T H E U N I V E R S I T Y O F M I C H I G A N

DEPARTMENT OF ENVIRONMENTAL AND INDUSTRIAL HEALTH
School of Public Health

Final Report

MILL CREEK WATER QUALITY EVALUATION

Covering Period December 1, 1972 - November 30, 1973

John J. Gannon, Project Director
Professor of Public Health Engineering

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STUDY PARTICIPANTS

Water Quality Program
Department of Environmental and Industrial Health
School of Public Health

Project Director

John J. Gannon, Professor of Public Health Engineering

Student Participants

Regular Basis

Loren Henke
Anthony Rutz

Part-Time Basis

Cynthia Edwards
Wendy Magadanz
Thomas Mester
Jeff Pretka
Lawrence Schwei
Charles Towsley

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SUMMARY AND CONCLUSIONS

The purpose of this study was to establish a program for the long-term evaluation of the water quality of the Mill Creek Study Area, involving sampling and appropriate laboratory analyses. The sampling program was conducted over a period of a year from December 1972 to November 1973 to reflect seasonal variations, and to establish a base line of existing water quality. A sampling schedule involving approximately one visit to the study area each week, including a minimum of three sampling stations was followed, with the collection time varied through the hours of the day and the days of the week.

The three primary sampling stations included: (1) Mill Creek at Liberty Road, (2) Mill Creek at Lima-Center Road, and (3) Mill Creek at Klinger Road. Analyses included: temperature, conductivity, pH, turbidity, dissolved oxygen, biochemical oxygen demand, total coliform organisms (membrane filter), fecal coliform organisms (membrane filter), fecal streptococci (membrane filter), total coliform (MPN), and fecal coliform (MPN).

A daily hydrograph for the study period showed the flow of Mill Creek to fluctuate substantially as a result of frequent and above average precipitation during the months of March, May, and July, 1973. The 1972-1973 study period stream flows were substantially above the 1 in 10-year, 7-day average drought flow.

Mill Creek is designated for the following uses at the present time by the Michigan Water Resources Commission in the vicinity of Guenther Road in Lima Township, Washtenaw County: Recreation - Partial body contact; Industrial water supply; Fish, wildlife and other aquatic life - Intolerant fish - warm-water species; and Agricultural uses. For recreational use, the fecal coliform requirement appears to have particular relevance which is of the order of magnitude of a geometric average of no more than 200 fecal coliforms per 100 ml for total body contact, and geometric average of no more than 1,000 fecal coliforms per 100 ml for all other waters. The dissolved oxygen requirement for the protection of fish life is a minimum of 5 mg/l as a daily average, and no single value less than 4 mg/l.

Seasonal bacteriological and chemical distributions have been developed and presented for most of the analyses. High bacteriological levels were observed in the summer, while low levels were observed in the winter and early spring. The fecal coliform distribution must be viewed in relation to the standard of 1,000/100 ml applicable to Mill Creek water, and it is apparent this level was exceeded at times during the summer of 1973. The seasonal distribution of temperature, dissolved oxygen, turbidity, and specific conductance followed expected patterns. The dissolved oxygen level was above the minimum requirement at all times during the year.

Samples were collected at nine locations in the study area twice during the study period, the first time on March 6, 1973, and the second time on July 11, 1973. In March, higher bacteriological levels were observed at stations in the lower part of the basin in the vicinity of the proposed park, with substantially lower levels observed at stations in the upper part of the basin. On the other hand, in July approximately the same bacterial levels were observed at all the sampling stations in the basin.

Special studies were conducted during July and August 1973 to evaluate the nutrient levels, involving the compounds of nitrogen and phosphorus, at the three primary sampling stations in the study area. These results involving levels of ammonia, nitrite, nitrate, and orthophosphate have been presented and are generally low. Additional sampling is necessary, especially during the spring period of fertilizer application, to evaluate overall levels.

The availability of total coliform, fecal coliform, and fecal streptococcus results using both the MPN and membrane filter techniques (for total and fecal coliform only) suggested several useful summaries and comparisons. Geldreich has indicated that domestic sewage has a fecal coliform/fecal streptococci ratio greater than 4.0, while the ratio is less than 0.7 for farm animals, cats, dogs, and rodents. The FC/FS ratio for various data groupings of this study was always less than 0.7 on a mean basis, suggesting an animal rather than a human origin. This confirms an opinion arrived at by the writer based on a field inspection of the drainage area.

In a comparison of the test procedures using the MPN and MF techniques, it is seen that the MPN/MF ratio for fecal coliform results is higher than for the total coliform results, and is of the order of magnitude of 2.15 for fecal coliforms and 1.38 for total coliforms. Certainly these results have significance in terms of an appropriate laboratory procedure to be used in testing for compliance with Michigan water quality standards.

Samples of Mill Creek water were collected at Klinger Road at the upstream end of the proposed impoundment during August 1973, and transported to an outdoor experimental reservoir located on the grounds of the Ann Arbor wastewater treatment plant for incubation under simulated natural impoundment conditions of no flow. For the unaltered Mill Creek water sample, there was a slight increase in total coliform levels followed by a more rapid dieoff, while the fecal coliform and fecal-streptococci organisms died off rapidly.

Predictions were made of the fecal coliform inactivation in the proposed impoundment. Detention times were calculated assuming complete displacement through the impoundment. If one takes the highest fecal coliform level of 13,000/100 ml observed at any time during 1973 at Klinger Road, and combines this with the shortest calculated detention time corresponding to the 1968 flood conditions, the calculated fecal coliform level at the dam using the observed fecal coliform inactivation rates would be less than 1/100 ml. This assumes no new bacterial contributions below Klinger Road. Obviously, this calculation is a very severe combination of conditions and for lower flow rates and longer impoundment detention times, we would expect to find more rapid decline further upstream in the impoundment. The development of bathing beaches in the proposed park should take these natural bacterial inactivation processes into account, with the beach located in the lower end of the impoundment as close to the dam as possible.

If the proposed impoundment would consist of two separate basins in series, there would be greater insurance of more complete displacement and less possibility of short circuiting by incoming water, lending greater reliability to the calculated detention times. Based on this assumption and the previous predictions, there is every expectation that the water quality in the lower part of the impoundment would meet the State of Michigan fecal coliform requirements for total body contact recreation. In addition, the existence of two separate basins would allow settling of solids to occur in the upper basin, thereby contributing to the clarity of water to be used for bathing in the lower basin.

RECOMMENDATIONS FOR FURTHER SURVEILLANCE

Water quality sampling should be continued on a weekly basis to better define water quality levels under varied hydrologic conditions, especially those involving low flow drought conditions. While there is expectation that during drought flow there would be less surface wash and therefore lower contaminant level (especially fecal coliform concentrations) in Mill Creek, this should be verified.

The regular sampling station network should be expanded to include the 9 stations covered in the basin studies, so as to better isolate pollution inputs upstream from the proposed park area.

Nutrient levels, involving the compounds of nitrogen and phosphorus, should be determined on all samples collected throughout the year to reflect contributions to Mill Creek during the spring, summer, fall, and winter.

I. INTRODUCTION

The Huron-Clinton Metropolitan Authority has proposed the development of a metropolitan park in Lima Township in western Washtenaw County. The focal point of the park will be an impoundment on Mill Creek created by the construction of a dam in the vicinity of Guenther Road. It is expected that this impoundment will be used for body contact sports, meaning that water quality will be important both from a health and aesthetic standpoint.

Water quality can be evaluated in a number of different ways which might include aesthetic, chemical, and bacteriological measures. Certainly the aesthetic factors are those that are readily apparent and could include such things as turbidity, foam, temperature differences, algal growths, etc. From the standpoint of the use of natural waters for swimming, boating, or drinking, they assume considerable importance.

Evaluation of the bacteriological quality of water in terms of potential disease transmission uses tests for the detection and enumeration of indicator organisms, rather than of pathogenic organisms directly harmful to man. The coliform group of bacteria has been the principal indicator of the suitability of a particular water for domestic or bathing use. Experience has established the significance of coliform group densities as criteria of the degree of pollution, and thus, of the sanitary quality of the sample under examination.

Much of the early work with coliform organisms has been in terms of total coliform levels, while in recent years laboratory tests have been developed which make it possible to separate out that portion of the coliform group which is present in the gut and feces of warm-blooded animals. This latter group has been designated as fecal coliform organisms. Increasing attention to the potential value of fecal streptococci as indicators of significant pollution of water has prompted the development of methods for the detection and enumeration of such microorganisms. The evaluation of total coliform, fecal coliform, and fecal streptococci organism levels in a given sample gives a picture that no one of the organisms alone can give.

The chemical evaluation of the waters of Mill Creek assumes importance because of the agricultural nature of the watershed, especially in relation to the nutrients which are washed into the stream as a result of the use of various fertilizers. These nutrients, particularly the compounds of nitrogen and phosphorus, can contribute to algal growths in the stream thereby creating a nuisance problem.

The specific aim of the present study was to establish a program for the long-term evaluation of the water quality of the Mill Creek Study Area, involving sampling and appropriate laboratory analyses.

The sampling program was conducted over a period of a year from December 1972 to November 1973 to reflect seasonal variations, and to establish a base line of existing water quality. A sampling schedule involving approximately one visit to the study area each week, including a minimum of three sampling stations was followed, with the collection time varied through the hours of the day and the days of the week.

The three primary sampling stations included: (1) Mill Creek at Liberty Road, (2) Mill Creek at Lima Center Road, and (3) Mill Creek at Klinger Road. The second station was originally established at Scio Church Road on a tributary of Mill Creek, but was discontinued at this location on January 11, 1973 due to the refusal of access to private property for necessary sampling by the property owner involved. Station 2 was relocated to Mill Creek at Lima Center Road on February 16, 1973 and stayed at this location for the remainder of the study period. All samples were brought immediately after collection to the laboratories in the School of Public Health and processed upon arrival. No storage or holding was involved. Analyses included: temperature, conductivity, pH, turbidity, dissolved oxygen, biochemical oxygen demand, total coliform organisms (membrane filter), fecal coliform organisms (membrane filter), fecal streptococci (membrane filter), total coliform (MPN), and fecal coliform (MPN).

A number of important physical characteristics of the Mill Creek Study Area were collected and evaluated as part of the present investigation. A daily hydrograph for the December 1972-November 1973 period shows the relationship between stream flow and sampling dates. In addition, relationship was established between the flow at Mill Creek at Klinger Road and at the Mill Creek near Dexter, Michigan U.S. Geological Survey stream gage.

Seasonal bacteriological and chemical distributions have been developed and presented for most of the analyses. In addition to the regular sampling program, samples were collected at nine locations in the study area twice during the study period, the first time on March 6, 1973 and the second time on July 11, 1973. Special studies were conducted during July and August 1973 to evaluate the nutrient levels involving the compounds of nitrogen and phosphorus at the three primary sampling stations in the study area. The U.S. Geological Survey has made water quality information available at two pertinent sampling stations on Mill Creek, one at Manchester Road, upstream of the proposed park, and the other at Jerusalem Road near Lima Center, which is downstream of the proposed park.

The availability of total coliform, fecal coliform, and fecal streptococcus results using both the MPN and membrane filter techniques (for total and fecal coliform only) suggested several useful summaries and comparisons. These included: fecal coliform/fecal streptococci relationships, a comparison of the MPN and membrane filter test procedures, and a comparison of results by sampling stations.

Interest centers on the survival possibilities of microbial organisms, especially total coliform, fecal coliform, and fecal streptococci under proposed impoundment conditions of Mill Creek. Samples of Mill Creek were collected during August 1973 at Klinger Road at the upstream end of the proposed impoundment, and transported to an outdoor experimental reservoir located on the grounds of the Ann Arbor wastewater treatment plant for incubation under simulated natural impoundment conditions of no flow. In addition to these studies, predictions were made of the fecal coliform inactivation in the proposed impoundment under the most adverse conditions.

A review was made of the significance of bacterial indicators in the evaluation of natural recreational water quality.

The reader who wishes a detailed discussion of the meaning of the various water quality concepts used in this report is referred to the standard text "Applied Stream Sanitation" by Velz (1). Also, a complete glossary (2) of terms used in the water quality field is available as prepared by a joint editorial board representing several national professional organizations interested in water quality and water pollution.

References

1. Velz, C. J., "Applied Stream Sanitation," Wiley-Interscience, New York, New York (1970).

2. Ingram, William T. (Editor), "Glossary, Water and Wastewater Control Engineering," APHA, ASCE, AWWA, WPCF (1969).

II. PHYSICAL CHARACTERISTICS

Introduction

A number of important physical characteristics of the Mill Creek Study Area were collected and evaluated as part of the present investigation. This section of the report includes: a basin description, surface discharge measurements, and precipitation information.

Basin Description

Mill Creek is a tributary of the Huron River (1) which is located in the southeastern part of the Lower Peninsula of Michigan, and the Huron River is in turn a tributary to Lake Erie as shown in Figure II-1. The Huron River Basin, with a drainage area of approximately 949 square miles, comprises parts of Ingham, Livingston, Oakland, Wayne, Monroe, Washtenaw, and Jackson Counties with the main cities including Ann Arbor, and Ypsilanti. Major tributaries include Portage Creek, Mill Creek, and Ore Creek.

Mill Creek joins the Huron at the Village of Dexter and has a reported drainage area of 128 square miles at the Mill Creek near Dexter, Michigan, U.S. Geological Survey stream gage (2) located at Parker Road as shown in Figure II-1.

The Mill Creek Study Area is located on the main branch of Mill Creek upstream from the junction with the North Fork and above the crossing of Liberty Road, as shown on the Huron Basin map of Figure II-1 and the detailed map of Figure II-2. Brater and Wylie (3) report a drainage area of 49 square miles for Mill Creek above Guenther Road based on measurements of the area using U.S.G.S. topographic maps.

The Huron River Basin above Ann Arbor is almost equally divided by moraines, till plains, and out wash (1). Mill Creek is mostly till plain with a zone of moraines on the west.

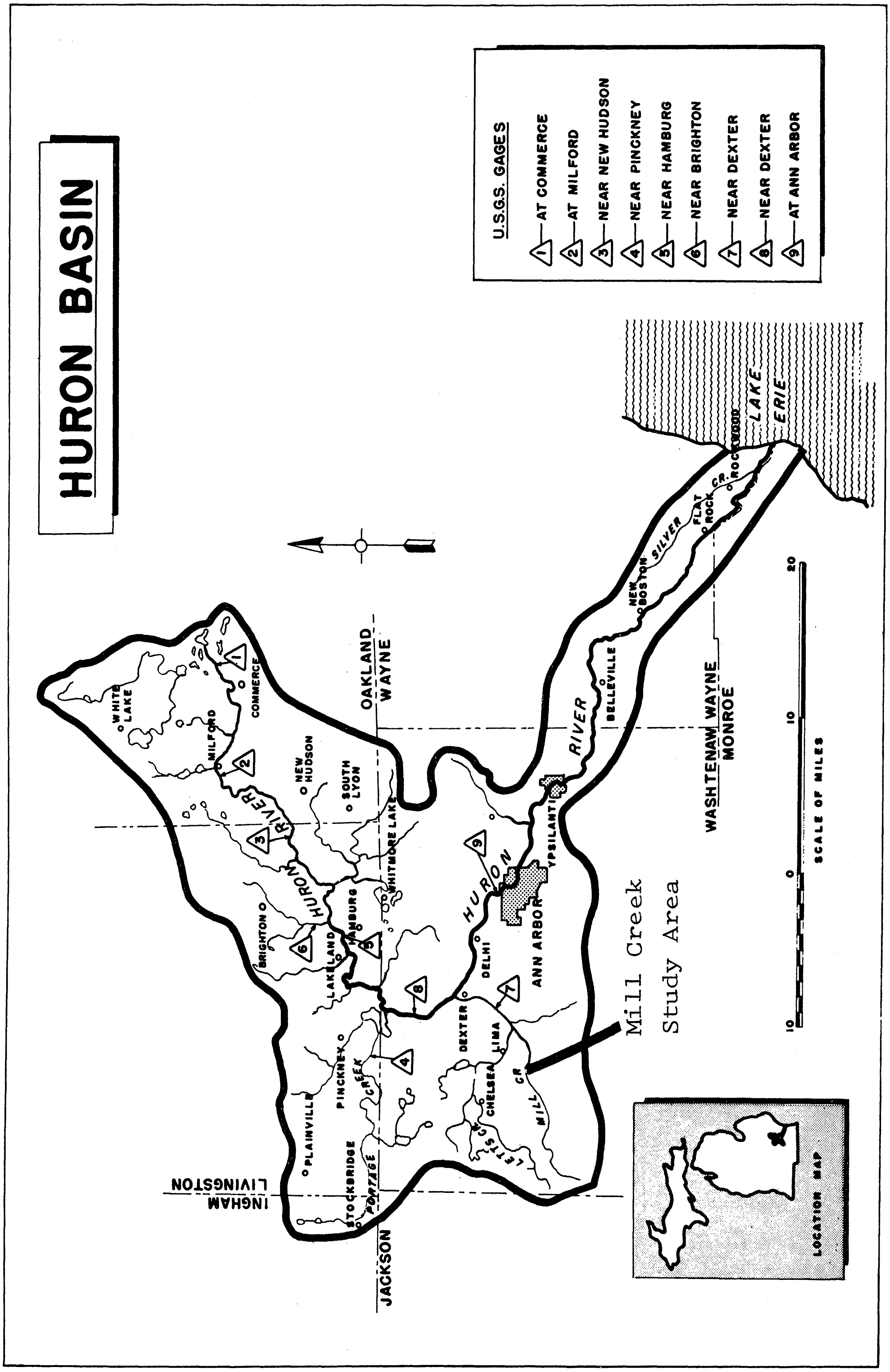

HURON BASIN
U.S.G.S. GAGES
1 AT COMMERCE
2 AT MILFORD
3 NEAR NEW HUDSON
4 NEAR PINCKNEY
5 NEAR HAMBURG
6 NEAR BRIGHTON
7 NEAR DEXTER
8 NEAR DEXTER
9 AT ANN ARBOR
LAKE ERIE
ROCKWOOD
FLAT ROCK CR.
SILVER
NEW BOSTON
BELLEVILLE
RIVER
HURON
YPSILANTI
ANN ARBOR
DELHI
DEXTER
LIMA
CHELSEA
MILL CR.
LETTS CR.
STOCKBRIDGE
PORTAGE
PLAINVILLE
PINCKNEY
CREEK
LAKELAND
HAMBURG
BRIGHTON
WHITMORE LAKE
SOUTH LYON
NEW HUDSON
MILFORD
WHITE LAKE
COMMERCE
OAKLAND
WAYNE
WASHTENAW
MONROE
INGHAM
LIVINGSTON
JACKSON
SCALE OF MILES
10
0
10
20
LOCATION MAP
Mill Creek
Study Area

Figure II-1

MILL CREEK

DRAINAGE AREA ABOVE GUENTHER RD.

