek	Fx	765	615	480	3	1
32	Pike Creek	Pk	840	620	505	15	2
33	Tributary of Sheboygan River	Sb	675	635	590	2	1
34	Little Menomonee River	Mn	815	675	345	4	1
35	Des Plaines River	DP	825	700	430	16	2
36	Menomonee River	Mn	1340	705	435	51	9
37	Root River	Rt	955	715	390	37	5
38	Root River Canal	Rt	790	740	710	3	1
39	Rubicon River	Rk	1970	745	275	16	2
40	Sucker Creek	Mh	790	760	725	2	1
41	Underwood Creek	Mn	1090	880	550	4	1
42	Honey Creek	Mn	2460	985	375	10	1
43	Muskego Canal	Fx	1420	1030	635	2	1
Total						537[a]	86[b]

[a] *Data pertaining to sampling station Ml-12 are omitted.*
[b] *Sampling station Ml-12 is not included.*

Source: SEWRPC.

The weighted average concentration of a parameter was calculated by multiplying the average concentration in each reach of stream by the corresponding length of the reach and then dividing the summation of the resultant products by the total mapped length of the stream. The number obtained from this computation is defined as the weighted average concentration of the given parameter for the specified stream and is intended as a measure of the prevailing level of quality throughout the mapped length of the stream.

The four comparative stream quality rating tables must be used with considerable reservation. The relative position of each stream in the four rating tables is, in fact, relative and not absolute. Comparisons of weighted average, minimum, and maximum numerical values of the four water quality parameters apply to streams having dissimilar numbers of sampling stations (as many as 12, as few as one); dissimilar numbers of total samples analyzed for chloride (as many as 123, as few as two), dissolved solids (also

Table 297

COMPARATIVE STREAM QUALITY RATINGS BASED UPON MINIMUM DISSOLVED OXYGEN CONCENTRATIONS IN 43 STREAMS OF SOUTHEASTERN WISCONSIN

Comparative Stream Quality Rating	Stream	Watershed	Dissolved Oxygen Concentration (in ppm)			Number of Stream Samples	Number of Sampling Stations
			Maximum	Weighted Average	Minimum		
1	Mukwonago River	Fx	16.5	11.6	9.3	13	1
2	Bark River	Rk	13.5	11.2	9.2	12	1
3	Nippersink Creek	Fx	21.6	12.3	8.8	11	1
4	Sugar Creek	Fx	13.9	10.9	8.5	10	1
5	Honey Creek	Mn	15.9	11.9	8.0	11	1
6	Turtle Creek	Fx	14.6	12.1	7.8	14	1
7	Kinnickinnic River	Kk	13.3	10.6	7.3	11	1
8	Delavan Lake Outlet	Rk	14.2	11.6	7.2	13	1
9	Barnes Creek	Mh	21.7	13.5	6.7	11	1
10	Oak Creek	Ok	13.7	10.9	6.4	25	2
11	Kohlsville River	Rk	14.5	10.7	6.0	11	1
12	White River	Fx	14.1	10.1	5.6	23	2
13	Whitewater Creek	Rk	11.4	8.7	5.6	11	1
14	Brighton Creek	DP	13.3	9.7	5.5	11	1
15	Ashippun River	Rk	15.9	10.3	5.0	12	1
16	Honey Creek	Fx	14.5	10.2	4.8	23	2
17	Como Creek	Fx	12.3	8.3	4.8	11	1
18	Oconomowoc River	Rk	14.1	10.8	4.6	39	3
19	Sussex Creek	Fx	12.2	7.7	4.3	12	1
20	Underwood Creek	Mn	20.4	12.6	4.2	11	1
21	Rubicon River	Rk	17.1	11.8	4.2	27	2
22	Wind Lake Drainage Canal	Fx	16.0	10.2	4.1	11	1
23	Pike Creek	Mh	12.0	7.1	3.5	10	1
24	Bassett Creek	Fx	19.5	9.2	3.3	23	2
25	Des Plaines River	DP	13.9	8.6	2.1	25	2
26	Jackson Creek	Rk	13.5	6.0	1.6	12	1
27	Tributary of Sheboygan River	Sb	16.5	9.7	1.0	11	1
28	Muskego Canal	Fx	14.3	6.2	0.8	10	1
29	Pewaukee River	Fx	12.6	7.3	0.7	27	2
30	Milwaukee River	Ml	24.2	10.2	0.5	102[a]	8[b]
31	North Branch Milwaukee River	Ml	13.5	8.8	0.4	12	1
32	Pike Creek	Pk	13.2	6.0	0.4	25	2
33	Sucker Creek	Mh	10.0	4.3	0.3	11	1
34	Little Menomonee River	Mn	13.2	7.5	0.2	12	1
35	Sauk Creek	Sk	19.3	10.6	0.1	25	2
36	Poplar Creek	Fx	12.1	5.9	0.1	13	1
37	Pike River	Pk	11.8	5.3	0.1	27	2
38	Fox River	Fx	19.0	9.6	0.0	166	12
39	East Branch Rock River	Rk	12.8	8.0	0.0	12	1
40	Menomonee River	Mn	18.9	7.6	0.0	99	9
41	Cedar Creek	Ml	13.4	7.5	0.0	25	2
42	Root River	Rt	14.6	7.2	0.0	64	5
43	Root River Canal	Rt	9.2	3.4	0.0	13	1
Total						1057[a]	86[b]

[a] *Data pertaining to sampling station Ml-12 are omitted.*
[b] *Sampling station Ml-12 is not included.*

Source: SEWRPC.

as many as 123, as few as two), dissolved oxygen (as many as 166, as few as 10), and coliform count (as many as 155, as few as 10); dissimilar dates of sampling within a given month in relation to significantly heavy rainfall (such as that which occurred on July 17 and 18, 1964); and dissimilar geographic spacing relative to significant natural and man-made factors that affect stream quality. However, despite these apparent limitations in making fully valid ratings of stream quality, the comparative stream quality ratings are presented as a first attempt in stream quality classification and are intended as a broad regional appraisal of each of the 43 streams studied by the SEWRPC in 1964 and 1965.

ASSESSMENT OF THE EFFECTS OF WATER QUALITY ON WATER USES AND CONCOMITANT EFFECTS ON LAND USE PATTERNS

The assessment of the effects of water quality on various water uses are indicated in Table 299. The exist-

Table 298

COMPARATIVE STREAM QUALITY RATINGS BASED UPON WEIGHTED AVERAGE COLIFORM COUNT IN 43 STREAMS OF SOUTHEASTERN WISCONSIN

Comparative Stream Quality Rating	Stream	Watershed	Coliform Count Expressed in Thousands (in MFCC/100 ml)			Number of Stream Samples	Number of Sampling Stations
			Maximum	Weighted Average	Minimum		
1	Mukwonago River	Fx	1	0.3	< 0.1	12	1
2	Kohlsville River	Rk	6	1.7	0.3	11	1
3	Wind Lake Drainage Canal	Fx	7	1.8	< 0.1	11	1
4	Poplar Creek	Fx	9	1.9	0.3	12	1
5	Ashippun River	Rk	10	2.5	0.1	12	1
6	Nippersink Creek	Fx	10	2.7	0.1	11	1
7	Sugar Creek	Fx	13	3.1	< 0.1	10	1
8	Delavan Lake Outlet	Rk	21	3.2	< 0.1	13	1
9	East Branch Rock River	Rk	21	3.8	0.3	12	1
10	Little Menomonee River	Mn	16	4.7	0.4	12	1
11	Brighton Creek	DP	56	5.9	< 0.1	11	1
12	Como Creek	Fx	21	7.2	0.3	11	1
13	Des Plaines River	DP	32	8.1	0.8	25	2
14	Oak Creek	Ok	33	8.5	0.5	25	2
15	Honey Creek	Fx	40	9.4	< 0.1	23	2
16	Underwood Creek	Mn	83	12.1	< 0.1	11	1
17	Fox River	Fx	610	12.6	< 0.1	155	12
18	Barnes Creek	Mh	88	14.7	< 0.1	11	1
19	Bark River	Rk	100	14.7	0.3	12	1
20	Milwaukee River	Ml	170	14.8	< 0.1	103[a]	8[b]
21	North Branch Milwaukee River	Ml	140	15.4	< 0.1	12	1
22	Sussex Creek	Fx	85	15.9	1.3	11	1
23	Cedar Creek	Ml	120	17.2	< 0.1	24	2
24	Sucker Creek	Mh	140	18.8	0.1	11	1
25	Turtle Creek	Rk	70	18.8	0.4	14	1
26	Sauk Creek	Rk	200	20	0.4	25	2
27	Rubicon River	Rk	270	22	< 0.1	27	2
28	Tributary of Sheboygan River	Sb	200	24	2.0	11	1
29	White River	Rk	570	28	0.4	23	2
30	Bassett Creek	Fx	250	32	0.2	23	2
31	Muskego Canal	Fx	70	33	0.4	10	1
32	Pike Creek	Pk	330	35	1.2	25	2
33	Menomonee River	Mn	1100	52	0.1	99	9
34	Honey Creek	Mn	430	62	< 1	11	1
35	Root River	Rt	1100	71	0.1	64	5
36	Kinnickinnic River	Kk	340	77	4.0	11	1
37	Jackson Creek	Rk	300	86	4.0	12	1
38	Oconomowoc River	Rk	2300	128	< 0.1	39	3
39	Pike Creek	Mh	740	130	10.0	10	1
40	Root River Canal	Rt	1700	150	< 0.1	13	1
41	Whitewater Creek	Rk	1000	196	17.0	11	1
42	Pewaukee River	Fx	3000	197	0.4	25	2
43	Pike River	Pk	1800	260	2.0	27	2
Total						1041[a]	86[b]

[a] *Data pertaining to sampling station Ml-12 are omitted.*
[b] *Sampling station Ml-12 is not included.*

Source: SEWRPC.

ing and forecast suitability of the water in the 43 streams studied for 10 major water uses are presented in this table.

The past and present quality of the streams in southeastern Wisconsin apparently has not, to date, been a major determinant in establishing riverine or areawide land use patterns. While the fresh-water streams are a significant asset to the natural resource base of the Region, this asset has apparently been taken for granted. Despite great advances in the treatment of sewage, the massive "urban sprawl" that has occurred in southeastern Wisconsin since 1950 has, however, contributed to a significant decrease in the quality of many streams and watercourses within the Region. The shifting of land use from rural agricultural, woodland, and wetland uses to urban residential, commercial, and industrial uses has not only increased the amount of surface runoff but has also massively increased the impact of bacteriological and chemical pollutants upon the streams through failure to adjust the new urban land use pattern and its liquid waste disposal facilities to the ability of the streams to assimilate these wastes. Moreover, many lakeside areas have been converted since 1950 from rural to urban use and from intermittent summer cottage use to year-round dwelling use. This change in land use within the catchment area of the inland lakes of the Region may be assumed to affect adversely the quality of these lakes and the quality of the streams fed by the lakes.

This general deterioration of surface water quality within the Region has served to deteriorate or destroy completely many of the more important resource values sought by the suburban and rural-urban dweller and has increased public awareness of the need for water pollution control. Unfortunately, it would seem that water pollution control measures are generally understood solely as facility construction measures that are directed at either initiating, expanding, or improving sewage collection and treatment works to decrease or obviate pollution; and the problem is not linked to its basic cause, that of changing land use. If past trends are continued to the year 1990, people adversely affected by increasing stream pollution within the Region may be expected to continue to demand governmental action to restore favorable stream quality conditions, at an expense which could be avoided, at least in part, through sound areawide land use planning and plan implementation. There is now available a considerable body of information on the quality of the streams of southeastern Wisconsin. It seems reasonable to expect that those who are responsible for water pollution abatement and water quality control within the Region would carefully consider the impact which land use development will have on stream quality. In any attempt to maintain or even improve this quality, consideration should be given as to whether it is justified to assume that technology alone will always provide effective and economically feasible solutions to water pollution problems resulting from indiscriminate or poorly planned land use.

FORECASTS OF FUTURE STREAM QUALITY IN THE MAJOR WATERSHEDS UNDER ALTERNATIVE LONG-RANGE REGIONAL DEVELOPMENT PLANS

Included in Table 299 are forecasts of expected stream quality conditions within the Region as related to the expected suitability of the streams by 1990 for 10 major water uses. Inspection of the tables in Chapter V, which list the forecast quality of each stream for the year 1990, shows almost without exception that, under each of the three alternative regional land use plans prepared by the SEWRPC under the regional land use-transportation study, the corresponding future suitability of a given stream for the various water uses are in the same category. For this reason the predicted suitability of each stream is indicated by one symbol rather than three separate symbols—one for each alternative plan.

GENERAL CONCLUSIONS

The following general conclusions can be drawn from the factual findings of this study with respect to stream quality conditions within the Region:

1. The original, naturally high quality of the streams and watercourses of the Region has markedly deteriorated through the impact of human activity. Stream quality conditions within the Region reflect the deleterious effect of human activity as reflected, for example, in the chloride, dissolved solids, and dissolved oxygen concentrations and in the coliform counts found in this study. Stream pollution may, therefore, be considered as occasionally or persistently severe either locally or widespread in all of the 12 major watersheds within the Region. Persistent, severe, widespread pollution occurs in the watersheds of the Fox, Kinnickinnic, Menomonee, Pike, and

Table 299

EXISTING AND FORECAST SUITABILITY OF STREAMS IN SOUTHEASTERN WISCONSIN FOR 10 MAJOR WATER USES[a]

Stream or Watercourse	Municipal (Public) Water Supply		Industrial Water Supply		Cooling		Waste Assimilation	
	Existing 1964	1990	Existing 1964	1990	Existing 1964	1990	Existing 1964	1990
Des Plaines	U1	U1	U1	U1	U1	U1	S4*	S4*
Brighton Creek	U1	U1	U1	U1	U3	U3	U4	U4*
Fox River	U1	U1	U3	U3	U3	U3	S4*	S4
Sussex Creek	U1	U1	U1	U1	U1	U1	U4*	U4*
Poplar Creek	U1	U1	U1	U1	U1	U1	U4*	U4
Pewaukee River	U1	U1	U1	U1	U1	U1	U4*	U4*
Mukwonago River	U1	U1	S	S	U3	U3	S4	S4
Muskego Canal	U1	U1	U1	U1	U1	U1	U4*	U4*
Wind Lake Drainage Canal	U1	U1	U1	U1	U1	U1	U4	U4*
White River	U1	U1	U1	U1	U1	U1	S4*	S4*
Como Creek	U1	U1	U1	U1	U1	U1	U4*	U4*
Honey Creek	U1	U1	U1	U1	U1	U1	U4*	U4*
Sugar Creek	U1	U1	U1	U1	U1	U1	U4*	U4*
Bassett Creek	U1	U1	U1	U1	U1	U1	U4	U4*
Nippersink Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Kinnickinnic River	U1	U1	U1	U1	U1	U1	U4*	U4*
Menomonee River	U1	U1	U1	U1	U1	U1	S4*	S4
Little Menomonee River	U1	U1	U1	U1	U1	U1	U4*	U4
Underwood Creek	U1	U1	U1	U1	U1	U1	U4*	U4
Honey Creek	U1	U1	U1	U1	U1	U1	U4*	U4
Sucker Creek	U1	U1	U1	U1	U1	U1	U4*	U4*
Pike Creek	U1	U1	U1	U1	U1	U1	U4*	U4*
Barnes Creek	U1	U1	U1	U1	U1	U1	U4*	U4
Milwaukee River	U1	U1	U3	U3	U3	U3	S4*	S4*
North Branch Milwaukee River	U1	U1	U3	U3	U3	U3	S4*	S4*
Cedar Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Oak Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Pike River	U1	U1	U1	U1	U1	U1	S4*	S4
Pike Creek	U1	U1	U1	U1	U1	U1	S4*	S4
East Branch Rock River	U1	U1	U3	U3	U3	U3	S4*	S4*
Kohlsville River	U1	U1	U1	U1	U1	U1	S4	S4
Rubicon River	U1	U1	U1	U1	U1	U1	S4*	S4*
Ashippun River	U1	U1	U1	U1	U1	U1	S4*	S4*
Oconomowoc River	U1	U1	U1	U1	U1	U1	S4*	S4*
Bark River	U1	U1	S	S	U3	U3	S4*	S4*
Whitewater Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Jackson Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Delavan Lake Outlet	U1	U1	U1	U1	U1	U1	S4*	S4*
Turtle Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Root River	U1	U1	U1	U1	U1	U1	S4*	S4
Root River Canal	U1	U1	U1	U1	U1	U1	U4*	U4*
Sauk Creek	U1	U1	U1	U1	U1	U1	S4*	S4*
Tirbutary of Sheboygan River	U1	U1	U1	U1	U1	U1	U4*	U4*

Table 299 (continued)

Stream or Watercourse	Livestock and Wildlife Watering		Irrigation		Preservation and Enhancement of Aquatic Life	
	Existing 1964	1990	Existing 1964	1990	Existing 1964	1990
Des Plaines River	S	S	U1	U1	S	U2
Brighton Creek	S	S	S	S	U5	U5
Fox River	S	U2	S	S	U2	U2
Sussex Creek	S	U2	U1	U1	U5	U5
Poplar Creek	S	S	S	S	U2	S
Pewaukee River	S	U2	U1	U1	U2	U2
Mukwonago River	S	S	S	S	S	S
Muskego Canal	S	U2	U1	U1	U2	U2
Wind Lake Drainage Canal	S	U2	U1	U1	S	U2
White River	S	S	S	S	S	S
Como Creek	S	S	U1	U1	U5	U5
Honey Creek	S	S	S	S	U2	S
Sugar Creek	S	S	S	S	S	S
Bassett Creek	S	U2	U1	U1	U2	U2
Nippersink	S	S	S	S	S	S
Kinnickinnic River	S	S	U1	U1	U5	U5
Menomonee River	S	S	S	S	U2	S
Little Menomonee River	S	S	U1	U1	U2	S
Underwood Creek	S	S	U1	U1	U5	U5
Honey Creek	S	U2	U1	U1	U5	U5
Sucker Creek	S	S	S	S	U2	U2
Pike Creek	U2	U2	U1	U1	U2	U2
Barnes Creek	S	S	U1	U1	U5	U5
Milwaukee River	S	S	S	S	U2	U2
North Branch Milwaukee River	S	S	S	S	S	S
Cedar Creek	S	S	S	S	U2	U2
Oak Creek	S	S	U1	U1	S	S
Pike River	S	S	U1	U1	U2	S
Pike Creek	S	S	U1	U1	U2	S
East Branch Rock River	S	S	S	S	U2	U2
Kohlsville River	S	S	S	S	S	S
Rubicon River	S	S	S	S	S	S
Ashippun River	S	S	S	S	U2	U2
Oconomowoc River	S	S	S	S	S	U2
Bark River	S	S	S	S	S	S
Whitewater Creek	S	S	S	S	S	U2
Jackson Creek	S	S	U1	U1	U2	U2
Delavan Lake Outlet	S	S	U1	U1	S	U2
Turtle Creek	S	S	S	S	S	S
Root River	S	S	S	S	U2	S
Root River Canal	U2	U2	U1	U1	U2	U2
Sauk Creek	S	S	S	S	U2	U2
Tributary of Sheboygan River	S	S	U1	U1	U2	U2