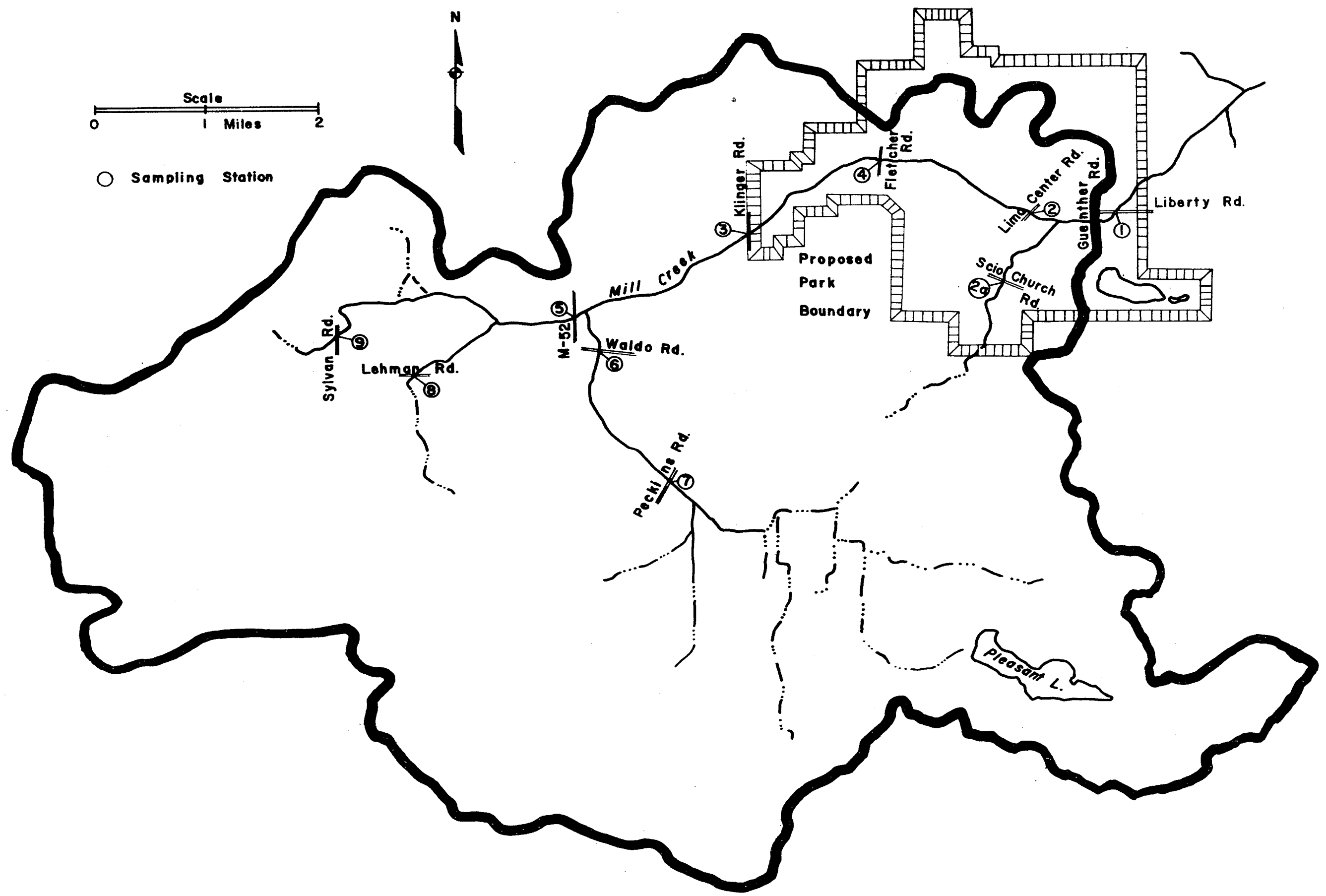


Figure II-2

Surface Discharge Measurements

The United States Geological Survey reports flow information for the Mill Creek near Dexter, Michigan gage from February 1952 to the present. Figure II-3 is a daily hydrograph for this gage for the December 1, 1972 - October 29, 1973 study period based on prepublication information (4) made available by John B. Miller, Hydrologist, U.S. Geological Survey. Flow information for the period April 3-19 is not immediately available and will have to be estimated because of gage malfunction. The days that samples were collected for water quality analyses at the three primary stations in the study area are indicated across the top, and daily precipitation in inches during this period as recorded at Ann Arbor, Michigan (5) is shown across the bottom. It is readily apparent that Mill Creek was subject to a number of freshets during the study period, which must be considered in the interpretation of water quality data.

In addition to the U.S.G.S. flow information, regular discharge measurements were made of the flow in Mill Creek at Liberty Road and Klinger Road, whenever samples were collected for water quality evaluation during the Spring-Summer period starting on March 8, 1973 and extending through August 16, 1973. Regular procedures for making stream discharge measurements as employed by the U.S. Geological Survey and as reported by Corbett (6) and Grover and Harrington (7) were followed.

Brater and Wylie (3) established a relationship between the daily average flows for the Mill Creek near Dexter gage and special discharge measurements of Mill Creek at Guenther Road. Their relationship was $Q_g = 0.366\ Q_d$, where Q_g equals the flow at Guenther Road and Q_d equals the flow at the Dexter gage. Generally the writer finds this relationship applicable to the 1973 measurements using Liberty Road instead of Guenther Road, with the exclusion of the June 28 and July 3 measurements which were periods of rapidly changing flow conditions. In addition to this study, the writer established a relationship between the flows as reported at the Mill Creek gage and the measured flows at Klinger Road using the theory of least squares. This is presented in Figure II-4 and has the form $Q_k = 4 + 0.254\ Q_d$ where Q_k equals the flow at Klinger Road and Q_d equals the reported daily average flow at the Dexter gage. The calculated correlation coefficient (r) is 0.977, indicating a high degree of relation.

Thus, it is possible using these relationships to predict the flow of Mill Creek at Liberty Road and Klinger Road, during low flow summer periods from a knowledge of the flow of Mill Creek at the Dexter gage. The relationships are applicable during stable flow conditions but should not be used during periods of rapidly changing flow situations.

The Michigan Water Resources Commission in new water quality standards (see Appendix B) that went into effect on December 12, 1973 indicated that the accepted design streamflow to which the water quality standards shall apply are those equal to or exceeding the 10-year recurrence of a minimum low-flow

DAILY HYDROGRAPH

MILL CREEK near DEXTER, MICHIGAN

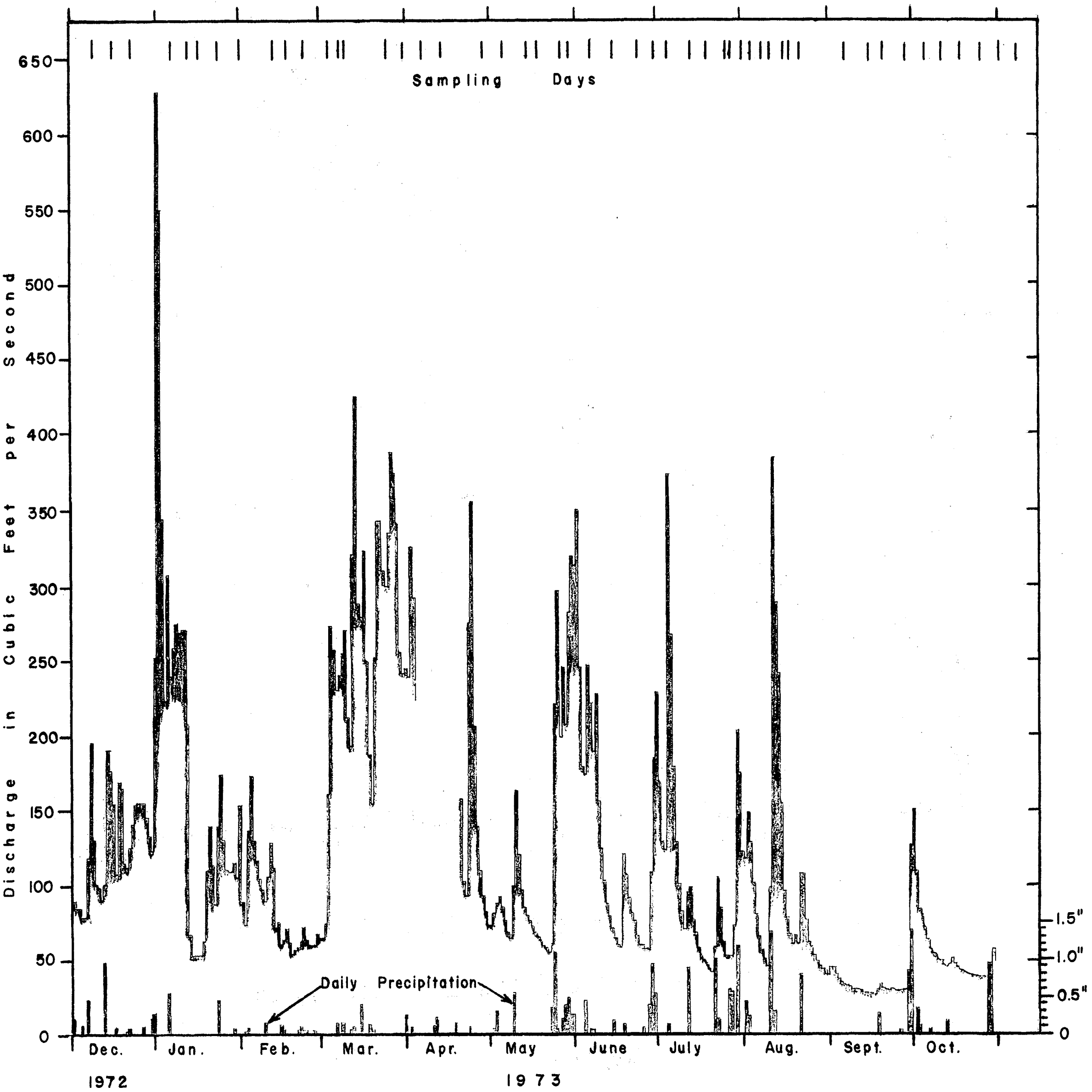


Figure II-3

FLOW RELATIONSHIPS

U.S.G.S. Gage and Klinger Road

Mill Creek

1973

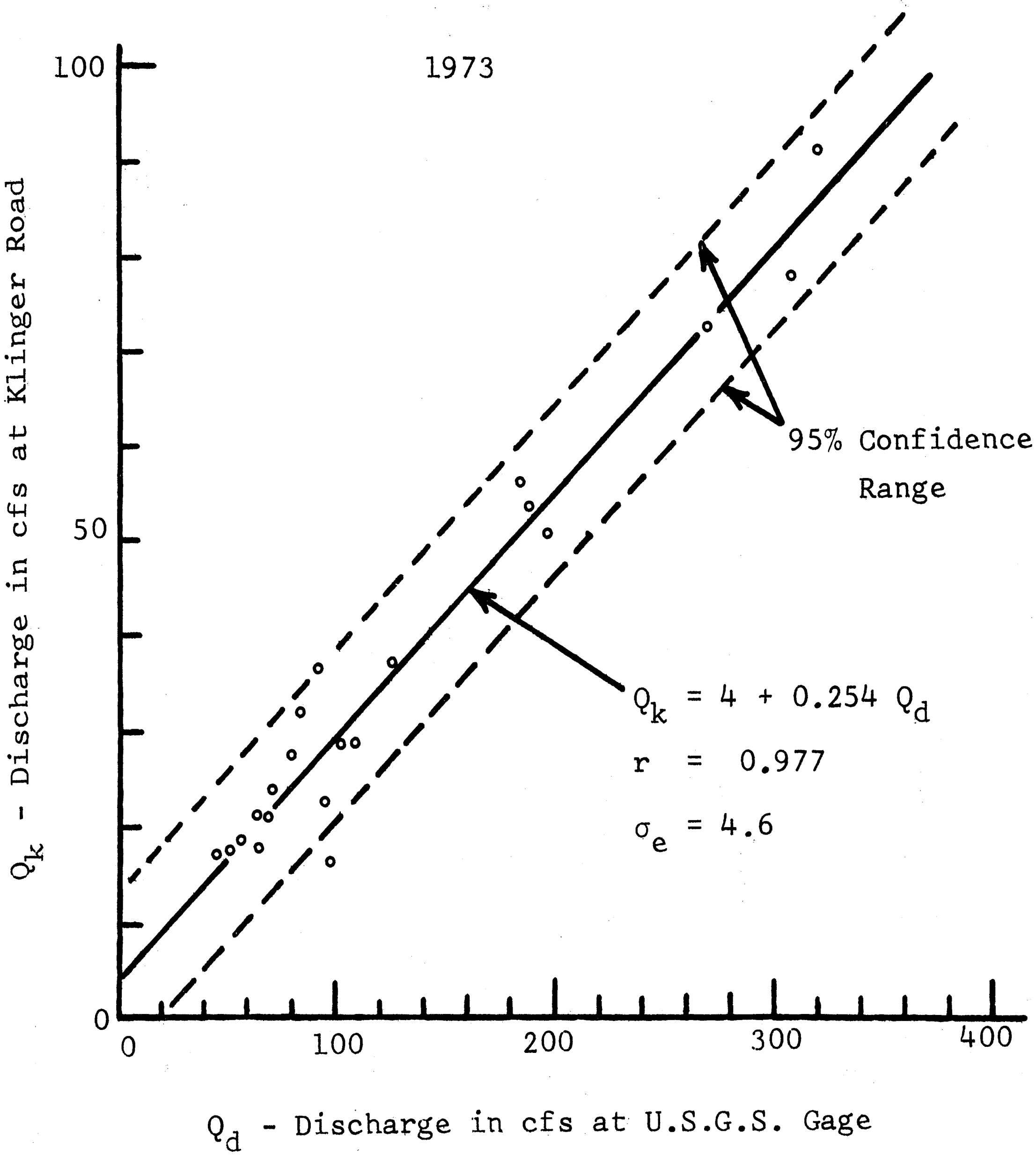


Figure II-4

average of 7-day duration, except where the commission determines that a more restrictive application is necessary to protect a particular designated use.

Brater and Wylie (3) prepared a low-flow frequency curve, Mill Creek near Dexter from information provided by Knutilla (8). From their curve, the 1 in 10-year, 7-day average drought flow is of the order of magnitude of 11.4 cfs. Using the relationships of Figure II-4, the Klinger Road flow is estimated as 6.9 cfs. It is apparent that none of the 1972-1973 study period flows approached this low level and generally were significantly higher.

Precipitation Information

Information on daily precipitation during the survey period has been presented in Figure II-3. The seasonal pattern of precipitation as observed at Ann Arbor, Michigan (9) is presented in Figure II-5 in terms of mean monthly precipitation. In addition, the total monthly precipitation for each month of the study period is presented in the same figure to allow a comparison of the precipitation during the study period with the long-term means. It is readily apparent that the months of March, May, and July 1973 had monthly precipitation well above the long-term average.

Summary

A number of important physical characteristics of the Mill Creek Study Area were collected and evaluated as part of the present investigation. These included: a basin description, surface discharge measurements, and precipitation information. A daily hydrograph for the study period showed the flow of Mill Creek to fluctuate substantially as a result of frequent and above average precipitation during the months of March, May, and July 1973. A strong relationship was established between the flow of Mill Creek at Klinger Road and at the Mill Creek near Dexter, Michigan, U.S. Geological Survey stream gage. The 1972-1973 study period stream flows were generally substantially above the 1 in 10-year, 7-day average drought flow.

S E A S O N A L P A T T E R N O F

P R E C I P I T A T I O N

Ann Arbor, Michigan

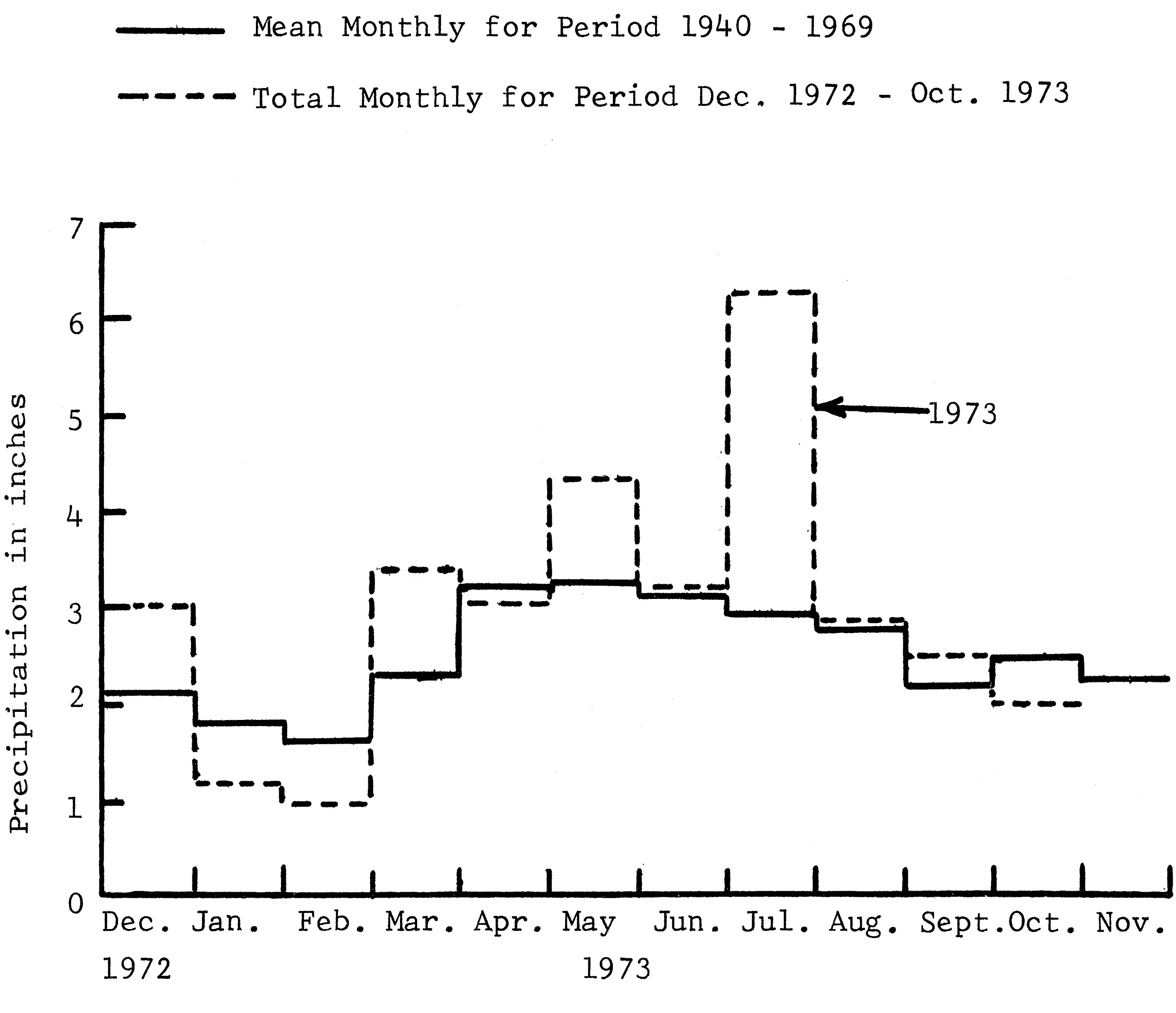


Figure II-5

References

1. Velz, C. J., and Gannon, John J., "Drought Flow of Michigan Streams," Department of Environmental Health, School of Public Health, The University of Michigan, Ann Arbor, Michigan (June 1960).

2. United States Department of the Interior, Geological Survey, "Water Resources Data for Michigan, Part 1. Surface Water Records, 1971," Okemos, Michigan (1972).

3. Brater, E. F., and Wylie, E. B., "Hydrologic Study of the Proposed Mill Creek Dam and Lake," report to the Huron-Clinton Metropolitan Authority, 40 pp. (July 1971).

4. Miller, John B., "Prepublication Information on Discharge of Mill Creek near Dexter, Michigan," private correspondence (1973).

5. University of Michigan Weather Station, "Daily Precipitation Observations," December 1972-October 1973.

6. Corbett, Don M., "Stream Gaging Procedure," Water Supply Paper 888, U.S. Geological Survey, Washington, D.C. (reprinted 1962).

7. Grover, Nathan C., and Harrington, Arthur W., "Stream Flow," John Wiley and Sons, Inc., New York City (1943).

8. Knutilla, R. L., "Statistical Summaries of Michigan Streamflow Data," United States Department of the Interior, Geological Survey, Lansing, Michigan (June 1970).

9. U.S. Department of Commerce, Environmental Data Service, "Climatological Summary, Ann Arbor, Michigan, covering period 1940-1969." Revised December 1971.

III. WATER QUALITY CHARACTERISTICS

Introduction

A number of important water quality characteristics of the Mill Creek Study Area were defined as part of the present study. This section of the report includes: a discussion of Michigan water quality standards and Mill Creek use designation, a discussion of field and laboratory procedures, seasonal bacteriological and chemical distributions, a discussion of special basin studies, results of summertime nitrogen and phosphorus observation, and a discussion of available U.S. Geological Survey observations.

Water Quality Standards and Stream Use Designation

Responsibility for protection of the waters of the State of Michigan rests with the Water Resources Commission, Michigan Department of Natural Resources. One of the important elements in accomplishing this protection is through the development and adoption of water quality standards for various uses, and then a designation of a specific use for the various waters of the state.

New water quality standards for the State of Michigan went into effect on December 12, 1973, and they are reproduced in their entirety as Appendix B of this report for the convenience of the reader who may not have ready access to them.

The purpose of the standards have been stated as follows:

> "It is the purpose of the water quality standards as prescribed by these rules to establish water quality requirements applicable to the Great Lakes, their connecting waterways and all other surface waters of the state, which shall protect the public health and welfare, enhance and maintain the quality of water, serve the purpose of United States Public Law 92-500 and the commission act; and which shall protect the quality of waters for recreational purpose, public and industrial water supplies, agriculture uses, navigation and propagation of fish, other aquatic life, and wildlife."

Mr. John M. Bohunsky, Regional Engineer, Michigan Water Resources Commission in a letter dated December 18, 1973 (see Appendix B) indicated that Mill

Creek is designated for the following uses in the vicinity of Guenther Road in Lima Township, Washtenaw County:

Recreation - Partial body contact
Industrial water supply
Fish, Wildlife and other aquatic life - Intolerant fish - warmwater species
Agricultural uses

It must be further recognized that when the proposed park and resulting impoundment becomes a reality, then the designation of total body contact would apply to the impoundment area used for swimming purposes.

For recreational use, the fecal coliform requirement appears to have particular relevance which is stated as follows:

Rule 1062 "(1) Waters of the state protected for total body contact recreation shall contain not more than 200 fecal coliforms per 100 milliliters and all other waters of the state shall contain not more than 1,000 fecal coliforms per 100 milliliters. These concentrations may be exceeded if due to uncontrollable non-point sources.

(2) Compliance with the fecal coliform standards prescribed by subrule (1) shall be determined on the basis of the geometric average of any series of 5 or more consecutive samples taken over not more than a 30-day period."

For fish, wildlife and other aquatic life - intolerant fish - warmwater species the dissolved oxygen requirement appears to have particular relevance which is stated follows:

Rule 1064 "....In all other waters except for inland lakes as prescribed by rule 1065, a minimum of 5 milligrams per liter of dissolved oxygen shall be maintained as a daily average and no single value shall be less than 4 milligrams per liter in waters naturally capable of supporting warmwater fish."

Field and Laboratory Procedures

The evaluation of the water quality in the Mill Creek Study Area involved a number of physical, bacteriological, and chemical analyses of water collected at three primary sampling stations, at approximately weekly intervals during the period December 1972 - October 1973. These stations are shown in Figure II-2 and include Station 1 - Mill Creek at Liberty Road, Station 2 - Mill Creek at Lima - Center Road and Station 3 - Mill Creek at Klinger Road. Station 2 was originally established at Scio Church Road on a tributary of Mill Creek, but was discontinued at this location on January 11, 1973 due to the refusal of access to private property for necessary sampling by the property owner involved. Station 2 was relocated to Mill Creek at Lima Center Road on February 16, 1973 and stayed at this location for the remainder of the study period. Station 1 was originally established on Mill Creek at Guenther Road but was moved to Mill Creek at Liberty Road on December 15, 1972 for ease of access. In addition to these primary sampling stations, other stations in the basin above the proposed park area as shown in Figure II-2 were sampled occasionally as time and resources permitted.

The sampling stations included Mill Creek at:

Station 1 - Liberty Road
Station 2 - Lima Center Road
Station 3 - Klinger Road
Station 4 - Fletcher Road
Station 5 - M-52
Station 6 - Waldo Road
Station 7 - Peckins Road
Station 8 - Lehman Road
Station 9 - Sylvan Road

Accepted sampling and analytical procedures as outlined in Standard Methods for the Examination of Water and Wastewater (1) or Limnological Methods (2) were employed, but in some instances modifications or improved procedures were necessary. All samples were brought immediately after collection to the laboratories in the School of Public Health and processed upon arrival. No storage or holding was involved.

The following analyses were performed on the samples collected at the three primary sampling stations:

Temperature in °C
Conductivity in micromhos/cm
pH
Turbidity in JTU
Dissolved oxygen (DO) in mg/l
Biochemical oxygen demand (BOD_5) in mg/l
Total coliform (Membrane Filter) as count/100 ml
Fecal coliform (Membrane Filter) as count/100 ml
Fecal streptococci (Membrane Filter) as count/100 ml
Total coliform (Fermentation tube) as MPN/100 ml
Fecal coliform (Fermentation tube) as MPN/100 ml

In addition to these routine analyses, further determinations were made as part of special studies reported elsewhere in this report.

The specific laboratory procedures are presented and referenced in further detail in Appendix C, while the results of the individual analyses are tabulated in Appendix D. Special attention has been given to the bacteriological evaluations, and coliform determinations, both total and fecal, have been made using both the MPN fermentation tube procedure and the membrane filter procedure on each sample. Standard Methods (1) recognizes either the MPN or the membrane filter procedure as being acceptable. Also, fecal streptococci were determined using only the membrane filter procedure. As a result of this information, special comparisons of bacteriological procedures are included elsewhere in this report.

Seasonal Bacyeriological and Chemical Distributions

Seasonal distributions have been developed for most of the bacteriological and chemical analyses performed on samples collected at the three primary Mill Creek sampling stations - Liberty Road, Lima Center Road, and Klinger Road. These distributions are presented in Figures III-1 through III-9.

The total coliform MPN results are presented in Figure III-1, the fecal coliform MPN results in Figure III-2, the total coliform membrane filter results in Figure III-3, the fecal coliform membrane filter results in Figure III-4, and the fecal streptococci membrane filter results in Figure III-5. It is apparent that high levels occur in the summer, while low levels occur in the winter and early spring. Temperature, of course, is an important factor, but the relatively wet 1973 summer cannot be overlooked. The fecal coliform distributions must be viewed in relation to the standard of 1000/100 ml. applicable to Mill Creek water, and it is apparent this level was exceeded at times during the summer of 1973.

The seasonal distribution of water temperature in °C is presented in Figure III-6. The summertime temperature averaged about 20°C, with a wintertime low close to 0°C. The seasonal distribution of turbidity in JTU is presented in Figure II-7, with the high values coinciding with the high summertime flow periods.

The seasonal distribution of dissolved oxygen is presented in Figure III-8, where it is apparent the low observations occurred during the warm summer period although no value was less than 5 mg/l. The seasonal distribution of specific conductance is presented in Figure III-9 with the high observations during the warm summer peoiod, no doubt influenced both by temperature and ground water contributions.

Seasonal pattern of pH and BOD_5 are not presented because of little variation in the case of pH, and erratic variation in the case of BOD_5.