Table 299 (continued)

Stream or Watercourse	Recreation: Whole-Body Contact, Existing 1964	Recreation: Whole-Body Contact, 1990	Recreation: Partial-Body Contact, Existing 1964	Recreation: Partial-Body Contact, 1990	Navigation: Existing 1964	Navigation: 1990	Aesthetics: Existing 1964	Aesthetics: 1990
Des Plaines River	U2	U2	U2	U2	U5	U5	S2	U2
Brighton Creek	U5	U5	U2	U2	U5	U5	S2	U2
Fox River	U2	U2	U2	U2	U5	U5	S2	U2
Sussex Creek	U5	U5	U5	U5	U5	U5	S2	U2
Poplar Creek	U	U	S	S	U5	U5	S2	S2
Pewaukee River	U5	U5	U5	U5	U5	U5	U	U2
Mukwonago River	U5	U5	S	S	U5	U5	S2	S2
Muskego Canal	U	U	U2	U2	U5	U5	S2	U2
Wind Lake Drainage Canal	U	U	S	U2	U5	U5	S2	U2
White River	U2	U2	U2	U2	U5	U5	S2	S2
Como Creek	U5	U5	U5	U5	U5	U5	S2	S2
Honey Creek	U2	U2	U2	U2	U5	U5	S2	S2
Sugar Creek	U5	U5	S	S	U5	U5	S2	S2
Bassett Creek	U5	U5	U5	U5	U5	U5	U	U2
Nippersink Creek	U5	U5	S	U2	U5	U5	S2	S2
Kinnickinnic River	U5	U5	U2	U2	S1	S1	S3	S3
Menomonee River	U2	U2	U2	U2	S1	S1	S2	S2
Little Menomonee River	U5	U5	U5	U5	U5	U5	S2	S2
Underwood Creek	U5	U5	U2	U5	U5	U5	S3	S3
Honey Creek	U5	U5	U2	U5	U5	U5	S3	S3
Sucker Creek	U2	U2	U2	U2	U5	U5	S2	S2
Pike Creek	U5	U5	U2	U2	U5	U5	U2	U2
Barnes Creek	U5	U5	U2	U2	U5	U5	S2	S2
Milwaukee River	U5	U5	U2	U2	S1	S1	S2	S2
North Branch Milwaukee River	U2	U2	U2	U2	U5	U5	S2	S2
Cedar Creek	U5	U5	U2	U2	U5	U5	S2	S2
Oak Creek	U5	U5	U2	S	U5	U5	S2	S2
Pike River	U5	U5	U2	S	U5	U5	S2	S2
Pike Creek	U5	U5	U2	S	U5	U5	S2	S2
East Branch Rock River	U2	U2	S	U2	U5	U5	S2	S2
Kohlsville River	U5	U5	S	S	U5	U5	S2	S2
Rubicon River	U5	U5	U2	U2	U5	U5	S2	S2
Ashippun River	U5	U5	S	S	U5	U5	S2	S2
Oconomowoc River	U5	U5	U2	U2	U5	U5	S2	S2
Bark River	U5	U5	U2	U2	U5	U5	S2	S2
Whitewater Creek	U5	U5	U2	U2	U5	U5	S2	S2
Jackson Creek	U5	U5	U2	U2	U5	U5	S2	S2
Delavan Lake Outlet	U5	U5	S	U2	U5	U5	S2	S2
Turtle Creek	U2	U2	U2	U2	U5	U5	S2	S2
Root River	U2	U2	U2	S	S1	S1	S2	S2
Root River Canal	U5	U5	U2	U2	U5	U5	U2	U2
Sauk Creek	U5	U5	U2	U2	S1	S1	S2	S2
Tributary of Sheboygan River	U5	U5	U2	U2	U5	U5	S2	S2

Table 299 (continued)

Symbols: S - Suitable stream for the specified use.

- S1 - Stream is navigable to ships in harbor area and in lower reaches of the stream.
- S2 - Stream has aesthetic value except locally.
- S3 - Aesthetic value of a stream occupying a channel that is deepened, straightened, banked, and concreted.
- S4 - Waste assimilation capacity commonly not exceeded.
- S4*- Waste assimilation capacity commonly exceeded by one or more pollutants.

U - Unsuitable stream for the specified use.

- U1 - Inadequate streamflow.
- U2 - Substandard quality.
- U3 - Other available sources of water are preferable to stream water.
- U4 - Unsuitable for waste assimilation under low-to-moderate flow conditions.
- U4*- Unsuitable for waste assimilation under low-to-moderate flow conditions. Polluted stream.
- U5 - Inadequate stream depth.

[a] *The evaluations of the suitability of the streams for the 10 major uses are based on the raw water quality of the streams.*

Source: SEWRPC.

Root rivers and in Pike Creek, which is a minor stream tributary to Lake Michigan. Chloride levels have not as yet reached critical levels in terms of most major water uses except in Honey Creek, in the Menomonee River watershed, and in the Rubicon River. With respect to dissolved solids, 26 of the 43 streams and watercourses within the Region have weighted average levels exceeding 500 ppm; with respect to dissolved oxygen, 19 of the 43 streams and watercourses occasionally have minimum levels of less than 3.0 ppm; and with respect to coliform count, 33 of the 43 streams and watercourses have weighted average levels exceeding 5,000 MFCC/100 ml. These findings, considered in the light of existing and potential water uses, indicate the seriousness of the water pollution problem within the Region. A more detailed comparison of the existing stream quality conditions to the standards adopted for existing and reasonable potential water uses further substantiates the seriousness of the pollution problem within the Region.

2. The deterioration of stream quality has impaired or prohibited certain water uses associated with an attractive urban, suburban, and rural environment, particularly full recreational use and use as an aesthetic setting for high-value residential park development.

   The pollution of streams and watercourses of the Region is directly related to urbanization, with the major waste sources being municipal sewage treatment plants and industries. Of the 339.7 square miles of the Region presently developed for urban use, 217.0 square miles, or approximately 64 percent, are served by 53 public sanitary sewage treatment plants, with a total connected population of about 1,419,000 persons, or 84.7 percent of the population of the Region. Of this total connected population, approximately 168,000 persons, or 11.8 percent of the total connected population, are presently served by 44 sewage treatment plants that discharge treated wastes to the 43 streams and watercourses within the Region. Lake Michigan receives the effluent from nine sewage treatment plants with outfalls in or very near the lake. These nine plants serve an estimated 1,196,000 persons.

3. The population of the Region is expected to increase by over one million persons in the next 25 years, thereby greatly increasing the connected populations of all of the sewage treatment plants and requiring the construction of new plants and tributary collection systems in certain areas of the Region. The pollution of the streams and watercourses of the Region is also related to storm water runoff and to the development of residential areas served by on-site sewage disposal systems which fail to function properly on certain soils. Over 15 percent of the present population of the Region, about 255,000 persons, is served by on-site sewage disposal systems. Detailed operational soil surveys covering the entire Region indicate that over 49 percent of the Region is covered by soils unsuitable for septic tank sewage disposal systems.

Although municipal sewage treatment plants are concluded to be the most important sources of pollution with respect to almost all of the parameters determined in the study, it is not implied that these plants are necessarily operating below efficiency or are of defective design. Although these wastes may be processed by conventional secondary sewage treatment methods, the discharge of treated sewage into the natural waterways of the Region poses a real and potential threat to the quality of the receiving streams because of the low natural base flow of the streams and concomitant low waste assimilation capacity. Moreover, ordinary sewage treatment methods do not remove all plant nutrients from the effluent and, therefore, serve to greatly enrich the streams. Such enrichment is indicated by the levels found by this study to prevail in many of the streams within the Region. Without the application of technically feasible means for improving the quality of the effluent from municipal sewage treatment plants and ultimately removing nutrients, the stream quality forecasts prepared in the study clearly indicate that the natural waste assimilation capacities of many of the streams and watercourses will be overwhelmed by increased treated waste loadings and certain streams reduced to little more than open sewers.

At least three general courses of action appear to be required if further deterioration of stream quality within the Region is to be avoided.

1. Further intensive urban development dependent upon on-site sewage disposal systems on soils not suited to the proper functioning of such systems must be avoided and this growth directed instead into those areas of the Region which can be readily served by gravity drainage sanitary sewer systems tributary to existing and, in some cases, new sewage treatment plants.

2. Within the context of a regional sanitary sewerage system plan and a comprehensive watershed planning program for each of the major watersheds within the Region, provision must be made either for the export of liquid wastes or for the provision of higher levels of treatment than are presently being provided. The latter course of action requires technological advances in the field of sewage treatment. It should also be noted that the export of sewage, particularly to Lake Michigan, may provide both problems and opportunities with respect to the abatement of pollution of Lake Michigan. The principal problems associated with such export are primarily the result of increased pollution loadings on Lake Michigan through decreased utilization of the natural ability of tributary streams to treat wastes. The opportunities are primarily associated with the concentration of liquid wastes at large centralized treatment plants where not only more efficient plant operation can be more readily achieved but where the future addition of improved treatment methods may be more readily and economically effected.