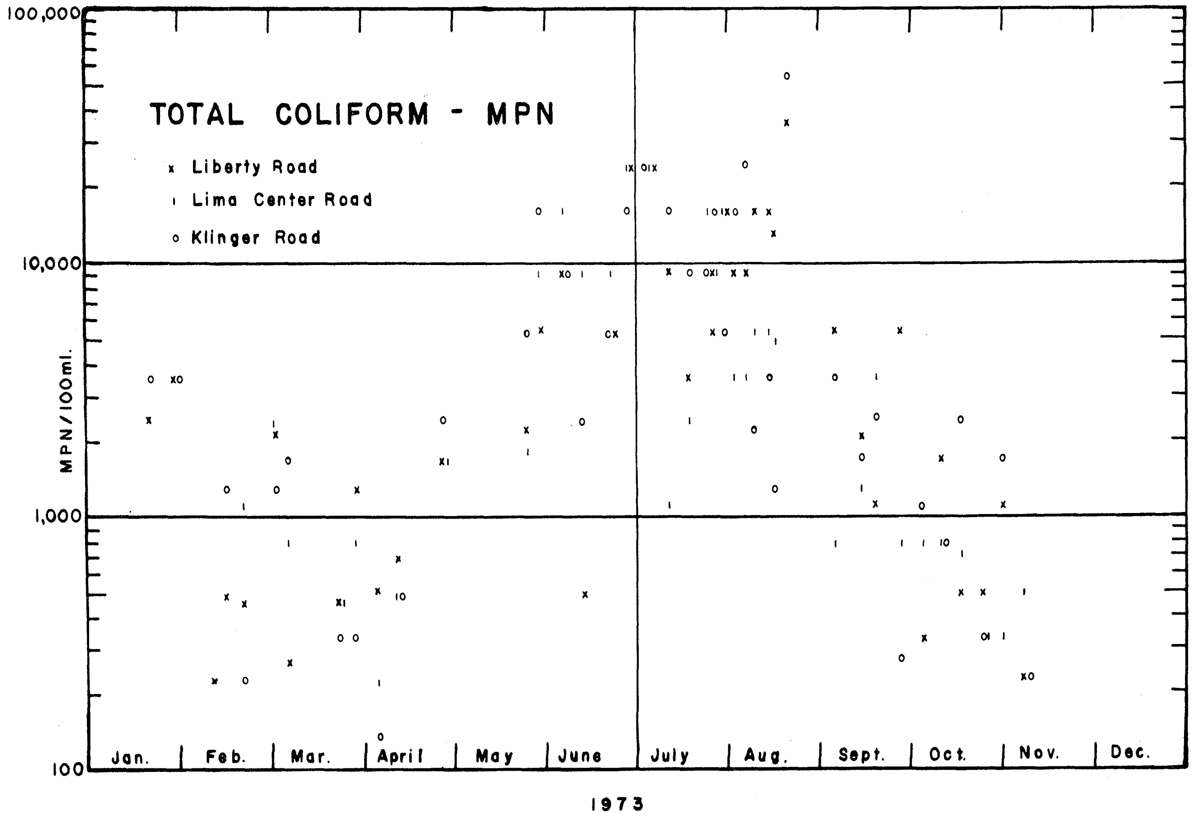


Figure III-1

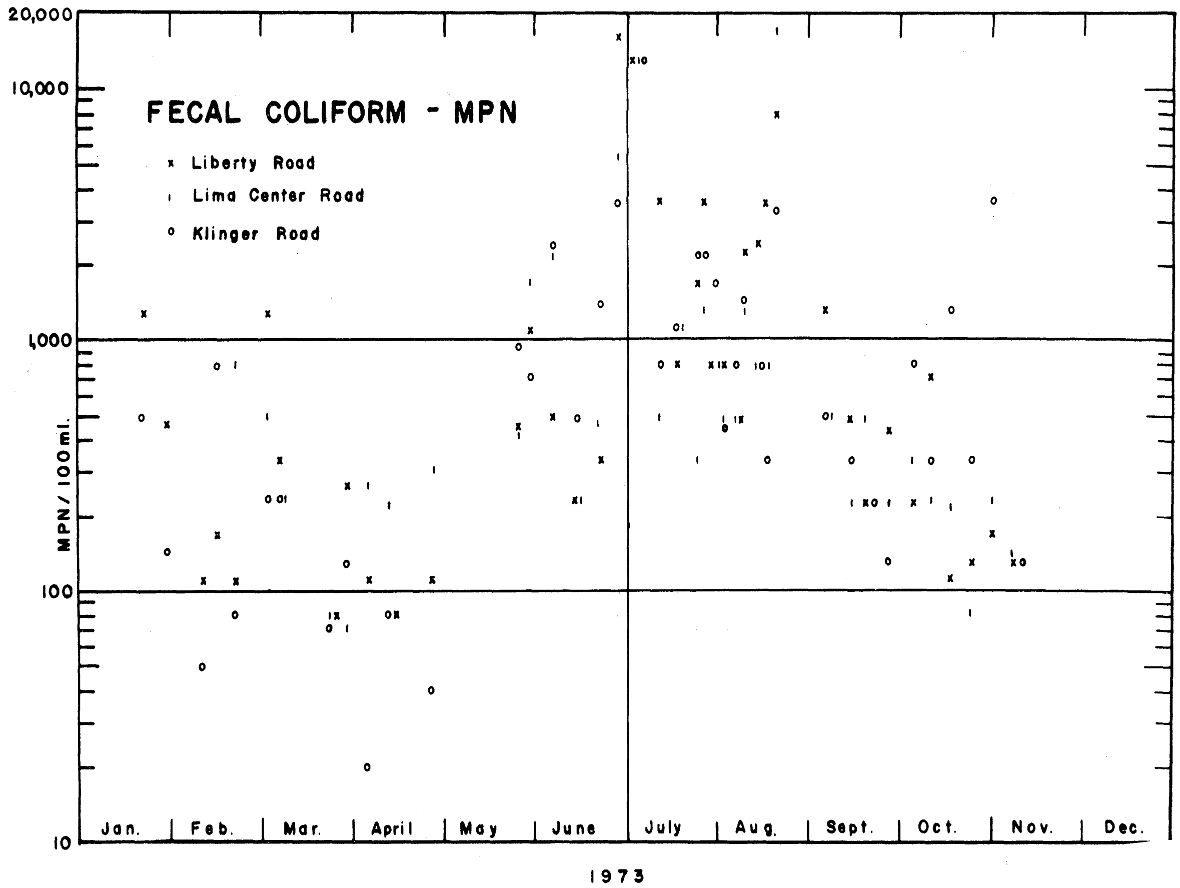


Figure III-2

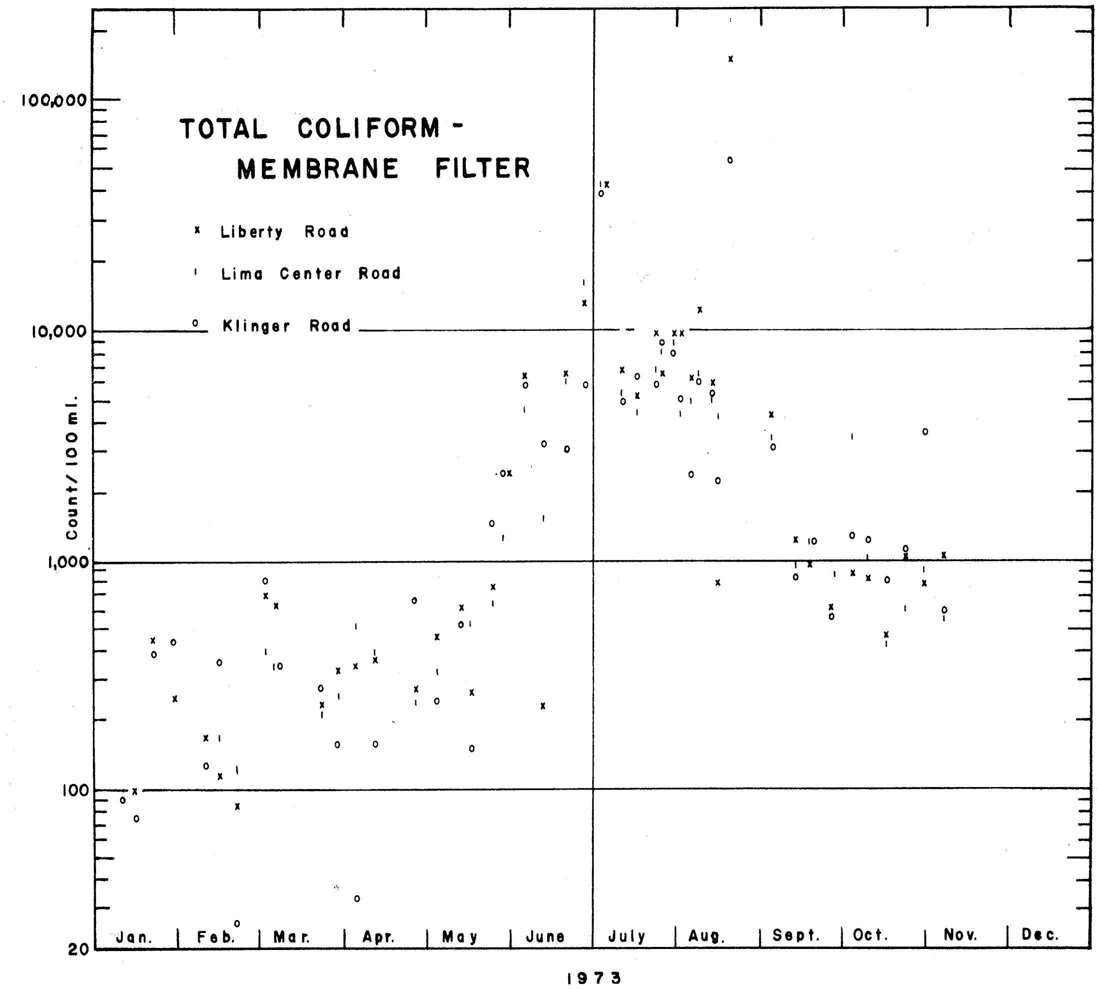


Figure III-3

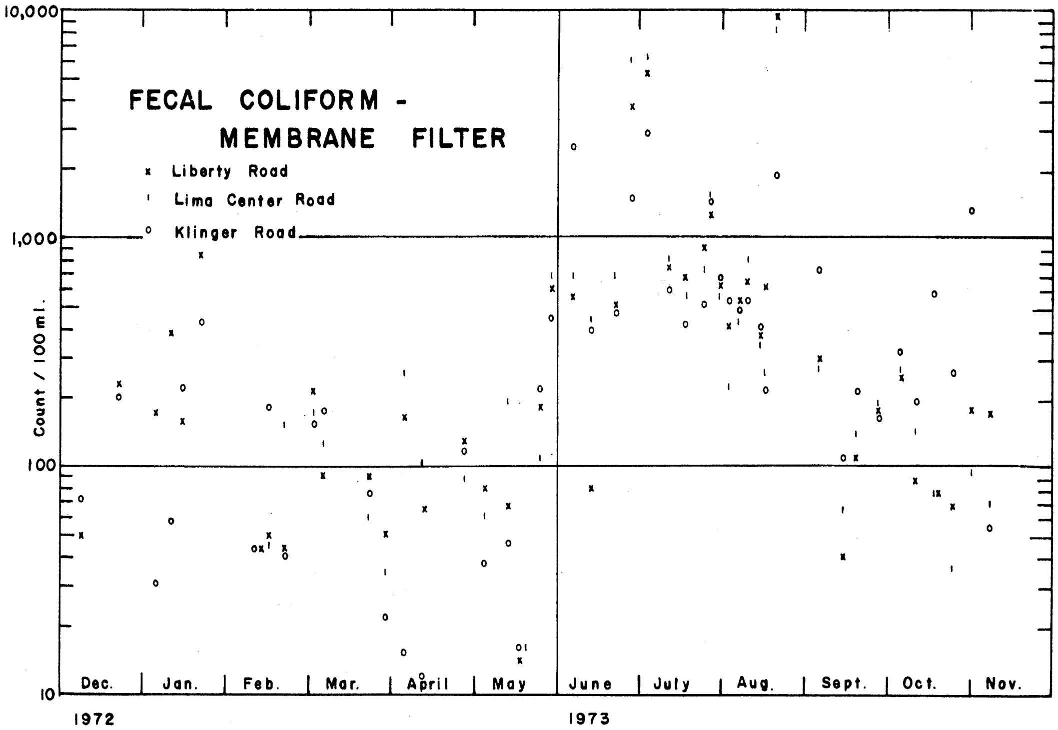


Figure III-4

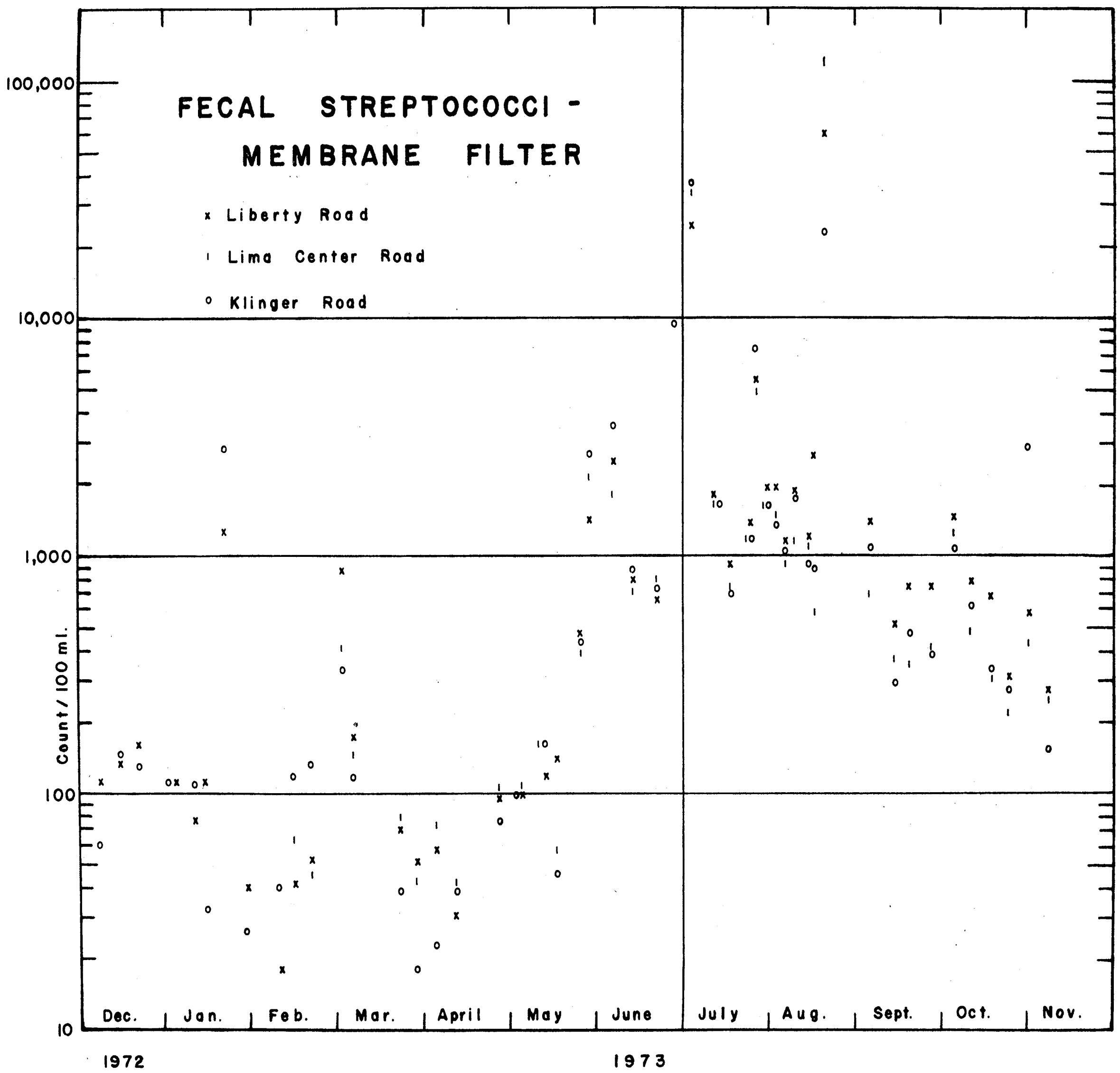

FECAL STREPTOCOCCI - MEMBRANE FILTER
x Liberty Road
ı Lima Center Road
o Klinger Road
100,000
10,000
1,000
100
10
Count / 100 ml.
Dec.
Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
1972
1973