3. Since the study clearly indicates a relationship between urbanization and stream pollution, it must be recognized that pollution abatement is, within southeastern Wisconsin, basically a problem of land use. Consequently, it will be extremely important in the preparation of future land use plans at the local, county, and regional levels to adjust, wherever possible, the future land use pattern to the waste assimilation capacities of the streams and watercourses. Such adjustment must be recognized as a complex design problem involving many factors and can best be accomplished within the context of comprehensive watershed planning programs properly related to an areawide regional planning effort. Perhaps the singularly most important conclusion indicated by the study is the close relationship between land use and stream pollution within the Region and the need to plan future land use and water quality control elements simultaneously. It is, indeed, dangerous to assume that technological advances in waste treatment will always solve pollution and that the application of these advances will always be economically feasible. Therefore, increased emphasis should be placed on coordinated land and water use planning in all future pollution abatement and water quality control efforts within the Region.

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Appendix A

METHODS OF WATER ANALYSIS

This presentation of the analytical methods used in determining the chemical, physical, biochemical, and bacteriological parameters is a documentation of procedures and is intended to facilitate evaluation of the analytical results and to permit duplication of procedures for future stream quality studies in the Region.

The water analyses of stream samples collected as part of the present study were performed by the State Laboratory of Hygiene and by the SEWRPC.

The State Laboratory of Hygiene determined the following parameters:

1. Fluoride
2. Chromium
3. Hexavalent chromium
4. Phosphorus
5. Cyanide
6. Oil
7. Biochemical oxygen demand
8. Coliform count

The SEWRPC determined the following parameters:

1. Silica
2. Iron
3. Manganese
4. Calcium
5. Magnesium
6. Sodium
7. Bicarbonate
8. Carbonate
9. Sulfate
10. Chloride
11. Nitrite
12. Nitrate
13. Detergents (synthetic)
14. Dissolved solids
15. Hardness
16. Noncarbonate hardness
17. Calcium hardness
18. Magnesium hardness
19. Alkalinity P
20. Alkalinity M
21. Specific conductance at 25°C
22. pH
23. Color
24. Turbidity
25. Dissolved oxygen
26. Temperature (°F)

STATE LABORATORY OF HYGIENE METHODS OF WATER ANALYSIS

The methodology of the State Laboratory of Hygiene in water analysis is omitted from discussion because it is based exclusively upon procedures set forth in the American Public Health Association, Standard Methods for the Examination of Water and Waste Water.

SEWRPC METHODS OF WATER ANALYSIS

The methodology of the SEWRPC in water analysis is based largely upon commercial analytical procedures set forth by the Hach Chemical Company and Hellige, Inc., and in part upon standard methods of the American Public Health Association.

The analytical methods selected and used by the SEWRPC were considered in relation to the level of precision and accuracy required to meet the objectives of the regional stream quality study and in relation to the water quality standards applied in the appraisal of stream quality. The analytical methods of the Hach Chemical Company and of Hellige, Inc., were followed exactly with few exceptions. These exceptions are mentioned briefly under the particular parameters to which the analytical methods apply.

Silica (Source of analytical method: Hellige, Inc.)

1. Fill square glass test tube to the 5 ml mark with the sample to be tested. If the sample is not clear (has a turbidity exceeding 25 ppm), filter a portion; but do not use the first 15 to 20 ml that pass through the filter.

2. Add 0.2 ml hydrochloric acid (2.4N).

3. Add 2 ml ammonium molybdate (11.4 percent). Mix and allow to stand for 2 minutes.

4. Add sodium sulfite (22.7 percent) until the solution in the tube reaches the 10 ml mark. Mix, note the time, and place tube in right-hand opening of color comparator.

5. Prepare a blank solution by repeating the procedure with a second tube, but using distilled water in place of sample in Step 1. Place this tube in left-hand opening of the comparator.

6. Place silica color disc in the comparator. Within 5 to 15 minutes after adding sodium sulfite in Step 4, make the color comparison while using a Hellige Daylite comparator illuminator. Revolve the color disc so that one color standard after another is brought into the observation field. When a color match is obtained with one of the standards, the result is read directly from the figure seen in the upper opening at the right side of the front cover. If the color of the test solution is intermediate, the result of the test will be intermediate and may be estimated by interpolation between corresponding color standards.

Iron (Source of analytical method: Hach Chemical Co.)

1. Measure 25 ml of sample and pour into 125 ml beaker.

2. Add 0.1 gram spoonful of TeVer (2,4,6,-Tripyridyl-s-triazine) powder to the sample. Swirl the beaker to mix the sample. Let stand for 5 minutes before measuring color in 1-inch test tube using the Spectronic 20 colorimeter at a wave length setting of 595 mu. If iron is present, a blue color will develop.

3. Use demineralized water for standardizing the colorimeter.

4. Measure the color of the prepared test sample and obtain iron concentration in ppm from table.

Note: Usually this indicator contains a small blank, which for most accurate work should be subtracted from the readings obtained from the table. The reagent blank is determined by measuring the color developed by the reagent in 25 ml of demineralized water, when compared with demineralized water alone. The blank was found to be 0.031 ppm and was subtracted from the readings obtained from the table.

Manganese (Source of analytical method: Hach Chemical Co.)

1. Measure 250 ml of sample and pour into 500 ml separatory funnel.

2. Measure 250 ml sample of demineralized water and pour into 500 ml separatory funnel.

3. Add to each separatory funnel 1.0 gram spoonful of citrate buffer. Stopper and shake each to mix.

4. Add to each separatory funnel 0.05 gram (in form of a commercially premeasured quantity). Stopper and shake each to mix. Allow 5 minutes for maximum color development.

5. Add to each separatory funnel one level 0.5 gram spoonful of tetraphenylarsonium chloride hydrochloride. Stopper and shake each to mix.

6. Add to each separatory funnel exactly 30 ml of dichloromethane. Stopper and grasp the top of the separatory funnel, gently inverting it. While it is in an inverted position, open the stopcock and vent the separatory funnel. Shake vigorously for 30 seconds and vent the funnel. Repeat using the other separatory funnel.

7. Remove the stopper and allow the separatory funnels to stand for one to two minutes to allow the dichloromethane to separate.

8. Drain the dichloromethane through a filter thimble containing a cotton plug into a one inch test tube. Repeat with the other sample.

9. Use the demineralized water sample for standardizing the Spectronic 20 colorimeter at a wave length setting of 530 mu.

10. Exactly 10 minutes after addition of the sodium periodate in Step 4, measure the color and obtain the manganese concentration in ppm from the table.

Calcium (Source of analytical method: Hellige, Inc.)
In the following analytical procedure, calcium is determined as calcium carbonate ($CaCO_3$) rather than as calcium in its ionic form (Ca^{++}). The ionic concentration of calcium is calculated from the analytical results.

1. Measure 58.3 ml of sample and pour it into a 250 ml beaker.

2. Add 2 ml sodium hydroxide (1.0N).

3. Add 1 measuring scoop of calcium indicator. Stir until the indicator dissolves.

4. Fill burette to the 0.0 ml mark with hardness titrating solution (Versene). Place beaker on white surface. Titrate slowly and stir well until the end point is just reached. As the end point is reached, the pink color of the sample begins to turn purple; and the end point is the complete disappearance of the pink color.

The results of this analytical procedure are expressed in terms of calcium hardness as calcium carbonate ($CaCO_3$) measured in grains per gallon. To express results in ppm, multiply grains per gallon by conversion factor 17.12. To obtain the concentration of calcium in its ionic form (Ca^{++}), divide the calcium hardness in ppm by 2.497.

Magnesium
The magnesium content of water samples was calculated from the analytical determinations of total hardness and calcium hardness. The ionic concentration of magnesium in ppm is equal to the difference between the total hardness in ppm and the calcium hardness in ppm divided by 4.116.

Sodium
The sodium content of water samples analyzed by the SEWRPC is computed. This computed value is based on the chemical analysis of other constituents of the water and equals the difference between the sum of the determined anions in epm (equivalents per million) and the determined cations expressed in epm. The sodium computation includes potassium, and these are not differentiated.

The computation method of determining sodium has been used extensively for years because the available methods for chemical analysis for this parameter were tedious and costly. Although flame photometry has simplified direct determination of sodium, this analytical technique was not available to the SEWRPC.

In computing values of sodium, it should be stated that these also include the algebraic sum of possible errors in analysis and errors that result from the possible analytical omission of important parameters.

Bicarbonate and Carbonate
Bicarbonate and carbonate are computed in ppm from the direct determinations of methyl-orange (total or M alkalinity) and phenolphthalein alkalinity (P alkalinity) according to the following equations:

$$\text{Bicarbonate} = \frac{M - 2P}{0.8202} \text{ when } P < 1/2\ M$$

$$\text{Carbonate} = 2P$$

Sulfate (Source of analytical method: Hach Chemical Co.)

1. Measure 25 ml of sample and pour into 125 ml beaker.

2. Add 1 gram spoonful of SulfaVer powder to the sample. Allow the sample to stand undisturbed for 30 seconds and then mix for 30 seconds with magnetic mixer.

3. Use some of the original water sample in 1/2-inch test tube to standardize the Spectronic 20 colorimeter after the instrument has been warmed up for at least 5 minutes, adjusted for zero reading, and set for 500 mu wave length. Measure turbidity of prepared sample in 1/2-inch test tube and obtain sulfate concentration in ppm from the table.

   The Hach Chemical Company recommends that "... if the sample is colored or turbid," the sample should be "... filtered and that the filtered water be used in Steps 1 and 3. Turbidity and/or color will interfere and cause high readings." Only those stream samples having a turbidity of over 25 units were filtered before chemical analysis for sulfate. No samples were filtered on the basis of natural color density unless the turbidity of the sample exceeded 25 ppm.

Chloride (Source of analytical method: Hellige, Inc.)