Figure III-5

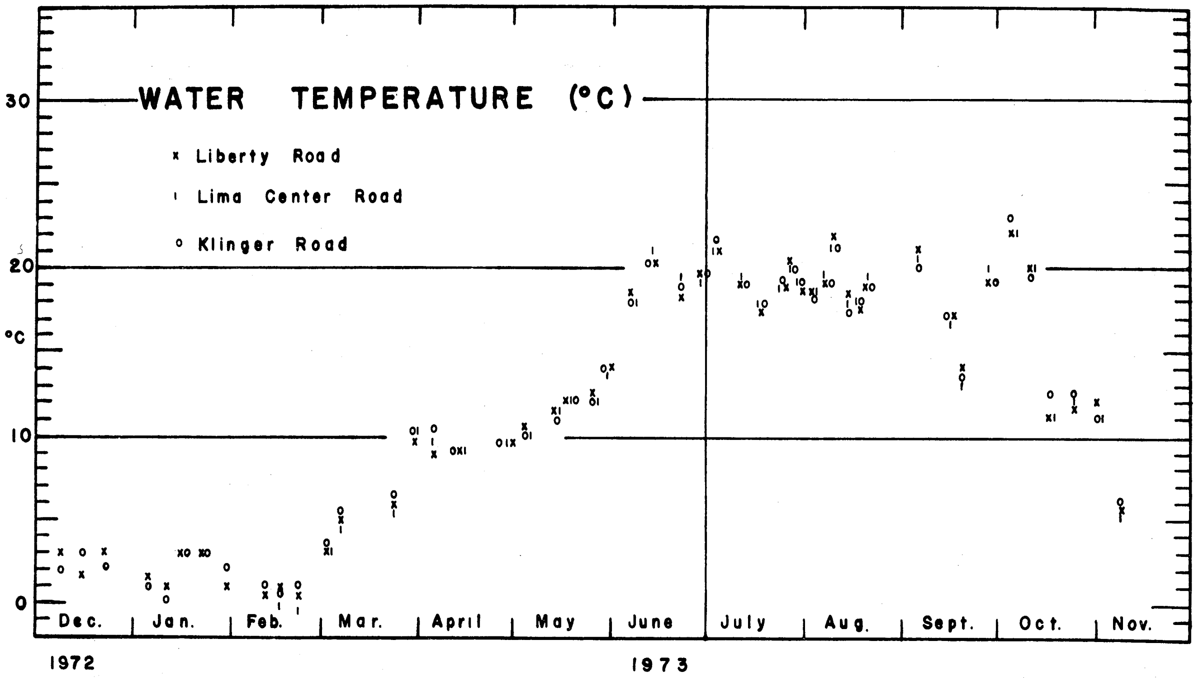


Figure III-6

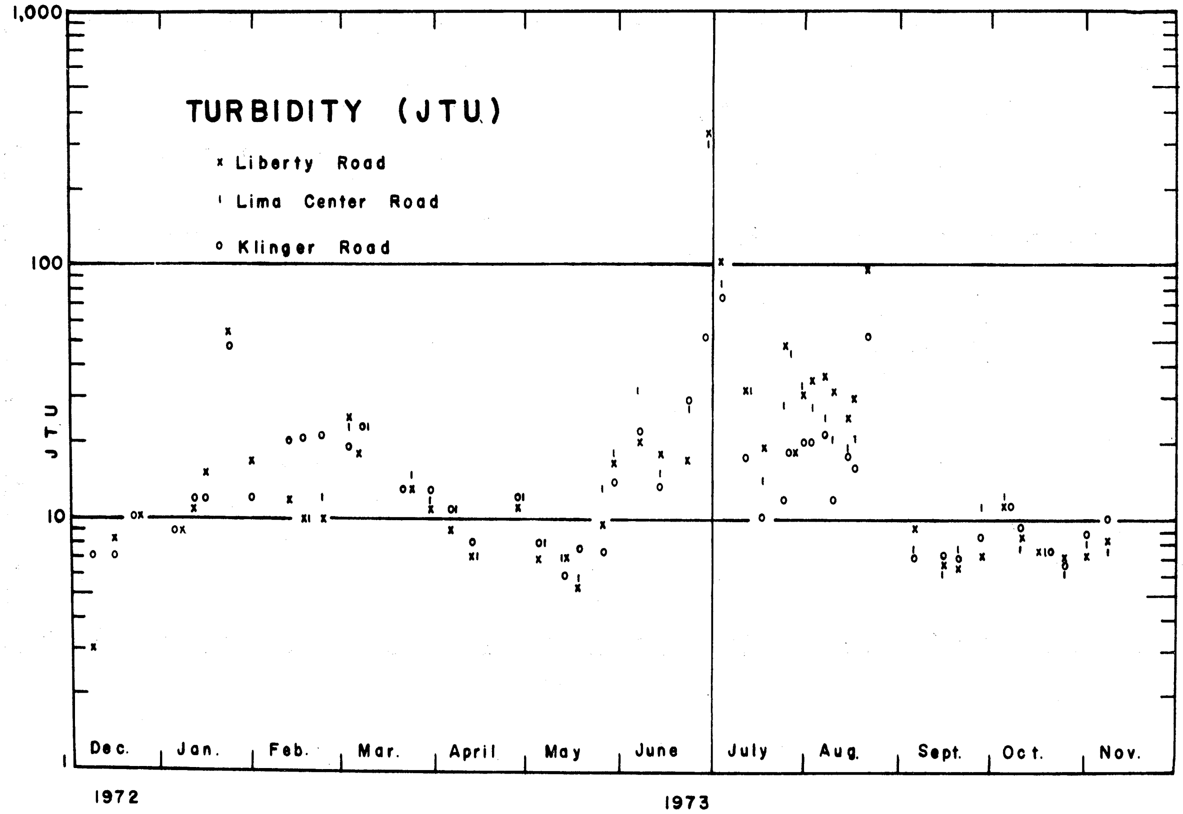


Figure III-7

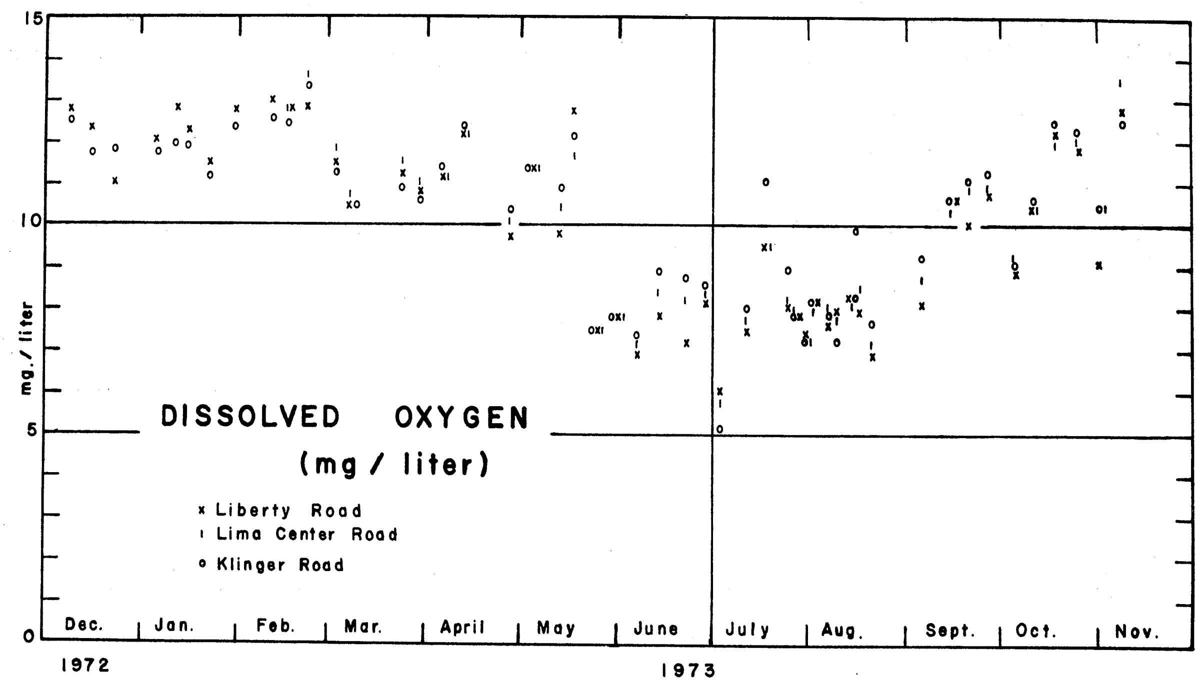


Figure III-8

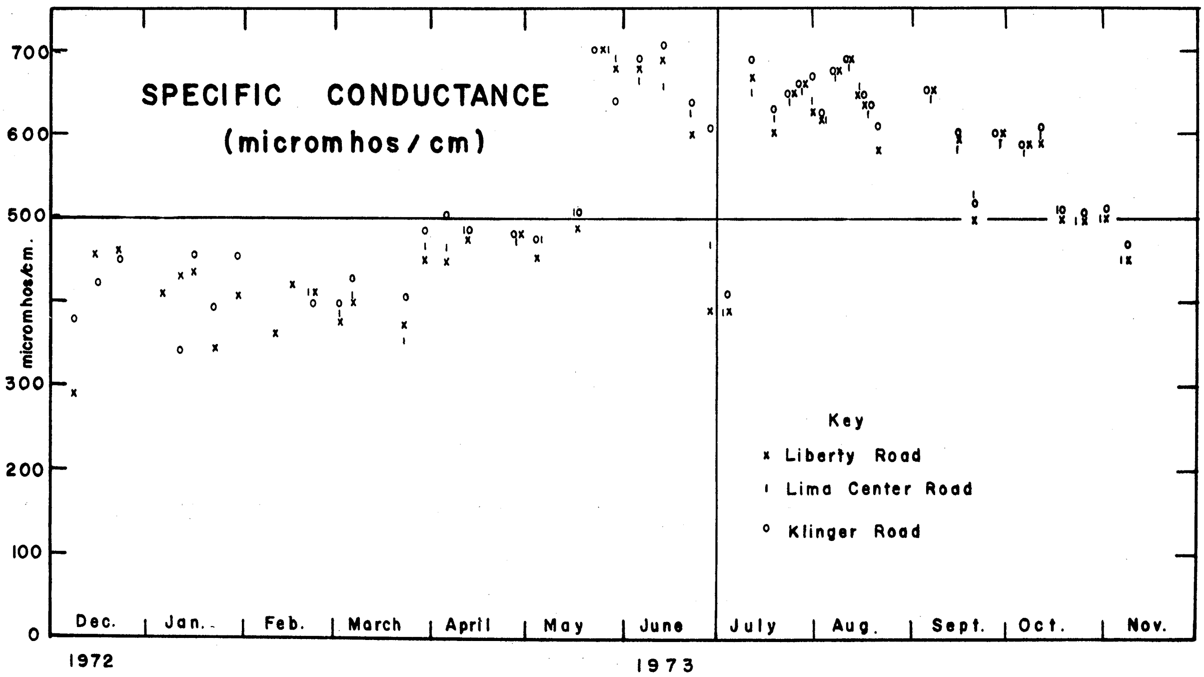


Figure III-9

Special Basin Studies

Samples were collected at nine locations in the study area as shown in Figure II-2 twice during the study period, the first time on March 6, 1973 and the second time on July 11, 1973. The detailed results of the two sampling efforts are presented in Appendix D. In March, the higher bacteriological levels were observed at stations 1, 2, 3, and 4 in the lower part of the basin, with substantially lower levels observed at Stations 5, 6, 7, 8, and 9 in the upper part of the basin. On the other hand, in July approximately the same bacterial levels were observed at all the sampling stations in the basin. It must be appreciated that two sampling efforts of this type are inadequate to allow the formation of any meaningful conclusions, and a much more extensive sampling program would be necessary to establish definite patterns.

Nitrogen and Phosphorus Observations

Special studies were conducted during July and August 1973 to evaluate the nutrient levels involving the compounds of nitrogen and phosphorus at the three primary sampling stations in the study area. These results involving levels of ammonia, nitrite, nitrate, and orthophosphate are presented in Table III-1 and are generally low. Sampling started on July 12, 1973 and extended until August 16, 1973, including twelve different days at most of the stations. Limited information on samples collected at Station 4 at Fletcher Road is also presented. Standard Methods (1) procedures were employed with the exception of the nitrate procedure and all methods which were used are detailed further in Appendix C.

It must be appreciated these nutrient observations were determined for Mill Creek water for only a limited period of the year, during the summer, and must be interpreted in this light. Additional sampling is necessary especially during the spring period of fertilizer application to evaluate overall levels.

U.S. Geological Survey Observations

The U.S. Geological Survey (3) has made water quality information available for two pertinent sampling stations on Mill Creek, one at Manchester Road which corresponds to Station 5 (M-52) of the present study, and the other at Jerusalem Road near Lima Center, which is downstream from the present study area. Detailed physical, chemical, and bacteriological data for samples collected on a bimonthly basis in 1971, 1972, and 1973 are presented in Appendix E of this report. Analyses for nitrogen and phosphorus species, bacteria, BOD, and MBAS

TABLE III - 1

NUTRIENT ANALYSIS OF MILL CREEK STATIONS
1973

Date	Ammonia (N) (mg/l)	Nitrite (N) (mg/l)	Nitrate (N) (mg/l)	Orthophosphate (P) (mg/l)
Station #1 - Mill Creek at Liberty Road				
July				
12...	.225	.053	.60	.015
24...	----	----	.40	.010
25...	.175	.004	.43	.016
26...	.150	.002	.26	.030
30...	.312	.012	.54	.066
August				
2...	.250	.014	.60	.050
6...	.200	.005	.35	.020
9...	.110	.003	.20	.015
10...	.400	.014	.50	.065
14...	.200	.003	.43	.020
16...	.025	.003	---	.020
Station #2 - Mill Creek At Lima Center Road				
July				
12...	.004	.019	.30	.020
24...	----	----	.26	.022
25...	.085	.004	.50	.025
26...	.175	.002	.35	.025
30...	.325	.009	.56	.060
August				
2...	.262	.014	.60	.036
6...	.162	> .140	.35	.017
9...	.110	.003	.20	.016
10...	.337	.014	.60	.065
13...	.375	.006	.30	.030
14...	.225	.003	.45	.025
16...	.050	.004	---	.020

TABLE III-1 (Concluded)

Date	Ammonia (N) (mg/l)	Nitrite (N) (mg/l)	Nitrate (N) (mg/l)	Orthophosphate (P) (mg/l)
	Station #3 - Mill Creek at Klinger Road			
July				
12...	.025	.010	.40	.200
24...	----	----	.35	----
25...	.050	.008	.54	.003
26...	.200	.007	.47	.025
30...	.287	.011	.51	.045
August				
2...	.262	.014	.56	.030
6...	.275	.008	.35	.020
9...	.162	.006	.25	.015
10...	.350	.018	.54	.065
13...	.337	.008	.35	.023
14...	.185	.005	.43	.020
16...	.012	.007	---	.015
	Station #4 - Mill Creek at Fletcher Road			
July				
12...	.000	.009	.50	.038
August				
13...	.275	.006	.25	.025
14...	.237	.003	.33	.023

were performed by the Washtenaw County Health Department, while other field determinations and chemical analyses were performed by the U.S. Geological Survey. Elevated coliform levels are apparent at both sampling stations. The varied chemical analyses performed by the U.S. Geological Survey extend the scope of the present study even though the analyses were performed on an infrequent basis.

Summary

A number of important water quality characteristics of the Mill Creek Study Area have been presented. These included: a discussion of Michigan Water quality standards and Mill Creek use designation, a discussion of field and laboratory procedures, seasonal bacteriological and chemical distributions, a discussion of special basin studies, results of summertime nitrogen and phosphorus observations, and a discussion of available U.S. Geological Survey observations.

Mill Creek is designated for the following uses by the Michigan Water Resources Commission in the vicinity of Guenther Road in Lima Township, Washtenaw Country: Recreation - Partial body contact; Industrial water supply; Fish, wildlife, and other aquatic life - Intolerant fish - warmwater species; and Agricultural uses. For recreational use, the fecal coliform requirement appears to have particular relevance which is of the order of magnitude of a geometric average of no more than 200 fecal coliforms per 100 ml for total body contact, and geometric average of no more than 1,000 fecal coliform per 100 ml for all other waters. The dissolved oxygen requirement for the protection of fish life is a minimum of 5 mg/l as a daily average and no single value less than 4 mg/l.

The evaluation of the water quality in the Mill Creek Study Area involved a number of physical, bacteriological, and chemical analyses of water collected at approximately weekly intervals during the period December 1972 - October 1973 at three primary sampling stations, including Mill Creek at Liberty Road, Mill Creek at Lima Center Road, and Mill Creek at Klinger Road. Special attention has been given to the bacteriological evaluations, and coliform determinations, both total and fecal, have been made using both the MPN fermentation tube procedure and the membrane filter procedure on each sample. In addition, fecal streptococci concentrations were determined using the membrane filter procedure.

Seasonal bacteriological and chemical distributions have been developed and presented for most of the analyses. High bacteriological levels were observed in the summer, while low levels were observed in the winter and early spring. Temperature, of course, is an important factor, but the relatively wet 1973 summer cannot be overlooked. The fecal coliform distribution must be viewed in relation to the standard of 1,000/100 ml applicable to Mill Creek water and it is apparent this level was exceeded at times during the summer of 1973. The seasonal distribution of temperature, dissolved oxygen, turbidity, and specific conductance followed expected patterns.

Samples were collected at nine locations in the study area twice during the study period, the first time on March 6, 1973, and the second time on July 11, 1973. In March, higher bacteriological levels were observed at stations in the lower part of the basin in the vicinity of the proposed park, with substantially lower levels observed at stations in the upper part of the basin. On the other hand, in July approximately the same bacterial levels were observed at all the sampling stations in the basin.

Special studies were conducted during July and August 1973 to evaluate the nutrient levels, involving the compounds of nitrogen and phosphorus at the three primary sampling stations in the study area. These results involving levels of ammonia, nitrite, nitrate, and orthophosphate have been presented and are generally low. Additional sampling is necessary, especially during the spring period of fertilizer application, to evaluate overall levels.

The U.S. Geological Survey has made water quality information available for two pertinent sampling stations on Mill Creek, one at Manchester Road which corresponds to Station 5 (M-52) of the present study, and the other at Jerusalem Road near Lima Center, which is downstream from the present study area. Elevated coliform levels are apparent at both sampling stations. The varied chemical analyses performed by the U.S. Geological Survey extend the scope of the present study even though the analyses were performed on an infrequent basis.

References

1. Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, Washington, D.C. (1971).

2. Welch, Paul S., Limnological Methods, McGraw-Hill Book Company, New York, New York (1948).

3. Private communication from Jon O. Nowlin, Hydrologist, U.S. Geological Survey, Okemos, Michigan (November, 1973).

IV. BACTERIOLOGICAL RELATIONSHIPS

Introduction

The availability of total coliform, fecal coliform, and fecal streptococcus results using both the MPN and membrane filter techniques (for total and fecal coliform only) for the study period suggested several useful summaries and comparisons. This section of the report includes: fecal coliform/fecal streptococci relationships, total coliform/fecal coliform relationships, a comparison of the MPN and membrane filter test procedures, and a comparison of results by sampling stations.

Fecal Coliform/Fecal Streptococci Relationships

Interest has centered on the fecal coliform/fecal streptococci ratio as an indication of the source of fecal contamination. Geldreich (1,2) and Geldreich and Kenner (3) have indicated that fecal coliform bacteria are more numerous than fecal streptococci in domestic sewage, with a fecal coliform/fecal streptococci ratio always greater than 4.0. Conversely, fecal streptococci are more numerous than fecal coliforms in the feces of farm animals, cats, dogs, and rodents. In feces from these animals, the fecal coliform to fecal streptococci ratios are less than 0.7. They report that similar low ratios are common to urban stormwater and farmland drainage.

Results of probability analyses of FC/FS ratios for the full year and for the summer bathing period of June through August, for the three primary sampling stations considered together and separately, are presented in Table IV-1.

TABLE IV-1

FC/FS - MEMBRANE FILTER

Data Grouping	Mean Ratio $\bar{X}$	σ_{log}	N
Stations 1,2,3 for year	0.48	0.404	71
Station 1 for year	0.40	0.463	26
Station 2 for year	0.47	0.338	32
Station 3 for year	0.48	0.390	31
Stations 1,2,3 (June-Aug.)	0.35	0.348	39
Station 1 (June-Aug.)	0.31	0.300	13
Station 2 (June-Aug.)	0.38	0.360	15
Station 3 (June-Aug.)	0.36	0.384	16

A typical probability plot using logarithmic normal probability paper is illustrated in Figure IV-1. Specific procedures for the use of probability paper in summarizing data have been presented by Gannon (4) and Velz (5). Figure IV-1 includes the FC/FS mean ratios for stations 1, 2, and 3 for the full year, and was arrived at using only the membrane filter results since this was the only method used for fecal streptococcus determination. It is apparent that the mean value of FC/FS is 0.48, which is the junction of the fitted distribution line and the 50% equal to or less than vertical line. The slope of the line is the standard deviation expressed in logarithms and has a value of σ_{log} = 0.404. Similar analyses were performed for each of the other data groupings of Table IV-1.

It is apparent from Table IV-1 that the mean FC/FS ratios for all the groupings are less than the 0.7 figure of Geldreich, suggesting an animal rather than a human origin. This confirms an opinion arrived at by the writer based on a field inspection of the drainage area.

It is not possible to demonstrate a statistically significant difference between the summer ratios (June-August) and the full year ratios, but an inspection of the Table IV-1 tabulation indicates a lower ratio for the summer months. Also, it is not possible to demonstrate any difference among the ratios for the three primary sampling stations.

Total Coliform/Fecal Coliform Relationships

A summary of total coliform/fecal coliform ratios for various data grouping analyzed by the use of log-normal probability paper as previously discussed is presented in Table IV-2. It is apparent that the summer groupings are higher than the full year values, and that the membrane filter ratios are higher than the MPN ratios. From the summary, it is seen that the total coliform values are 5.0 to 9.0 times higher than the fecal coliform values for Mill Creek water.

TABLE IV-2

TC/FC RATIOS

Data Grouping	Mean Ratio $\bar{X}$	σ_{log}	N
Sta. 3, Full year (Membrane Filter)	6.3	0.346	40
Sta. 3, Full year (MPN)	5.4	0.535	40
Sta. 1,2,3, Summer (MPN)	6.7	0.452	47
Sta. 1,2,3, Summer (Membrane Filter)	8.7	0.350	57

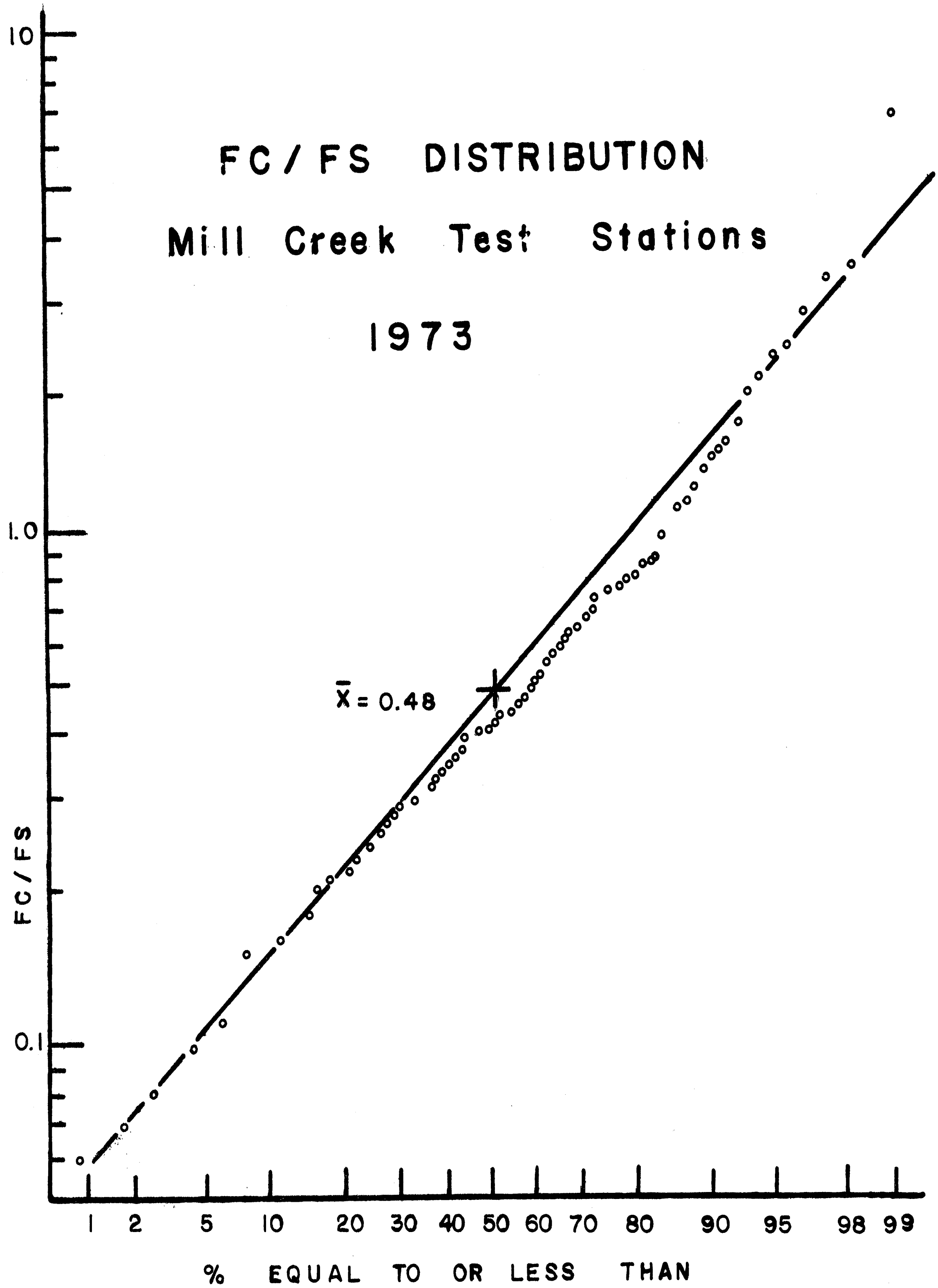

FC / FS DISTRIBUTION
Mill Creek Test Stations
1973
X̄ = 0.48
10
1.0
0.1
FC / FS
1 2 5 10 20 30 40 50 60 70 80 90 95 98 99
% EQUAL TO OR LESS THAN

Figure IV-1

Comparison of Test Procedures
MPN and Membrane Filter

Probability summaries have been developed for the MPN/Membrane Filter ratios for total coliform results and fecal coliform results for the full study year for all the primary sampling stations. As previously, log-normal probability paper was used. The summary results are presented in Table IV-3. It is apparent that the MPN/MF ratio for fecal coliform results is higher than for the total coliform results, and this difference has been demonstrated to be statistically significantly different at the 95% level. Certainly these results have significance in terms of an appropriate laboratory procedure to be used in testing for compliance with Michigan water quality standards. Standard Methods accepts both the MPN and the Membrane Filter procedures, but it is seen that in testing for fecal coliform levels the MPN results were over twice the Membrane Filter results for Mill Creek water.