1. Measure 50 ml of sample and pour into a 250 ml beaker.

2. Add 3 drops of phenolphthalein indicator solution. If a red color appears, add sulfuric acid (N/10) one drop at a time with constant stirring until the red color just disappears.

3. Add 5 drops of potassium chromate indicator solution and stir.

4. Fill burette to 0.0 ml mark with silver nitrate solution (N/10). Place beaker on white surface. Titrate carefully, controlling the stopcock of the burette to add a few drops at a time to the sample. Stir well after each addition and continue titrating until the end point is just reached. The end point is the first permanent change in color from lemon yellow to pale orange or the first appearance of a permanent reddish color.

5. At the end point, note the burette reading in milliliters and multiply by 71 to obtain the result in terms of parts per million chloride (Cl^-).

6. If more than 14 ml silver nitrate is required to reach the end point, repeat the test with a diluted sample and multiply by the dilution factor.

Note: A blank determination should be made on 50 ml of distilled water. Subtract the burette reading for the blank (0.1 ml) from the burette reading for the sample before multiplying as in Step 5.

Nitrite (Source of analytical methods: Hach Chemical Co.)
Two procedures were used for the determination of nitrite. The first procedure involved visual color comparison and was applied to all samples collected from the beginning of the water quality study in January 1964 through June 1964. The second procedure involved the use of a photoelectric colorimeter, and this procedure was applied to all samples collected from July 1964 through February 1965.

Procedure for Visual Comparison:

1. Measure 25 ml sample and pour into 150 ml beaker.

2. Add 1 premeasured quantity (about 0.25 gram) of NitriVer and swirl to mix. Allow the color to develop for 10 minutes, during which time occasionally swirl the sample for several seconds.

3. Measure the color by filling a sample viewing tube and placing it on a viewing block. Select the color standard ampule that makes the nearest color match by placing color standard ampules on the block beside the sample tube and comparing colors. The nitrite concentration in ppm is read from the label on the selected color standard ampule.

Note: The color standard ampules used for color comparison covered the following nitrite concentrations in ppm: 0.025, 0.05, 0.075, 0.1, 0.2, 0.3, and 0.4.

Nitrite is subject to relatively rapid oxidation and conversion to nitrate. The nitrite determinations made from January 1964 through June 1964 are considered to be less than satisfactory as indicating the nitrite concentration at the time of sampling. Nitrite was not placed sufficiently high on the list of test priorities established as a guide for the sequence of analytical tests run on all samples.

Procedure for Photometric Determination:

1-2. Same as Steps 1 and 2 above but allow to stand for 15 minutes.

3. Pour some of the original sample in a 1/2-inch test tube and standardize the Spectronic 20 colorimeter at 525 mu wave length setting.

4. Rinse test tube used in Step 3 with distilled water and with a portion of the sample to be tested. Refill test tube with test sample, measure the transmissivity and obtain nitrite determination from table.

Note: The nitrite determinations made from July 1964 through February 1965 are considered to be satisfactory as indicating the nitrite concentration at the time of sampling. All nitrite determinations were made within three days from the time of sampling, and most were made within 24 hours.

Nitrate (Source of analytical method: Hach Chemical Co.)
The analytical method described in the following steps determines nitrate and nitrite in combination. Subtract the nitrite content from the nitrate test value to obtain the nitrate content in ppm.

1. Measure 5.0 ml sample and transfer to 125 ml beaker.

2. Measure 5.0 ml sample of demineralized water and transfer to 125 ml beaker.

3. Measure 20.0 ml titanium free concentrated sulfuric acid and add to each beaker. Swirl each beaker gently to mix.

4. Promptly add to each beaker one 0.1 gram measuring spoonful of NitraVer II. Swirl each beaker to mix. If nitrate and nitrite are present, a yellow color will develop. Allow $10^{\pm}1$ minutes for maximum color development.

5. Pour prepared demineralized water sample into 1/2-inch test tube and standardize the Spectronic 20 colorimeter. The wave length setting is 415 mu.

6. Rinse test tube used in Step 5 with distilled water and a portion of the prepared test sample. Refill test tube with prepared test sample and measure transmissivity. Obtain combined nitrate and nitrite concentration from table.

7. To obtain the nitrate concentration, subtract the nitrite content (determined from the direct analytical procedure for nitrite) from the nitrate and nitrite test value obtained in Step 6 above.

Detergents, synthetic (Source of analytical method: Hach Chemical Co.)

1. Measure 9.4 ml sample and place in test tube.

2. Add 6 drops (0.4 ml) ABS test solution and shake to mix.

3. Add 2 ml chloroform. Stopper and shake vigorously for 30 seconds and allow to stand for one minute to permit chloroform to separate and settle.

4. Using a dropper, remove and discard the water from the test tube.

5. Refill the test tube with about 7.5 ml demineralized water. Using the dropper, remove and discard water. This step washes away original water sample used in Step 1.

6. Place a small ball of glass wool in glass filter thimble. Allow 2 ml chloroform to slowly move through thimble and discard the chloroform. This step eliminates an interference effect that has been directly ascribed to the use of the fiber glass filtering process.

7. Refill the test tube with about 7.5 ml demineralized water, stopper and shake vigorously for 30 seconds. Allow to stand for one minute to permit the chloroform to separate and settle.

8. Using a dropper, remove the test chloroform and filter the chloroform into a viewing tube and place on a viewing block. Select the color standard ampule that makes the nearest color match by placing color standard ampules on the block beside the sample tube and by comparing colors. The detergents concentration in ppm is read from the label on the selected color standard ampule.

Note: The color standard ampules used for color comparison covered the following detergents concentration in ppm: 0.0, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, and 2.0.

Dissolved Solids

The calculation method is used in determining dissolved solids. This method involves the summation of all solid constituents in their anhydrous form. For this reason bicarbonate must be converted mathematically to carbonate before summation by multiplying the bicarbonate concentration by the conversion factor 0.4917.

Determinations of dissolved solids by the SEWRPC include the following 13 parameters: silica, iron, manganese, calcium, magnesium, sodium (and potassium), bicarbonate (converted to carbonate), carbonate, sulfate, chloride, nitrite, nitrate, and detergents. Of the parameters listed, iron, manganese, and nitrate were determined infrequently and were often not included in the dissolved solids calculation. Iron was determined on water samples collected in April and in the September-October period of 1964. Manganese was determined during the September-October period. Nitrate determinations were made on all water samples collected during the 5-month period extending from October 1964 through February 1965.

Iron, manganese, and nitrate are very minor constituents of the water samples collected by the SEWRPC; therefore, the dissolved solids determinations indicate closely the total mineralization of the samples. This statement is correct if the determination of each reported parameter is valid and if the water analysis is adequately complete.

Hardness (Source of analytical method: Hellige, Inc.)

1. Measure 58.3 ml sample and pour into 250 ml beaker.

2. Add 12 drops hardness buffer solution.

3. Fill measuring scoop with hardness indicator and add to sample. Stir until the indicator dissolves.

4. Fill burette to 0.0 ml mark with hardness titrating solution (Versene). Place beaker on white surface. Titrate slowly and stir well until end point is just reached. As the end point is reached, the red color of the sample begins to turn blue. The end point is the complete disappearance of the red color.

The results of this analytical procedure are expressed in terms of calcium carbonate measured in grains per gallon. To express results in ppm, multiply grains per gallon by conversion factor 17.12.

Noncarbonate Hardness

Noncarbonate hardness is calculated according to the following equation:

Noncarbonate hardness	=	50.05 x (epm hardness-epm alkalinity)
where: epm hardness	=	sum of epm Ca, Mg, and Ba and
epm alkalinity	=	sum of epm bicarbonate and epm carbonate

Noncarbonate hardness is expressed in ppm.

Calcium Hardness and Magnesium Hardness

Calcium hardness is obtained as part of the analytical procedure for calcium determination. Step 4 under the discussion of calcium expresses the calcium content as calcium carbonate, which is the calcium hardness.

Magnesium hardness is the arithmetic difference between hardness (also referred to as total hardness) and calcium hardness and expresses the magnesium content as magnesium carbonate.

Alkalinity P (Source of analytical method: Hellige, Inc.)

Alkalinity P, phenolphthalein alkalinity, is determined as an indirect measurement of carbonate. Carbonate equals the concentration of phenolphthalein alkalinity multiplied by 2.

1. Measure 50 ml sample and pour into 250 ml beaker.

2. Add 4 drops of phenolphthalein indicator solution and stir. If a red color does not occur, alkalinity P is absent. If a red color appears, proceed to Step 3.

3. Fill burette to 0.0 ml mark with sulfuric acid (N/10). Place the beaker on white surface. Titrate slowly and stir well until the end point is just reached. As the end point is reached, the red color changes to colorless. The end point is the complete change of red to colorless.

4. At the end point, note the burette reading and multiply by 100 to obtain alkalinity P in ppm calcium carbonate.

Note: Hellige, Inc., recommends filtering the sample used in Step 1 if "the sample is very turbid." None of the water samples analyzed by the SEWRPC for determination of alkalinity P were filtered regardless of the turbidity of the sample.

Alkalinity M (Source of analytical method: Hellige, Inc.)

Alkalinity M, methyl-orange alkalinity (or total alkalinity), is determined as an indirect measurement of bicarbonate. The alkalinity as calcium carbonate is divided by 0.8202 to convert to bicarbonate.

1. Follow the analytical procedure for the determination of alkalinity P.

2. Do not refill burette if it was used for titrating alkalinity P. If alkalinity P was absent in Step 2, fill burette to 0.0 ml mark with sulfuric acid (N/10).

3. Add 3 drops of methyl-orange indicator solution to the sample used for alkalinity P determination and stir. The test sample becomes yellow.

4. Titrate slowly and stir well until the end point is just reached. As the end point is reached, the yellow color changes to pale pink. The end point is the complete change of yellow to pink.

5. At the end point, note the burette reading and multiply by 100 to obtain alkalinity M in ppm calcium carbonate.

Note: None of the water samples analyzed by the SEWRPC for determination of alkalinity M were filtered regardless of the turbidity of the sample.

Specific Conductance at 25°C (Source of analytical procedure: U. S. Public Health Service and American Public Health Association)

1. Prepare temperature bath of approximately 35°C.

2. Place water sample (in original 2-quart plastic sampling bottle) in temperature bath and stir sample with stainless steel centigrade thermometer rod, noting slow temperature buildup from sample storage temperature of 20-21°C.

3. As temperature approaches approximately 24.3°C, remove sample from bath and continue stirring. Note stabilization temperature. Replace sample in temperature bath for a few seconds only, slowly building sample temperature to 25.0°C. Reduce sample temperature in cold water bath if 25.0°C is bypassed in temperature buildup.

4. Measure conductance with electric conductivity bridge pretested on standard potassium chloride solution to ensure no change in dip cell constant (2.0) since previous series of conductivity tests. Remove dip cell from distilled water container where cell is stored between sample tests. Vigorously shake dip cell to remove droplets of distilled water adhering to inner wall of cell casing and remove all external moisture to avoid chemical contamination of sample to be tested. Place dip cell in water sample and move cell up and down repeatedly to ensure removal of air bubbles inside cell casing through air vents. Immerse cell to a point at least 1/2 inch above air vents. Turn dial control to a position where electron ray "eye" tube null indicator is in balanced position. Record conductance scale reading. If conductance is near or beyond the extreme ranges of the instrument scale at position 1 on the conductivity scale selector, reset scale selector to appropriate position to ensure that conductance readings fall properly within the extreme ends of the scale.

5. Multiply conductance scale reading by conductance range-scale factor to obtain unadjusted conductance reading.

6. Multiply cell constant (2.0) by unadjusted conductance reading to obtain specific conductance at 25°C.

Note: The cell constant was determined according to APHA Standard Methods. The following cell-constant determinations, made near the beginning and near the end of the 14-month period of chemical analysis, are listed below:

1) Date of determination: February 4, 1964.
Cell constant: 2.0550

2) Date of determination: January 12, 1965.
Cell constant: 2.0197

pH (Source of analytical method: Hellige, Inc.)

1. Fill square glass test tube to the 5 ml mark with the sample to be tested.

2. Add 0.5 ml cresol red pH indicator solution and mix.

3. Place tube in right-hand opening of color comparator.

4. Fill a second square glass test tube with 5 ml of sample and place in left-hand opening of comparator.

5. Place color disc that corresponds with the indicator solution used in Step 2 in color comparator. Make color comparisons while using a Hellige Daylite comparator illuminator. Revolve the color disc so that one color standard after another is brought into the observation field. When a color match is obtained with one of the standards, the result is read directly from the figure seen in the upper opening at the right side of the front cover. If the color is intermediate, the result of the test will be intermediate and may be estimated by interpolation between corresponding color standards. The color disc may be read to the closest one-tenth of a pH unit.

6. If the pH of the test sample is at or beyond the pH range covered by cresol red, use appropriate pH indicator solution and corresponding color disc and proceed from Step 1 to Step 6.

Color (Source of analytical method: Hach Chemical Co.)
The color determination of water is not an analytical procedure that provides information on the kind and amount of dissolved substances that cause the color. Rather, an arbitrary standard scale is used to compare the color density with the water sample.

Color determinations are subject to interference effects by the turbidity of the sample. The analytical procedure used by the SEWRPC does not involve filtration or centrifuging prior to color determination. An 8-ounce portion of the sample is set aside for a two-to-three week storage under undisturbed condition at 20-21^{o}C. At the time of analysis, the photoelectric colorimeter is standardized with distilled water; and the stored test sample is carefully poured into the colorimeter to avoid dispersing the solids which have accumulated at and near the bottom of the storage bottle.

The method of color determination presented below involves the use of the Hach Direct-Reading Colorimeter and an APHA platinum-cobalt standard with a color meter scale range of 0-500 units.

1. Insert color meter scale in the photoelectric colorimeter and use the 5543 color filter. Fill colorimeter bottle with distilled water to the base of the bottle neck. Note ground mark on neck of bottle and always place bottle in light cell with ground mark turned toward light switch. Press light switch and adjust light control for a meter reading of zero units.

2. Rinse colorimeter bottle with small part of test sample. Fill colorimeter bottle with test sample to base of bottle neck. This filling process must be very carefully done to avoid dispersal of settled suspended solids into that part of sample to be poured into colorimeter bottle.

3. Place colorimeter bottle into light cell in same position as indicated in Step 1. Press light switch and read density of color in platinum-cobalt standard units.

Note: The accuracy of this test is not definitely known. All readings are thought to be accurate to the nearest five units.

Turbidity (Source of analytical method: Hellige, Inc.)
The measurement of water turbidity is similar to color determination in that the kind and amount of substances causing turbidity are not determined but, rather, the amount of optical obstruction of light passing through a test sample. Turbidity is expressed in Jackson candle units.

The analytical procedure discussed below omits many details which are important in the mechanics of running the turbidity test but are beyond the scope of this presentation. The manufacturer's procedural methods were followed without modification.

1. Inspect turbidity of test sample to select turbidity tube of appropriate viewing depth. (The SEWRPC analyses were based on 20 and 50 mm viewing depths.)

2. Select calibration graph for the desired range of turbidity measurement and place filter frame and rectangular door mirror in positions designated on the graph.

3. Fill turbidity tube to the level mark on the tube with representative test sample. Immediately insert glass plunger into turbidity tube and place it in the circular groove of the turbidimeter mirror.

4. Immediately close door of apparatus and switch on the light.

5. Rapidly balance light intensity of the central spot with the surrounding field of observation by turning light control dial on right side of instrument. The interval of uniform illumination is approached from the lower (dark) side, and the reading is taken at a point where the dark central part first merges with the surrounding field.

6. Record light control dial reading. Correlate reading with calibration graph to obtain turbidity reading in Jackson candle units.

Note: All procedures from Step 3 through Step 5 should be performed rapidly to avoid erroneous readings due to settling of suspended matter.

Dissolved Oxygen (Source of analytical method: APHA Standard Methods)

1. Collect sample as specified on page 12 and inspect for air bubbles rising within the sample or adhering to the inner surface of the sample bottle. Precaution is required to avoid entrapment and solution of atmospheric oxygen in bottle. Reject sample if there is evidence of air bubbles and resample until satisfactory condition is obtained.

2. Add 2 ml manganous sulfate solution to the bottle followed by 2 ml alkali-iodide-azide reagent well below the surface of the sample. Stopper with care to avoid entrapment of air bubbles below stopper. Mix by rapidly inverting bottle 20 times.

3. When the precipitate settles, leaving a clear supernatant above the manganese hydroxide floc, shake again by successive inversions (20 in number). When settling has resulted in at least 100 ml clear supernatant, proceed to Step 4.

4. Carefully remove stopper and immediately add 2 ml concentrated sulfuric acid by allowing the acid to pour down the neck of the bottle, restopper, and mix by inversion until dissolution is complete.

5. Pour 203 ml sample into 500 ml Erlenmeyer flask.

6. Titrate with 0.025N thiosulfate to a pale straw color. Add 1-2 ml freshly prepared starch solution and continue titration to the first disappearance of the blue color that appeared by the addition of the starch. If the end point is overrun, the sample may be back-titrated with 0.025N biniodate, which is added dropwise. Correction for the amount of biniodate added should be made. Subsequent recolorations should be disregarded.

7. Record the quantity of titrant used to bring test to completion. Each milliliter of titrant used is equivalent to 1 mg/1 or 1 ppm dissolved oxygen. Record to 0.1 ppm.

Note: Steps 1 through 4 are performed in the field at the time of sampling. Steps 5 through 7 are performed in the laboratory.

Temperature

Stream temperature was measured at the time of sampling with either a Fahrenheit or a centigrade thermometer placed directly into the stream and held in an almost completely submerged position to avoid effects of air temperature. This position was held until a stable temperature reading was obtained. In the present report, all stream temperatures were recorded in Fahrenheit.

EXPRESSION OF ANALYTICAL RESULTS

The analytical concentrations or numerical values of 28 of the 34 parameters listed above are expressed in ppm (parts per million). In recent years mg/l (milligrams per liter) has become frequently used in expressing analytical concentrations. This unit of measurement is equivalent to ppm. Coliform count, specific conductance, pH, color, turbidity, and temperature are not measured in ppm (or mg/l). Coliform count is expressed as MFCC/100 ml (membrane filter coliform count per 100 milliliters of sample). Specific conductance is measured in micromhos per centimeter at 25°F. The pH, color, and turbidity are expressed in units, which are spearately explained in Chapter IV under the discussion of each parameter. Temperature is measured in degrees Fahrenheit.

THE ROUNDING OF NUMBERS OBTAINED FROM THE RESULTS OF SEWRPC WATER ANALYSES

The results of the water analyses run by the SEWRPC on the 26 parameters listed in Table A-1 are rounded to conform to the accuracy involved in the analytical methods.