TABLE IV-3

MPN/MF RATIOS FOR FULL YEAR

(Stations 1,2,3)

Data Grouping	Mean Ratio $\bar{X}$	σ_{log}	N
Total Coliform	1.38	0.440	109
Fecal Coliform	2.15	0.339	114

Comparison of Sampling Station Results

Total and fecal coliform summaries by station for the summer period (July-August) are presented in Table IV-4. Because of the relatively small number of individual observations at specific stations, no statistically significant differences could be demonstrated. However, in all four groupings station 1 - Mill Creek at Liberty Road is consistently higher on a mean basis than the other two stations.

TABLE IV-4

TOTAL AND FECAL COLIFORM SUMMARIES
BY STATION FOR SUMMER PERIOD (JULY-AUGUST)

Data Grouping	Mean X - Count/100 ml	σ_{log}	N
Total Coliform MF			
Sta. 1	7800	0.824	14
Sta. 2	7500	0.505	15
Sta. 3	6900	0.404	14
Total Coliform MPN			
Sta. 1	8900	0.351	8
Sta. 2	7300	0.438	9
Sta. 3	7500	0.505	8
Fecal Coliform MF			
Sta. 1	1000	0.532	16
Sta. 2	700	0.331	16
Sta. 3	720	0.346	14
Fecal Coliform MPN			
Sta. 1	1600	0.636	11
Sta. 2	1060	0.494	11
Sta. 3	1320	0.430	11

Summary

The availability of total coliform, fecal coliform, and fecal streptococcus results, using both the MPN and membrane filter techniques (for total and fecal coliform only) for the study period, suggested several useful summaries and comparisons. These included: fecal coliform/fecal streptococci relationships, a comparison of the MPN and membrane filter test procedures, and a comparison of results by sampling stations.

Geldreich has indicated that domestic sewage has a fecal coliform/fecal streptococci ratio greater than 4.0, while the ratio is less than 0.7 for farm animals, cats, dogs, and rodents. The FC/FS ratio for various data groupings of this study was always less than 0.7 on a mean basis, suggesting an animal rather than a human origin. This confirms an opinion arrived at by the writer based on a field inspection of the drainage area.

A summary of total coliform/fecal coliform ratios shows that the summer groupings are higher than the full year values, and that the membrane filter ratios are higher than the MPN ratios.

In a comparison of the test procedures using the MPN and MF techniques, it is seen that the MPN/MF ratio for fecal coliform results is higher than for the total coliform results, and is of the order of magnitude of 2.15 for fecal coliforms and 1.38 for total coliforms. Certainly these results have significance in terms of an appropriate laboratory procedure to be used in testing for compliance with Michigan water quality standards. Standard Methods accepts both the MPN and membrane filter procedures, but it is seen that in testing for fecal coliform levels the MPN results were over twice the membrane filter results for Mill Creek water.

Total and fecal coliform summaries have been presented by station for the summer period (July-August). Because of the relatively small number of individual observations at a specific station, no statistically significant difference could be demonstrated, however, in all four groupings station 1 - Mill Creek at Liberty Road is consistently higher on a mean basis than the other two stations.

References

1. Geldreich, E. E., "Buffalo Lake Recreational Water Quality: A Study in Bacteriological Data Interpretation," Water Research, Pergamon Press, Great Britain, Vol. 6, pp. 913-924 (1972).

2. Geldreich, E. E., "Applying Bacteriological Parameters to Recreational Water Quality," Journal American Water Works Association, Vol. 62, No. 2, 113 (1970).

3. Geldreich, E. E., and Kenner, Bernard A., "Concepts of Fecal Streptococci in Stream Pollution," Journal Water Pollution Control Federation, Vol. 41, No. 8, Part 2, pp. R336-R352 (August 1969).

4. Gannon, John J., "Statistical Basis for Interpretation of Data," Proceedings of the Michigan Sewage and Industrial Wastes Association 1959 Annual Meeting, 34 pp. (1959).

5. Velz, C. J., "Applied Stream Sanitation," Wiley-Interscience (1970).

V. BACTERIAL INACTIVATION STUDIES

with
Anthony C. Rutz

Introduction

Interest centers on the survival possibilities of microbial organisms, especially total coliform, fecal coliform, and fecal streptococci, under proposed impoundment conditions of Mill Creek. This section of the report describes bacterial inactivation studies conducted during August 1973, including procedures employed and illustration of typical results. Also included are predicted microbial levels, especially those involving fecal coliform, under proposed impoundment conditions. In addition, a section of the report describes bacterial inactivation or microbial self-purification results of others, which generally show that total coliform, fecal coliform, and fecal streptococci organisms of human or animal origin die off rapidly under the complex environment of natural waters.

Procedures

Samples of Mill Creek water were collected at Klinger Road at the upstream end of the proposed impoundment, and transported to an outdoor experimental reservoir located on the grounds of the Ann Arbor wastewater treatment plant, for incubation under simulated natural impoundment conditions of no flow. Five-gallon glass carboys were used as sampling and incubation vessels. These vessels were secured for submerged incubation in the outdoor experimental reservoir and were thus subjected to the natural conditions of day and night, temperature, etc. Particular care was given to sample handling involving the use of sterile techniques so as not to introduce contamination as part of the the experimental procedure. In the laboratory, the membrane filter method of bacterial evaluation was used for all determinations.

In addition to the incubation of the Mill Creek water sample as collected, the variables of light and dark conditions, turbidity level, and microorganism level were included in the experimental design. One vessel was completely darkened using two layers of heavy duty aluminum foil, one vessel had the turbidity artifically increased using sterilized Mill Creek soil added to a level approximating the highest observed natural turbidity conditions, and two vessels had the bacterial level increased to approximate a high natural stream level using Ann Arbor sewage as a seed. All samples were thoroughly mixed as part of the initial processing, but were then incubated in a quiescent state for the duration of the experiment.

The first experiment was started on August 6, 1973 and extended for a five-day period, while the second experiment which was a duplicate of the first experiment was started on August 13, 1973, and this in turn lasted for another five days.

Results

The results from two experimental vessels which have greatest relevance to the present study are shown in Figure V-1 and Figure V-II. Figure V-1 involves a Mill Creek at Klinger Road sample, which was incubated as collected, while Figure V-2 involves a sample as collected which then had artificial turbidity induced by the addition of sterilized Mill Creek soil. This latter experiment was included to evaluate a condition observed by Streeter (1) many years ago, when he found that the rate of summer decrease in bacterial concentration was abnormally high in the Ohio River below Cincinnati, when low stream flows and velocities permitted sedimentation of turbidity. His conclusion was that bacteria were adsorbed by the solids and carried to the river bottom.

Inspection of Figure V-1 shows a slight increase in total coliform levels followed by a rapid die off, while the fecal coliform and fecal streptococci die off at a slow rate for the first two days of incubation, followed by a more rapid rate. In Figure V-2 it is seen that a more rapid rate of inactivation occurs in the early days of incubation lending credence to Streeter's observations on the Ohio River.

The sample incubated under continuously dark conditions showed longer organisms survival, while the sample with artificially increased organism level followed the same pattern as illustrated in Figure V-1. The second experimental series started on August 13, 1973 generally confirmed the results of the first experiment.

Predicted Bacterial Behavior in the Impoundment

Special attention is given to a prediction of the behavior of the fecal coliform organism in the proposed impoundment, based on the previously reported bacterial inactivation results and the State of Michigan fecal coliform requirements.

Bacterial Inactivation Rates

Sample Collected August 6, 1973

Mill Creek at Klinger Road

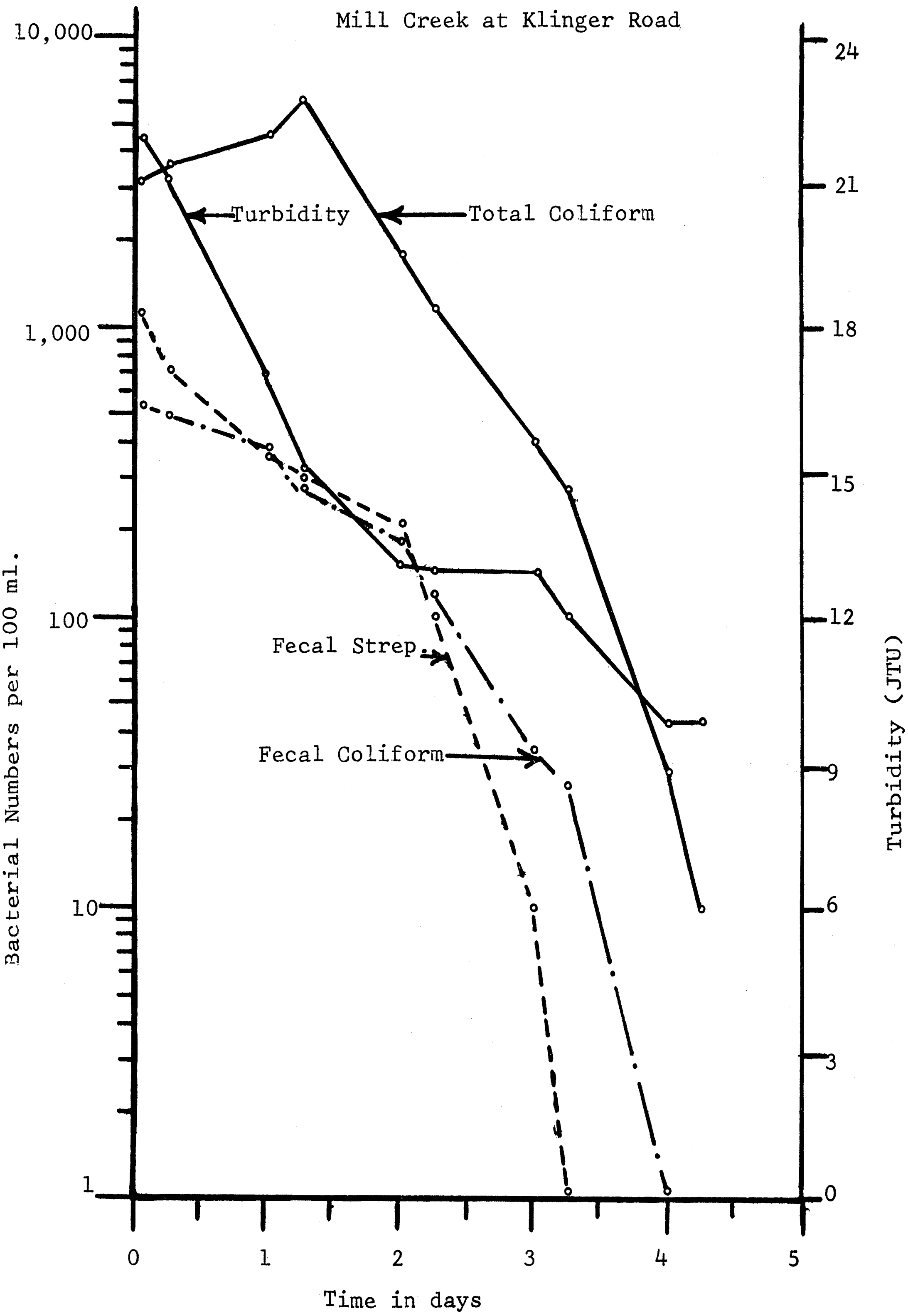
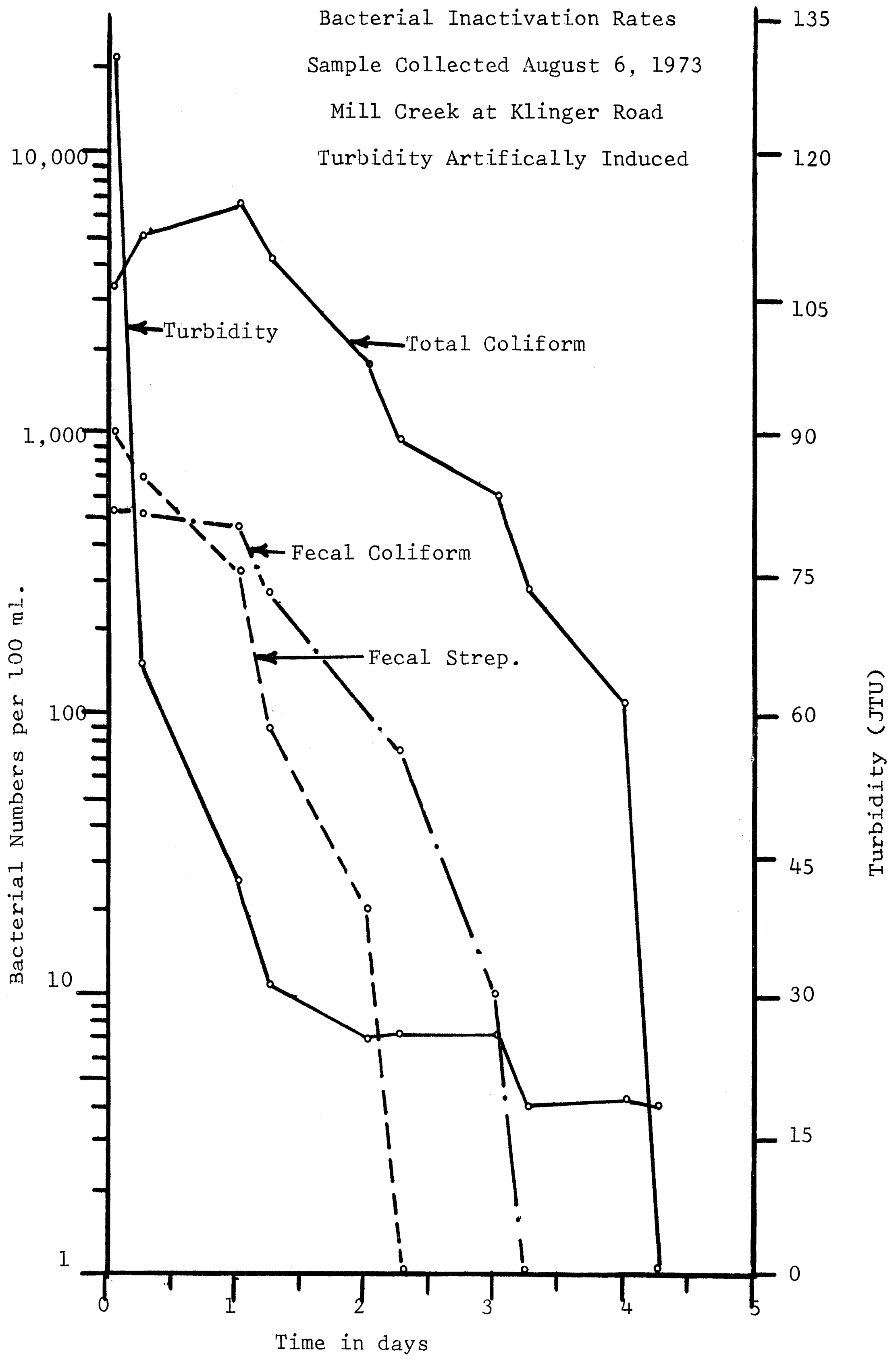


Figure V-1



Bacterial Inactivation Rates
Sample Collected August 6, 1973
Mill Creek at Klinger Road
Turbidity Artifically Induced
10,000
1,000
100
10
1
Bacterial Numbers per 100 ml.
Turbidity
Total Coliform
Fecal Coliform
Fecal Strep.
135
120
105
90
75
60
45
30
15
0
Turbidity (JTU)
0
1
2
3
4
5
Time in days

Figure V-2

It is assumed that Chick's law (2) defines the inactivation process, which says that bacteria die at a constant rate; that is, a given percentage of the residual population dies during each successive time unit. Velz (2) has proposed a mathematical formulation as follows:

$$\frac{dB}{dt} = KB$$

which integrates in common logarithms to:

$$\log \frac{B}{B_o} = - kt \text{ or } \frac{B}{B_o} = 10^{-kt}$$

where B_o is the initial number,
B is the residual after any time t,
k is the reaction, or death rate.

Using the data of Figure V-1 for fecal coliform, it is seen that k = 0.253 for the slow rate of the first two days, and k = 1.176 for the more rapid rate of the remaining time.

Brater and Wylie (3) report that the proposed impoundment will have a volume of 5530 acre feet, a surface area of 650 acre, and an average depth of 8.5 feet. At a flow of 5 cfs, the detention time would be 560 days assuming complete displacement through the impoundment. For the June 26, 1968 flood conditions, Brater and Wylie (3) estimate the flow through the impoundment as 460 cfs and for this flow the calculated detention time is 6.1 days.

If one takes the highest fecal coliform level of 13,000/100 ml observed at any time during 1973 at Klinger Road, and combines this with the shortest calculated detention time corresponding to the 1968 flood conditions, the calculated fecal coliform level at the dam would be less than 1/100 ml using the fecal coliform inactivation rates of Figure V-1. Obviously this is a very severe combination of conditions and for lower flow rates and longer impoundment detention times we would expect to find more rapid decline further upstream in the impoundment. The development of bathing beaches in the proposed park should take these natural bacterial inactivation processes into account, with the beach located in the lower end of the impoundment as close to the dam as possible.

Literature Review

Much has been written over the years on the subject of bacterial inactivation in natural streams and lakes, and also in ocean and estuary locations. A great deal of the early work conducted at the Cincinnati Stream Pollution Laboratory, and elsewhere, has been effectively summarized by Earle B. Phelps (4) in his classis book Stream Sanitation published in 1944. Phelps applied Chick's first-order reaction to bacterial death in streams, and for the decreasing portion of the curve, where deaths exceeded increased by multiplication, he developed a two-term equation to describe the reaction.

Orlob (5) provided an extensive literature review in 1956 on the viability of sewage bacteria in seawater as a result of a special investigation of the efficacy of submarine outfall disposal of sewage and sludge that he and Professor Erman A. Pearson conducted for the California Water Pollution Control Board.

Hedrick and associates (6,7) of the Biology Department, Illinois Institute of Technology, Chicago, reported on survival of *Salmonella*, *Shigella*, and coliforms in Lake Michigan water. They stated that "In general, pure culture studies with *E. coli* [*Escherichia coli*] and *Salmonella schottmuelleri* parallel the survival of the coliforms in Lake Michigan water during the two-year study period."

Kittrell and Furfari (5) reported on observations of coliform bacteria in streams. They described both qualitative and quantitative fundamentals of the coliform patterns in large streams receiving wastewater from typical large cities, as developed by earlier workers. The effects of certain environmental factors that cause the coliform pattern to deviate from the normal were discussed. Several case illustrations were presented.

Slanetz *et al.* (9) reported on the correlation of coliform and fecal streptococcal indices with the presence of *Salmonella* and enteric viruses in seawater and shellfish at the Second International Conference on Water Pollution Research, held in Tokyo in August, 1964. They stated that "*Salmonella* species or serotypes were isolated from seawater and oysters collected from areas having high coliform, fecal coliform, and fecal streptococcal densities.

Scarce *et al.* (10) reported on the survival of indicator bacteria in receiving waters, particularly Lake Michigan, under various conditions. They indicated that the survival of coliform bacteria and fecal streptococci, when sewage treatment plant effluent was combined with Lake Michigan water, survived through several weeks in laboratory tests. Results indicated that the survival patterns exhibited considerable variation in response to changes in water temperature, dilution factors, illumination, and composition of the effluent.

Slanetz *et al.* (11) reported on the survival of fecal streptococci in seawater. They found these organisms did not increase in numbers to any appreciable extent when suspended in seawater or sewage effluent in cellophane bags and suspended in New Hampshire Bay water at the mouth of a river estuary. There was generally a decrease of 50-85 percent in the original numbers of these organisms within the first 1-2 days, with practically complete die off within 7-11 days. Coliforms and fecal coliforms in sewage effluent were found to increase in number during the first 1-4-day period of immersion in this bay water. A marked die off of the bacteria then occurred during the next 4-6 days of exposure.

Berg et al. (12) gave an extensive review of the survival of bacteria and viruses in natural waters. They concluded that survival times vary broadly as experimental conditions are altered and as natural conditions change.

Hanes and Fragala (13) reported in 1967 on the effect of seawater concentration of sruvival of indicator bacteria. Among their findings they stated that various concentrations of seawater affect the growth phase of the coliform and E. coli, type 1, organisms. The most pronounced effect occurs between 33 percent and 67 percent seawater, where the growth phase disappears.

Gelfreich et al. (14) reported that studies of bacterial survival in storm water indicated organisms persisted at higher levels for winter studies (10°C) than they did in the summer studies (20°C).

Gallagher and Spino (15) reported on the significance of numbers of coliform bacteria as an indicator of enteric pathogens. They state that a summary of data shows little apparent correlation between levels of total or fecal coliform and the isolation of Salmonella.

Velz (2) as mentioned previously, has a chapter on microbial self-purication in his book Applied Stream Sanitation. A number of specific illustrations are presented.

Savage and Hanes (16) conducted a study to examine the effect of nutrient levels, as measured by BOD analysis, on the toxicity of seawater to total coliforms and fecal coliforms. They found that somewhere between 1 and 10 mg/l initial BOD, fresh seawater temporarily loses its toxicity to total and fecal coliform bacteria. In fresh seawater with BOD levels to 10-120 mg/l, the relationship between the log of the maximum bacterial densities and the intial BOD seemed to be linear. Further, by themselves total and fecal coliform bacteria are not reliable indicators of the degree of recent fecal pollution in seawater because, given sufficient nutrient levels, the bacterial density will increase.

Dutka (17) is a recent paper included results of a study of survival of coliforms and fecal streptococci in relatively unpolluted lake water. Total coliform levels increased temporarily and then died off, while fecal streptococci steadily decreased.

Summary

Interest centers on the survival possibilities of microbial organisms, especially total coliform, fecal coliform, and fecal streptococci under proposed impoundment conditions of Mill Creek. This section of the report described bacterial inactivation studies conducted during August 1973, including procedures employed and illustrations of typical results. Also included are predicted microbial levels, especially those involving fecal coliform under proposed impoundment conditions. In addition, a section of the report describes bacterial inactivation or microbial self-purification results of others, which generally show that total coliform, fecal coliform, and fecal streptococci organisms of human or animal origin die off rapidly under the complex environment of natural waters.

Samples of Mill Creek water were collected at Klinger Road at the upstream end of the proposed impoundment, and transported to an outdoor experimental reservoir located on the grounds of the Ann Arbor wastewater treatment plant for incubation under simulated natural impoundment conditions of no flow. In addition to the incubation of Mill Creek water sample as collected, the variables of light and dark conditions, turbidity level, and microorganism level were included in the experimental design. For the unaltered Mill Creek water sample, there was a slight increase in total coliform levels followed by a more rapid die off, while the fecal coliform and fecal streptococci died off at a slow rate for the first two days of incubation, followed by a more rapid die off.

Predictions were made of the fecal coliform inactivation in the proposed impoundment. If one takes the highest fecal coliform level of 13,000/100 ml observed at any time during 1973 at Klinger Road, and combines this with the shortest calculated detention time corresponding to the 1968 flood conditions, the calculated fecal coliform level at the dam would be less than 1/100 ml, using the observed fecal coliform inactivation rates. Obviously this is a very severe combination of conditions and for lower flow rates and longer impoundment detention times, we would expect to find more rapid decline further upstream in the impoundment. The development of bathing beaches in the proposed part should take these natural bacterial inactivation processes into account, with the beach located in the lower end of the impoundment as close to the dam as possible.

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VI. BACTERIAL INDICATORS IN THE EVALUATION OF NATURAL RECREATIONAL WATER QUALITY

Introduction

This section of the report will discuss the role of bacterial indicators in the evaluation of natural recreational water quality. To be considered will be certain historical aspects, indicator organisms, coliform organisms, fecal streptococcus, pathogens as indicators, and recreational water quality requirements.

Historical Aspects

The "father of epidemiology" J. Snow in London performed experiments in the mid 1800's that implicated drinking water as a transmission vector in an epidemic of cholera that was erupting at that time. Since then the role of water in transmitting many diseases found in man and animals has been documented. These include such disorders as salmoellosis, shigellosis, leptospirosis, tularemia, cholera, tuberculosis, human enteric viruses, parasitic protozoa and parasitic worms (1). The agents responsible are as diverse as the diseases produced and there are no available routine diagnostic procedures to cover this broad range of pathogenic organisms. With that in mind and the need for a surveillance system to detect potential disease carrying water, the concept of "indicator organisms" developed. It must be appreciated that the risk of disease transmission in the case of drinking water is greater than where water is used for bathing purposes. Although water may be ingested while swimming, it is not an expected continuous part of this water use; on the other hand, continuous ingestion is a usual part of the drinking process. With this in mind, the bacteriological requirements for finished drinking water as defined by the U.S. Public Health Service Drinking Water Standards are much more restrictive than the requirements for natural bathing waters.

Indicator Organisms

The term "indicator organism" generally refers to a bacterial organism which directly or indirectly may reflect a potential health hazard and, of course, comes from the same source as pathogenic organisms. They have been used traditionally in efforts to determine if contamination exists in dangerous levels in either natural or artificial water systems.

Dutka (3) indicated that indicator organisms should:

"(1) be present and occur in much greater numbers than the pathogens concerned,
(2) not be able to proliferate to any greater extent than entering pathogens in the aqueous environment,
(3) be more resistant to disinfectants and to the aqueous environment than the pathogens,
(4) yield characteristic and simple reactions enabling as far as possible an unambiguous identification of the group."

As in many areas, few individual organisms can be considered ideal. Water bacteriologists, therefore, developed a system for bacteriological evaluation using the coliform organisms as the most representative one available.

Coliform Organisms

Coliform organisms have been employed as an indicator for nearly 60 years, since they were first incorporated into Standard Methods of the American Public Health Association in 1912, and the Public Health Service Drinking Water Standard of 1914 (4).

The tests for their quantification employ morphological and physiological traits specific for the group, and require from one to six days for completion depending on the specific test, necessary incubation times, and degree of completeness involved. For example, the coliform group are defined as, aerobic and facultative anaerobic, gram-negative, nonspore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C, or produce a dark metallic sheen within 24 hours on an Endo-type medium containing lactose. These characteristics are the basis for the two accepted procedures in coliform identification, multiple-tube fermentation and membrane filter technique found in Standard Methods (5).

The traditional tests for total coliform do not distinguish fecal from non-fecal sources, and there has been a need to differentiate members of the coliform group found in the feces of warm blooded animals from those of other environmental sources. Procedures for such differentiation were first proposed by Eijkman (4) in 1904 involving an elevated temperature incubation process, and since then a number of workers have followed through on his suggestion resulting in the present method (5). This involves for fecal coliform coliform evaluation, incubation at an elevated temperature of 44.5°C employing selective media.

Relationships between fecal coliform and total coliform levels for Mill Creek water, using both the MPN and membrane filter methods, have been presented in section IV of this report.

Fecal Streptococcus

Standard Methods (5) states: "The streptococci group are indicators of fecal pollution of water, inasmuch as the normal habitat of these organisms is generally the intestine of man and animals." One of the most interesting uses of fecal streptococci has been in combination with fecal coliforms, generally expressed as a ratio, to indicate origin of fecal contamination. As mentioned previously, Geldreich (6,7,8) has interpreted the ratios as follows:

$FC/FS \geq 4.0$		strong evidence that origin is human wastes
$FC/FS \leq 0.7$		strong evidence that origin is farm animals, cats, dogs, and rodents

For ratios between 0.7 and 4.0, the origin is, no doubt, mixed, and is a higher proportion of human origin as the ratio of 4.0 is approached, and is a higher proportion of animal origin as the ratio of 0.7 is approached.

Pathogens as Indicators

Some few authors have cited unusual cases to support their casting of suspicion on the validity of the coliform test. However, Standard Methods (5) comments on these cases as follows:

"The circumstances surrounding these isolations are not at all clear and it should not be concluded that the coliform test is unreliable or even needs to be supplemented by routine examinations for pathogens at this time."

Pathogen evaluation in water is time consuming, complex, inaccurate in some cases and generally beyond a normal water laboratories capabilities. Standard Methods (5) presents research procedures for *Salmonella*, *Shigella*, enteric viruses, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*.

Recreational Natural Water Quality Requirements

Michigan Water Quality Standards (Appendix B) which went into effect on December 12, 1973 indicate that waters of the state protected for total body contact recreation shall contain not more than 200 fecal coliforms per 100 ml, and all other waters of the state shall contain no more than 1,000 fecal coliforms per 100 ml. These levels are in agreement with those recommended in 1968 by the National Technical Advisory Committee on Water Quality Criteria (9). The focus on fecal coliform level as a primary control measure is a shift from the previous Michigan standards which included both total coliform and fecal coliform limitations. The Recreation and Aesthetics Subcommittee of the National Technical Advisory Committee (9) state: "It is the Subcommittee's opinion that of the groups of organisms commonly employed in evaluating sanitary conditions in surface waters, fecal coliform is by far the best choice for use in criteria for contact reaction."

The Subcommittee further states: "There is an urgent need for research to refine correlations of various indicator organisms, including fecal coliforms to water-borne disease." The classical epidemiological studies conducted over twenty years ago by the U.S. Public Health Service involving the Great Lakes (10), the Ohio River (11), and Long Island Sound (12) failed to show a statistically significant relationship between swimmer illness and bathing water quality. It should be stated that this may have been due more to the location of appropriate study areas and the need for large study populations, rather than the fact that no effect exists.

In addition to these epidemiological considerations, Geldreich (7) showed that the presence of salmonella organisms rose significantly when the fecal coliform level of 200/100 ml was exceeded. Recent work of Smith et al. (13) on the Saline River, Michigan, which has basin characteristics similar to Mill Creek, showed 1 salmonella to 227 fecal coliform. It is the opinion of the writer that the fecal coliform level of 200/100 ml is a reasonable one for bathing water quality, but there is also a definite need for further research to refine correlations of various indicator organisms to water-borne disease, as recommended by the Recreation and Aesthetics Subcommittee of the National Technical Advisory Committee.

Summary

This section of the report has considered the role of bacterial indicators in the evaluation of natural recreational water quality including: historical aspects, indicator organisms, coliform organisms, fecal streptococcus, pathogens as indicators, and recreational natural quality requirements.

Water has been recognized as a carrier of disease organisms since the mid-1800's, but the agents responsible are as diverse as the diseases produced, and there are no available routine diagnostic procedures to cover this broad range of pathogenic organisms. With this in mind and the need for a surveillance system to detect potential disease carrying water, the coliform organisms were developed as indicators.

In recent years, a test for fecal coliforms was developed which allows the differentiation of members of the coliform group found in the feces of warm-blooded animals from those of other environmental sources.

Standard Methods supports the coliform test and says the test does not need to be supplemented by routine examination for pathogens at this time.

It is the opinion of the writer that the fecal coliform level of 200/100 ml is a reasonable one for bathing water quality, but there is also a definite need for further research to refine correlation of various indicator organisms to water-borne disease, as recommended by the Recreation and Aesthetics Subcommittee of the National Technical Advisory Committee.

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APPENDIX A

PROPOSAL FOR MILL CREEK WATER QUALITY EVALUATION

Proposal for

MILL CREEK WATER QUALITY EVALUATION

To: Huron-Clinton Metropolitan Authority
600 Woodward Avenue
Detroit, Michigan 48226

From: John J. Gannon, Principal Investigator
Water Quality Program
Department of Environmental and Industrial Health
The University of Michigan
Ann Arbor, Michigan

October 1972

Proposal for

Mill Creek Water Quality Evaluation

A. Introduction

The Huron-Clinton Metropolitan Authority has proposed the development of a metropolitan park in Lima Township in Western Washtenaw County. The focal point of the park will be an impoundment on Mill Creek created by the construction of a dam in the vicinity of Guenther Road. It is expected that this impoundment will be used for body contact sports meaning that water quality will be important from both a health and aesthetic standpoint.

Preliminary effort on the part of the Huron-Clinton Metropolitan Authority and the Washtenaw County Health Department has shown high bacteriological levels in the waters of Mill Creek in and around the proposed park area. This, of course, assumes considerable importance from the standpoint of the use of the proposed impoundment for body contact sports.

An inventory has been made of all potential sources of pollution in the watershed above the proposed dam at Guenther Road with the inventory categories including residential, farm, industry, and park. A large number of small farms exist in the area with a diversified animal population including cows, sheep, etc. No major population center exists with the majority of individual homes interspersed among the farms.

Water quality can be evaluated in a number of different ways and might include aesthetic, chemical and bacteriological measures. Certainly the aesthetic factors are those that are readily apparent and could include such things as turbidity, foam, temperature differences, algal growths, etc. From the standpoint of the use of natural waters for swimming, boating, or drinking, they assume considerable importance.

Evaluation of the bacteriological quality of water in terms of potential disease transmission uses tests for the detection and enumeration of indicator organisms rather than of pathogenic organisms directly harmful to man. The coliform group of bacteria has been the principal indicator of the suitability of a particular water for domestic or bathing use. Experience has established the significance of coliform group densities as criteria of the degree of pollution and thus of the sanitary quality of the sample under examination.

Much of the early work with coliform organisms has been in terms of total coliform levels, while in recent years laboratory tests have been developed which make it possible to separate out that portion of the coliform group which is present in the gut and feces of warm-blooded animals. This latter group has been designated as fecal coliform organisms.

Increasing attention to the potential value of fecal streptococci as indicators of significant pollution of water has prompted the development of methods for the detection and enumeration of such microorganisms. The evaluation of total coliform, fecal coliform, and fecal streptococci organism levels in a given sample gives a picture that no one of the organisms alone can give.

The chemical evaluation of the waters of Mill Creek assumes importance because of the agricultural nature of the watershed, especially in relation to the nutrients which are washed into the stream as a result of the use of various fertilizers. These nutrients, particularly the compounds of nitrogen and phosphorus, can contribute to algal growths in the stream thereby creating a nuisance problem.

In summary, Mill Creek water quality evaluation should include physical, chemical, and bacteriological measures of quality with an adequate number of samples to define spatial and temporal variations. Also, a knowledge of stream flow at the time of sampling assumes importance in making any material or organism balance studies.

B. Specific Aims:

1. To establish a program for the long-term evaluation of the water quality of the Mill Creek study area, involving sampling and appropriate laboratory analyses.