Table A-1

ROUNDING OF ANALYTICAL RESULTS

Parameter	Rounding of Analytical Results
Silica	Nearest whole ppm
Iron	Nearest 1/100 ppm
Manganese	Nearest 1/100 ppm
Calcium	Nearest whole ppm
Magnesium	Nearest whole ppm
Sodium	Nearest 5 ppm
Bicarbonate	Nearest 5 ppm
Carbonate	Nearest 5 ppm
Sulfate	Nearest whole ppm
Chloride	Nearest 5 ppm
Nitrite	Nearest 1/10 ppm
Nitrate	Nearest 1/10 ppm
Detergents	Nearest 1/10 ppm
Dissolved solids	Nearest 5 ppm; nearest 10 ppm at 1,000 ppm and larger
Hardness	Nearest whole ppm
Noncarbonate Hardness	Nearest 5 ppm
Calcium Hardness	Nearest whole ppm
Magresium Hardness	Nearest whole ppm
Alkalinity, Phenolphthalein (P)	Nearest 2.5 ppm for numbers below 5 ppm; 2.5 ppm is an estimate only. Nearest 5 ppm for concentrations of 5 ppm or more
Alkalinity, Methyl-Orange (M)	Nearest 5 ppm
Specific Conductance at 25°C	Nearest even micromhos; nearest 10 at 1,000 micromhos and larger.
pH	Nearest 1/10 unit
Color	Nearest 5 units
Turbidity	Nearest unit; nearest 5 Jackson candle units from 10 units to 100 units; nearest 10 units at 100 units or more
Dissolved Oxygen	Nearest 1/10 ppm
Temperature	Nearest whole degree Fahrenheit

Source: SEWRPC.

COMPARATIVE CHEMICAL ANALYSES

To permit direct comparison of analytical results, three water samples were collected and split for chemical analyses by the Laboratory of the Wisconsin State Board of Health and by the SEWRPC. The results of these three analyses are listed in Table A-2 and indicate close agreement for all but two of the parameters.

Table A-2

COMPARATIVE CHEMICAL ANALYSES

Parameter	Sample 1[a] 1-28-64		Sample 2[b] 4-2-64		Sample 3[c] 2-11-65	
	WSBH	SEWRPC	WSBH	SEWRPC	WSBH	SEWRPC
Silica	8.5	8	--	--	4.2	4
Iron	0.14	0.08	--	--	0.46	0.32
Manganese	0.06	--	--	--	< 0.05	0.01
Calcium	68.9	67	--	--	27.3	29
Magnesium	29	25	--	--	16	14
Sodium	--	25	--	--	--	55
Bicarbonate	--	280	--	--	--	150
Carbonate	--	0	--	--	--	0
Sulfate	79	82	--	--	37	41
Chloride	5.5	5	--	--	51.5	55
Nitrite	0.005	0.025	--	--	0.09	0.05
Nitrate	< 0.08	--	--	--	1.22	3.0
Detergents	0.04	0.0	< 0.04	0.1	0.13	0.1
Dissolved Solids	352	350	--	--	290	275
Hardness	279	272	--	--	134	131
Alkalinity M	203	230	208	225	96	125
Specific Conductance	655	566	493[d]	439	550	434
pH	7.9	8.0	--	--	6.9	7.1
Turbidity	< 1	0	--	--	2	6

[a] *Cold water tap, Old County Courthouse Building, Waukesha, Wisconsin.*

[b] *Oconomowoc River at sampling station Rk-8; synthetic detergent added to sample.*

[c] *Rubicon River at Rk-4.*

[d] *Determined at 24° C.*

Source: SEWRPC and State Laboratory of Hygiene.

Appendix B

CHEMICAL, BIOCHEMICAL, AND BACTERIOLOGICAL STREAM SAMPLE ANALYSES BY THE SEWRPC AND THE STATE LABORATORY OF HYGIENE

Due to its large bulk and inclusive nature, Appendix B is omitted from this report but may be obtained from the following source:

Administrative Officer
Southeastern Wisconsin Regional
Planning Commission
P.O. Box 769
916 N. East Avenue
Waukesha, Wisconsin 53186

Appendix B contains all the complete chemical analyses, supplemental chemical analyses, determinations of biochemical oxygen demand, analyses for dissolved oxygen, determinations of coliform count, and the temperature measurements that are discussed in Chapter II. More than 16,200 analytical determinations and physical measurements are tabulated in Appendix B.

Appendix B and Appendix C (which is included in this report) together comprise all information pertaining to the stream samples that were collected in 1964 and 1965 as part of this study of the water quality and flow of streams in southeastern Wisconsin.

For residents of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Waukesha, and Washington counties, Wisconsin, the purchase price of Appendix B is $5.00. For those persons residing outside this Region, the purchase price is $10.00. All remittances shall be paid in advance.

Appendix C

SPECIAL CHEMICAL ANALYSES

Appendix Table C-I

SPECIAL CHEMICAL ANALYSES[a]

Station No.	Date of Sampling	Chromium	Hexavalent Chromium	Fluoride	Phosphorus	Oil	Date of Sampling	Cyanide
DP- 3	10-20-64	< .005	0.00	< 0.7	0.31	< 1	11-11-64	< .01
Fx- 1	10- 7-64	< .02	0.00	< 0.4	0.16	< 0.5	--	--
Fx- 2	10- 7-64	< .005	0.00	< 0.35	0.66	< 1	--	--
Fx- 3	10- 7-64	< .005	0.00	< 0.60	0.20	< 2	--	--
Fx- 4	10- 7-64	< .02	0.00	< 0.75	2.0	< 0.5	12-28-64	< .01
Fx- 5	10- 7-64	< .005	0.00	< 1.5	3.2	< 1	--	--
Fx- 6	10- 7-64	< .02	0.00	< 0.6	0.96	< 0.5	12-28-64	< .01
Fx- 7	10- 7-64	< .01	0.00	< 0.75	0.26	< 0.5	12-28-64	< .01
Fx- 8	10- 7-64	.04	< 0.02	< 1.0	2.3	< 0.5	12-28-64	< .01
Fx-11	--	--	--	--	--	--	1-27-65	< .04
Fx-12	--	--	--	--	--	--	1-27-65	< .04
Fx-13	10- 7-64	< .005	0.00	< 0.8	1.12	< 1	1-27-65	< .08
Fx-16	10- 8-64	< .005	0.00	< 0.65	0.38	< 1	--	--
Fx-17	10- 7-64	< .005	0.00	< 0.6	0.46	< 1	1-28-65	< .08
Fx-19	10- 8-64	< .01	0.00	< 0.4	0.24	2	--	--
Fx-20	10- 8-64	< .01	0.00	< 0.55	0.36	< 1	--	--
Fx-23	10- 8-64	< .01	0.00	< 0.85	0.14	1	--	--
Fx-24	10- 7-64	< .005	0.00	< 1	0.46	< 1	1-28-65	< .08
Fx-26	10- 8-64	< .01	0.00	< 0.6	1.9	1	--	--
Fx-27	10- 7-64	< .01	0.00	< 0.9	0.42	< 1	1-28-65	< .04
Fx-28	10- 8-64	< .005	0.00	< 0.35	0.24	< 2	--	--
Kk- 1	9-23-64	< .06	0.00	< 0.7	0.72	< 2	10- 4-64	< .03
Mn- 1	10-14-64	< .004	0.00	< 0.45	0.06	3	12-17-64	< .01
Mn- 2	10-14-64	< .005	0.00	< 0.4	1.44	< 1	--	--
Mn- 4	10-14-64	< .005	0.00	< 1.15	4.6	< 1	--	--
Mn- 6	10-14-64	< .004	0.00	< 1.1	3.68	3	12-17-64	< .01
Mn- 7	10-14-64	< .005	0.00	< 0.9	0.24	< 2	--	--
Mn- 7A	--	--	--	--	--	--	12-17-64	< .01
Mn- 8	10-14-64	.01	0.00	< 0.85	0.16	< 2	--	--
Mn- 9	10-14-64	< .01	0.00	< 0.95	0.32	3	--	--
Mn-10	10-14-64	< .01	< 0.01	< 0.9	1.32	3	12-17-64	< .01
Mh- 1	10-15-64	< .005	0.00	< 0.85	0.24	< 2	--	--
Mh- 2	10-16-64	< .005	0.00	< 0.55	0.80	< 1	11-11-64	< .1
Ml- 1	9-30-64	< .02	0.00	< 0.45	0.24	1.4	12-21-64	< .01
Ml- 4	9-30-64	< .02	0.00	< 0.45	0.20	1.4	--	--
Ml- 5	9-30-64	< .01	0.00	< 0.55	0.56	< 2	12-21-64	< .01
Ml- 8	9-30-64	< .005	0.00	< 0.5	0.32	< 1	12-21-64	< .01
Ml- 9	9-30-64	< .02	0.00	< 0.55	0.40	1.6	--	--
Ml-11	9-30-64	< .02	0.00	< 0.55	0.28	1.6	12-21-64	< .01

[a] *Analyses by State Laboratory of Hygiene.*

Source: SEWRPC.

Appendix Table C-1 (continued)

Station No.	Date of Sampling	Chromium	Hexavalent Chromium	Fluoride	Phosphorus	Oil	Date of Sampling	Cyanide
Ok- 2	9-23-64	< .01	0.00	< 0.75	0.48	< 0.5	10- 4-64	< .03
Pk- 4	9-23-64	< .01	0.00	< 0.65	1.37	< 1	10- 4-64	< .03
Rk- 1	9-16-64	< .005	0.00	< 0.55	0.24	< 2	11-18-64	< .01
Rk- 4	9-16-64	< .02	0.00	< 0.85	4.0	< 1	11-18-64	< .01
Rk- 5	9-14-64	< .005	0.00	< 0.3	0.24	< 1	--	--
Rk- 6	9-14-64	< .005	0.00	< 0.35	0.12	< 1	--	--
Rk- 8	9-14-64	< .02	0.00	< 1.5	5.3	< 1	11-19-64	< .01
Rk-13	9-16-64	< .02	0.00	< 0.4	0.64	< 1	11-19-64	< .01
Rt- 4	--	--	--		--	--	11- 5-64	< .03
Rt- 5	9-11-64	< .02	0.00	< 0.9	1.3	< 1	--	--
Rt- 6	--	--	--		--	--	11- 5-64	< .03
Sk- 1	10-15-64	< .005	0.00	< 0.70	1.92	< 2	--	--
Sk- 2	10-15-64	< .005	0.00	< 0.6	0.26	< 0.5	11-13-64	< .01
Sb- 1	10-15-64	< .005	0.00	< 0.65	0.52	< 2	--	--

Source: SEWRPC.

Appendix D

TECHNICAL ADVISORY COMMITTEE ON NATURAL RESOURCES AND ENVIRONMENTAL DESIGN

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GLOSSARY

Aerobic bacteria	Microscopic, typically one-celled organisms that thrive in the presence of oxygen.
Algae	Simple aquatic or terrestrial plants containing chlorophyll. Aquatic forms may become adversely prolific when conditions are suitable.
Alkali metals.	The chemical elements sodium and potassium (and lithium, rubidium, and cesium).
Alkaline earth metals	The chemical elements calcium and magnesium (and beryllium, strontium, barium, and radium).
Anaerobic bacteria.	Microscopic, typically one-celled organisms that thrive in the absence of oxygen.
Anion	Negatively charged ion which flows toward the anode under the influence of an electrical potential.
Cation	Positively charged ion which flows toward the cathode under the influence of an electrical potential.
Facultative fish	Fish species that are able to thrive under varying conditions but require dissolved oxygen concentrations of no less than 4.0 ppm. Alewives, bluegill, sunfish, crappies, largemouth bass, northern pike, perch, shiners, and walleyed pike are examples of facultative fish species.
Human (waste) sources . . .	A phrase applied in this report to include all domestic, industrial, agricultural, and commercial sources of treated or raw wastes that have impact upon the quality of receiving waters or that cause water pollution.
Ion	Electrically charged atomic particle resulting from dissociation of molecules in solution.
Ion, predominant	The anionic or cationic constituent occurring in largest concentration in a given sample of water.
Impact	As applied in this report, the buildup of a specific parameter to concentrations above the natural "background" concentration but below concentrations adopted as standards for certain water uses, thus, representing intermediate water quality between the natural condition and the condition of pollution.
Intolerant fish	Fish species that are intolerant to pollution and require dissolved oxygen concentrations of no less than 5.0 ppm. Trout are an example of intolerant fish species.
Parameter, water quality . .	A substance, property, or organism identified in a water analysis, such as a chemical constituent, a physical property, a biochemical effect, or a bacteriological determination, for the purpose of expressing the quality of the water. This term is applied in the same sense as used by the U. S. Public Health Service.
Phytoplankton	Plant plankton.
Plankton	Aquatic organisms mostly of microscopic size that live unattached and have little ability to move and, therefore, drift with water movement.
Pollutant	A substance which causes pollution.
Pollution, stream	A condition in which the quality of water in a stream is adversely affected by waste discharges from human sources, so that one or more uses of the stream are obviated.
Protozoa	Mostly microscopic, aquatic organisms consisting of a single cell or cell colonies in which each cell performs all vital functions of life.
Saprophyte	An organism subsisting on dead or decaying matter.

Tolerant fish.	Fish species that are tolerant to pollution and require a dissolved oxygen concentration of no less than 3.0 ppm. Bream, carp, catfish, gar, goldfish, and suckers are examples of tolerant fish species.
Tributary	A branch stream flowing to a main stream.
Tributary, first-rank	A branch stream flowing directly into a main stream.
Tributary, second-rank . . .	A branch stream flowing directly into a first-rank tributary.
Zooplankton	Animal plankton.

BIBLIOGRAPHY

1. American Public Health Association and Others, Standard Methods for the Examination of Water and Wastewater, 11th Edition. New York: American Public Health Association, Inc., 1960.

2. Betz Laboratories, Inc., Betz Handbook of Industrial Water Conditioning, 1962.

3. Biesecker, J. E. and George, J. R., Stream Quality in Appalachia as Related to Coal-Mine Drainage-1965. U. S. Geological Survey Circular 526, 1966.

4. Camp, Thomas R., Water and Its Impurities. New York: Reinhold Publishing Corporation, 1963.

5. Clark, Frank W., The Data of Geochemistry. U. S. Geological Survey Bulletin 770, 1924.

6. Corbett, Don M., Stream-Gaging Procedure. U. S. Geological Survey Water-Supply Paper 888, Reprint 1962.

7. Drescher, W. J., Dreher, F. C., and Brown, P. N., Water Resources of the Milwaukee Area, Wisconsin. U. S. Geological Survey Circular 247, 1953.

8. Feth, J. H., Calcium, Sodium, Sulfate and Chloride in Stream Water of the Western Conterminous United States to 1957. U. S. Geological Survey Hydrologic Investigations, Atlas HA-189, 1965.

9. Flint, Richard F., Glacial and Pleistocene Geology. New York: John Wiley and Sons, Inc., 1957.

10. Foley, F. C., Walton, W. C., and Drescher, W. J., Ground-Water Conditions in the Milwaukee-Waukesha Area, Wisconsin. U. S. Geological Survey Water-Supply Paper 1229, 1953.

11. Glover, Robert E., Dispersion of Dissolved or Suspended Materials in Flowing Streams. U. S. Geological Survey Professional Paper 433-B, 1964.

12. Green, J. H., and Hutchinson, R. D., Ground-Water Pumpage and Water-Level Changes in the Milwaukee-Waukesha Area, Wisconsin, 1950-1961. U. S. Geological Survey Water-Supply Paper 1809-I, 1965.

13. Guy, H. P., An Analysis of Some Storm-Period Variables Affecting Stream Sediment Transport. U. S. Geological Survey Professional Paper 462-E, 1964.

14. Hem, John D., Methods for Collection and Analysis of Water Samples. U. S. Geological Survey Water-Supply Paper 1454, 1959.

15. Hem, John D., Study and Interpretation of the Chemical Characteristics of Natural Water. U. S. Geological Survey Water-Supply Paper 1473, 1959.

16. Lange, Norbert A., Handbook of Chemistry. New York: McGraw-Hill Book Company, Inc., 1961.

17. Leopold, Luna B.; Bagnold, Ralph A.; Wolman, M. Gordon; and Brush, Lucien M. Jr., Flow Resistance in Sinuous or Irregular Channels. U. S. Geological Survey Professional Paper 282-D, 1960.

18. Mackenthun, Kenneth M., and Ingram, William M., Limnological Aspects of Recreational Lakes. U. S. Public Health Service, Publication No. 1167, 1964.

19. Mackenthun, Kenneth M., and Ingram, William M., Nitrogen and Phosphorus in Water. U. S. Public Health Service, Publication No. 1305, 1965.

20. Mckee, J. E., and Wolf, H. W., Editors, Water Quality Criteria. Sacramento, California: State Water Quality Control Board, Publication No. 3-A, 1963.

21. Needham, James G., and Needham, Paul R., A Guide to the Study of Fresh-Water Biology. San Francisco, California: Holden-Day, Inc., 1962.

22. New York State Department of Health, Manual of Instruction for Sewage Treatment Plant Operations. Albany, New York: Health Education Service.

23. Oborn, Eugene T., and Hem, John D., Some Effects of the Larger Types of Aquatic Vegetation on Iron Content of Water. U. S. Geological Survey Water-Supply Paper 1459-I, 1962.

24. Palmer, C. Marvin, Algae in Water Supplies. U. S. Public Health Service, Publication No. 657, Reprint 1962.

25. Reid, George K., Ecology of Inland Waters and Estuaries. New York: Reinhold Publishing Corporation, 1961.

26. Ryling, Roy W., A Preliminary Study of the Distribution of Saline Water in the Bedrock Aquifers of Eastern Wisconsin. Wisconsin Geological and Natural History Survey Information Circular No. 5, 1961.

27. Schraufnagel, F. H., Wisconsin Surface Water Quality 1961-1964. Madison, Wisconsin: Committee on Water Pollution.

28. Schraufnagel, F. H., Chlorides. Madison, Wisconsin: Committee on Water Pollution, 1965.

29. Symons, James M., et al, Influence of Impoundments on Water Quality. U. S. Public Health Service, Publication No. 999-WP-18-1964.

30. Symons, James M., and Robeck, Gordon G., Research on Impoundments for the Solution of Streamflow Regulation Problems. U. S. Public Health Service, 1965.

31. Texas Water and Sewage Works Association, Manual for Sewage Plant Operators. Lancaster, Pennsylvania: Lancaster Press, Inc., 1964.

32. Thwaites, F. T., Outline of Glacial Geology. Ann Arbor, Michigan: Edwards Brothers, Inc., 1959.

33. Todd, David K., Ground Water Hydrology. New York: John Wiley and Sons, Inc., 1959.

34. U. S. Public Health Service, Drinking Water Standards. U. S. Public Health Service, Publication No. 956, 1962.

35. Walton, Graham, Effectiveness of Water Treatment Processes. U. S. Public Health Service, Publication No. 898, 1961.

36. Weidman, Samuel, and Schultz, A. R., The Underground and Surface Water Supplies of Wisconsin. Wisconsin Geological and Natural History Survey Bulletin 35, 1915.