C. Procedure

It is proposed that an initial sampling program be conducted over a period of at least a year to reflect seasonal variations and to establish a base line of existing water quality. A sampling schedule involving one visit to the study area each week including a minimum of three sampling stations is suggested. The collection time would be varied through the hours of the day and the days of the week.

1. Sampling Stations

Guenther and Liberty Roads

Klinger Road

Scio-Church Road - South Branch

Other stations as time and resources permit. This initial proposal is limited to three stations because of financial limitations, although it is recognized that the sampling of seven additional stations in the basin would give a more complete description of the area.

2. Physical and Chemical Evaluation

Dissolved Oxygen

Biochemical Oxygen Demand

Temperature

pH

Turbidity

Specific Conductance

Nutrient evaluation involving compounds of nitrogen and phosphorus have been deferred to future years because of budgetary limitations.

3. <u>Bacteriological Evaluation</u>

   Total Coliform

   Fecal Coliform

   Fecal Streptococci

4. <u>Discharge Evaluation</u>

   It is proposed that each of the three base sampling stations be evaluated as to the best method of estimating stream discharge at the time of sampling. This probably will involve regular discharge measurements using a current meter and following accepted procedures of the U.S. Geological Survey, resulting in the eventual development of a rating curve for each station relating stream discharge and water elevation.

APPENDIX B

MILL CREEK USE DESIGNATION,
STATE OF MICHIGAN WATER QUALITY STANDARDS

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, Governor

DEPARTMENT OF NATURAL RESOURCES

STEVENS T. MASON BUILDING, LANSING, MICHIGAN 48926

A. GENE GAZLAY, Director

December 18, 1973

Mr. John J. Gannon
Professor of Public Health Engineering
School of Public Health
Department of Environmental and Industrial Health
University of Michigan
Ann Arbor, Michigan 48104

Dear Mr. Gannon:

Mr. Ralph W. Purdy has requested that we respond to your letter concerning the designated uses of Mill Creek. Mill Creek, which is tributary to the Detroit River, is designated for the following uses in the vicinity of Guenther Road in Lima Township, Washtenaw County:

Recreation - Partial body contact
Industrial water supply
Fish, wildlife and other aquatic life - Intolerant fish - warmwater species
Agricultural uses

Also enclosed for your review and consideration is the recently promulgated Part 4 Rules of the Water Resources Commission. These rules comprise the new water quality standards that went into effect on December 12, 1973.

If we may be of any further assistance to you, please free to contact us.

Very truly yours,

WATER RESOURCES COMMISSION

John M. Bohunsky

John M. Bohunsky
Regional Engineer

JMB/FB:clp
cc: R. Courchaine
W. Denniston
F. Baldwin

DEPARTMENT OF NATURAL RESOURCES

WATER RESOURCES COMMISSION

GENERAL RULES

Filed with Secretary of State, November 27, 1973

These rules take effect 15 days after filing with the Secretary of State

(By authority conferred on the water resources commission by sections 2 and 5 of Act No. 245 of the Public Acts of 1929, as amended, being sections 323.2 and 323.5 of the Michigan Compiled Laws.)

Part 4. Water Quality Standards, is added to the General Rules of the commission to read as follows:

PART 4. WATER QUALITY STANDARDS

R 323.1041. Purpose

Rule 1041. It is the purpose of the water quality standards as prescribed by these rules to establish water quality requirements applicable to the Great Lakes, their connecting waterways and all other surface waters of the state, which shall protect the public health and welfare, enhance and maintain the quality of water, serve the purposes of United States Public Law 92-500 and the commission act; and which shall protect the quality of waters for recreational purposes, public and industrial water supplies, agriculture uses, navigation and propagation of fish, other aquatic life and wildlife.

R 323.1043. Definitions A to N.

Rule 1043. As used in this part:

(a) "Agricultural water use" means a use of water for agricultural purposes, including but not limited to livestock watering, irrigation and crop spraying.

(b) "Application factor" means a numerical factor applied to the TL_m, or concentration producing other effect end points to provide the concentration of a toxic substance that would be safe for test organisms in the waters of the state.

(c) "Best practicable waste treatment technology for control of total phosphorus" means chemical-physical or chemical-physical-biological treatment processes, including but not limited to treatment with aluminum salts, iron salts or lime in conjunction with appropriate coagulant chemicals, settling or filtration or both, with operation and management of the treatment facilities and the process to achieve optimum phosphorus removal rates, or equivalent treatment.

(d) "Anadromous salmonids" means those trout and salmon which ascend streams to spawn.

(e) "Coldwater fish" means those fish species whose populations thrive in relatively cold water, including but not limited to trout, salmon, whitefish and cisco.

(f) "Connecting waterways" means the St. Marys river, Keweenaw waterway, Detroit river, St. Clair river and lake St. Clair.

(g) "Designated use" means a use of the waters of the state as established by these rules, including but not limited to industrial, agricultural and public water supply; recreation; fish, other aquatic life and wildlife; and navigation.

(h) "Dissolved oxygen" means the amount of oxygen dissolved in water, commonly expressed as a concentration in terms of milligrams per liter.

(i) "Dissolved solids" means the amount of materials dissolved in water commonly expressed as a concentration in terms of milligrams per liter.

(j) "Effluent" means a wastewater discharged from a point source to the waters of the state.

(k) "Fecal coliform" means a type of coliform bacteria found in the intestinal tract of humans and other warm-blooded animals.

(l) "Fish, other aquatic life and wildlife use" means the use of the waters of the state by fish, other aquatic life and wildlife for any life history stage or activity.

(m) "Industrial water supply" means a water source not protected for public water supply and intended for use in commercial or industrial applications and non-contact food processing.

(n) "Mixing zone" means a region of a water body which receives a wastewater discharge of a different quality than the receiving waters, and within which the water quality standards as prescribed by these rules do not apply.

(o) "Natural water temperature" means the temperature of a body of water without an influence from an artificial source, or a temperature as otherwise determined by the commission.

R 323.1044. Definitions P to W

Rule 1044. As used in this part:

(a) "Palatability" means the state of being agreeable or acceptable to the senses of sight, taste or smell.

(b) "Plant nutrients" means those chemicals, including but not limited to nitrogen and phosphorus, necessary for the growth and reproduction of aquatic rooted, attached and floating plants, fungi or bacteria.

(c) "Point source" means a discernible, confined and discrete conveyance, from which wastewater is or may be discharged to the waters of the state including but not limited to a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, concentrated animal feeding operation or vessel or other floating craft.

(d) "Public water supply" means a surface raw water source which, after conventional treatment, will provide a safe, clear, potable and aesthetically pleasing water for uses which include but are not limited to human consumption, food processing and cooking and as a liquid ingredient in foods and beverages.

(e) "Raw water" means the waters of the state prior to any treatment.

(f) "Receiving waters" means the waters of the state into which an effluent is or may be discharged.

(g) "Sanitary sewage" means treated or untreated wastewaters which contain human metabolic and domestic wastes.

(h) "Standard" means a definite numerical value or narrative statement promulgated by the commission to enhance or maintain water quality to provide for and fully protect a designated use of the waters of the state.

(i) "Suspended solids" means the amount of material suspended in water, commonly expressed as a concentration in terms of milligrams per liter.

(j) "TL_m" means median tolerance limit which is the concentration of a test material in a suitable diluent at which 50% of the exposed organisms survive for a specified period of exposure.

(k) "Total body contact recreation" means an activity where the human body may come into direct contact with water to the point of complete submergence, including but not limited to activities such as swimming, water skiing and skin diving.

(l) "Toxic substance" means a substance of unnatural origin, except heat, in concentrations or combinations which are or may become harmful to plant or animal life.

(m) "Warmwater fish" means those fish species whose populations thrive in relatively warm water, including but not limited to bass, pike, walleye and panfish.

(n) "Wastewater" means liquid waste resulting from commercial, municipal and domestic operations and industrial processes, including but not limited to cooling and condensing waters, sanitary sewage and industrial waste.

(o) "Waters of the state" means the Great Lakes, their connecting waterways, all inland lakes, rivers, streams, impoundments, open drains and other surface watercourses within the confines of the state, except drainage ways and ponds used solely for wastewater conveyance, treatment or control.

R 323.1050. Suspended solids.

Rule 1050. All waters of the state shall contain no unnatural turbidity, color, oil films, floating solids, foams, settleable solids or deposits in quantities which are or may become injurious to any designated use.

R. 323.1051. Dissolved solids.

Rule 1051. (1) The addition of any dissolved solids shall not exceed concentrations which are or may become injurious to any designated use. Point sources containing dissolved solids shall be considered by the commission on a case-by-case basis and increases of dissolved solids in the waters of the state shall be limited through the application of best practicable control technology currently available as prescribed by the administrator of the United States environmental protection agency pursuant to section 304 (b) of United States Public Law 92-500, except that in no instance shall total dissolved solids in the waters of the state exceed a concentration of 500 milligrams per liter as a monthly average nor more than 750 milligrams per liter at any time, as a result of controllable point sources.

(2) In addition to the standards prescribed by subrule (1), waters of the state used for public water supply shall, at the point of water intake, not exceed the permissible inorganic and organic chemicals criteria for raw public water supply in "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968", except chlorides. For the Great Lakes and connecting waters, chlorides shall, at the point of water intake, not exceed 50 milligrams per liter as a monthly average. For all other waters of the state, chlorides shall, at the point of water intake, not exceed 125 milligrams per liter as a monthly average.

R 323.1053. Hydrogen ion concentration.

Rule 1053. The hydrogen ion concentration expressed as pH shall be maintained within the range of 6.5 to 8.8 in all waters of the state except as otherwise prescribed by rule 1080. Any artificially induced variation in the natural pH shall remain within this range and shall not exceed 0.5 units of pH.

R 323.1055. Taste and odor producing substances.

Rule 1055. The waters of the state shall contain no unnatural substances in concentrations which are or may become injurious to their use for public, industrial or agricultural water supply, or in concentrations which lower the palatability of fish as measured by test procedures acceptable to the commission.

R 323.1057. Toxic substances

Rule 1057. (1) Toxicity of undefined toxic substances not specifically included in subrules (2) and (3) shall be determined by development of 96 hour TL_m's or other appropriate effect end points obtained by continuous-flow or in situ bioassays using suitable test organisms. Concentrations of undefined toxic substances in the waters of the state shall not exceed safe concentrations as determined by applying an application factor, based on knowledge of the behavior of the toxic substances and the organisms to be protected in the environment, to the TL_m or other appropriate effect end point.

(2) For all waters of the state, unless on the basis of recent information a more restrictive limitation is required to protect a designated use, concentrations of defined toxic substances, including heavy metals, shall be limited by application of the toxic substances recommendations contained in the chapter on Freshwater Organisms, "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968", or by application of any toxic effluent standard, limitation or prohibition promulgated by the administrator of the United States environmental protection agency pursuant to section 307 (a) of the United States Public Law 92-500, whichever is more restrictive.

(3) In addition to the standards prescribed in subrules (1) and (2), waters of the state used for public water supply shall, at the point of water intake, not exceed the permissible inorganic and organic chemicals criteria for raw public water supply in "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968", except that chlorides shall be limited to the same extent as prescribed by rule 1051(2).

R 323.1058. Radioactive substances.

Rule 1058. The control and regulation of radioactive substances discharged to the waters of the state shall be in accordance with and subject to the criteria, standards or requirements prescribed by the United States atomic energy commission as set forth in the applicable Code of Federal Regulations, Title 10, Part 20.

R 323.1060. Plant nutrients.

Rule 1060. Nutrients originating from domestic, industrial, municipal or domestic animal sources shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the waters of the state. Phosphorus which is or may readily become available as a plant nutrient shall be controlled from point source discharges by the application of methods utilizing best practicable waste treatment technology for control of total phosphorus, with the goal of achieving a monthly average effluent concentration of one milligram per liter as P.

R 323.1062. Fecal coliform.

Rule 1062. (1) Waters of the state protected for total body contact recreation shall contain not more than 200 fecal coliforms per 100 milliliters; and all other waters of the state shall contain not more than 1,000 fecal coliforms per 100 milliliters. These concentrations may be exceeded if due to uncontrollable non-point sources.

(2) Compliance with the fecal coliform standards prescribed by subrule (1) shall be determined on the basis of the geometric average of any series of 5 or more consecutive samples taken over not more than a 30-day period.

R 323.1064. Dissolved oxygen; Great Lakes, connecting waterways and inland streams.

Rule 1064. A minimum of 6 milligrams per liter of dissolved oxygen in all Great Lakes and connecting waterways shall be maintained and, except for inland lakes as prescribed in rule 1065, a minimum of 6 milligrams per liter of dissolved oxygen shall be maintained at all times in all inland streams designated by these rules to be protected for coldwater fish. In all other waters, except for inland lakes as prescribed by rule 1065, a minimum of 5 milligrams per liter of dissolved oxygen shall be maintained as a daily average and no single value shall be less than 4 milligrams per liter in waters naturally capable of supporting warmwater fish.

R 323.1065. Dissolved oxygen; inland lakes.

Rule 1065. (1) The following standards for dissolved oxygen shall apply to inland lakes capable of supporting coldwater fish:

(a) In warmwater inland lakes with little water exchange which are capable of sustaining a cold stratum of well-oxygenated water throughout the summer above a hypolimnion with very little oxygen, a minimum of 6 milligrams per liter of dissolved oxygen shall be maintained throughout the epilimnion and the upper one-third of the thermocline during the entire summer stagnation period. At all other times, the dissovled oxygen concentration shall be maintained at natural levels.

(b) In inland lakes capable of sustaining high oxygen values throughout the hypolimnion during periods of stagnation, dissolved oxygen concentrations greater than 6 milligrams per liter shall be maintained throughout the entire lake.

(c) In inland lakes which serve a principal anadromous fish migration routes, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the epilimnion and the upper one-third of the thermocline in stratified lakes throughout periods of fish migration. In unstratified lakes, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the entire lake during periods of fish migration.

(d) In shallow, unstratified coldwater inland lakes, dissolved oxygen concentrations greater than 6 milligrams per liter shall be maintained throughout the entire lake.

(2) The following standards for dissolved oxygen shall apply to inland lakes capable of supporting warmwater fish.

(a) In warmwater lakes with little water exchange, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the epilimnion and the upper one-third of the thermocline during the entire summer stagnation period. At all other times, dissolved oxygen concentrations shall be maintained at natural levels.

(b) In warmwater lakes with a high rate of water exchange, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained throughout the epilimnion and the upper one-third of the thermocline during the summer stagnation period. At all other times, dissolved oxygen concentrations greater than 5 milligrams per liter shall be maintained except in areas where natural oxygen depressions occur.

R 323.1069. Temperature; general considerations.

Rule 1069. (1) In all waters of the state, the points of temperature measurement normally shall be in the surface 1 meter; however, where turbulance, sinking plumes, discharge inertia or other phenomena upset the natural thermal distribution patterns of receiving waters, temperature measurements shall be required to identify the spatial characteristics of the thermal profile.

(2) Monthly maximum termperatures, based on the ninetieth percentile occurrence of natural water temperatures plus the increase allowed at the edge of the mixing zone and in part on long-term physiological needs of fish, may be exceeded for short periods when natural water temperatures exceed the ninetieth percentile occurrence. Temperature increases during these periods may be permitted by the commission, but in all cases shall not be greater than the natural water temperature plus the increase allowed at the edge of the mixing zone.

(3) Natural daily and seasonal temperature fluctuations of the receiving waters shall be preserved.

R 323.1070. Temperature; Great Lakes and connecting waterways.

Rule 1070. (1) The Great Lakes and connecting waterways shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.

(2) The Great Lakes and connecting waterways shall not receive a heat load which would warm the receiving water at the edge of the mixing zone to temperatures in degrees Fahrenheit higher than the following monthly maximum temperatures:

(a) Lake Michigan north of a line due west from the city of Pentwater:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	50	55	70	75	75	75	65	60	45

(b) Lake Michigan south of a line due west from the city of Pentwater:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	45	55	60	70	80	80	80	65	60	50

(c) Lake Superior and the St. Marys River:

J	F	M	A	M	J	J	A	S	O	N	D
38	36	39	46	53	61	71	74	71	61	49	42

(d) Lake Huron north of a line due east from Tawas Point:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	50	60	70	75	80	75	65	55	45

(e) Lake Huron south of a line due east from Tawas Point, except Saginaw bay:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	55	60	75	80	80	80	65	55	45

(f) Lake Huron, Saginaw bay:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	45	60	70	75	80	85	78	65	55	45

(g) St. Clair river:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	40	50	60	70	75	80	75	65	55	50

(h) Lake St. Clair:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	45	55	70	75	80	83	80	70	55	45

(i) Detroit river:

J	F	M	A	M	J	J	A	S	O	N	D
40	40	45	60	70	75	80	83	80	70	55	45

(j) Lake Erie:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	45	60	70	75	80	85	80	70	60	50

R 323.1072. Temperature: inland lakes, general standards.

Rule 1072. Inland lakes shall not receive a heat load which would:

(a) Increase the temperature of the thermocline or hypolimnion or decrease the volume thereof.

(b) Increase the temperature of the receiving waters at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.

(c) Increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

J	F	M	A	M	J	J	A	S	O	N	D
45	45	50	60	70	75	80	85	80	70	60	50

R 323.1073. Temperature; inland lakes, anadromous salmonid migrations.

Rule 1073. Warmwater inland lakes which serve as principal migratory routes for anadromous salmonids shall not receive a heat load during periods of migration at such locations and in a manner which may adversely affect salmonid migration or raise the receiving water temperature at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.

R 323.1074. Impoundments.

Rule 1074. (1) River and stream standards as prescribed by rule 1075 shall apply to all impoundments.

(2) The commission shall determine, when necessary, whether a body of water shall be considered as an inland lake or an impoundment for the purpose of these rules. This determination shall be made partially on the basis of aquatic life resources to be protected.

R 323.1075. Temperature; rivers and streams.

Rule 1075. (1) Rivers and streams naturally capable of supporting coldwater fish shall not receive a heat load which would:

(a) Increase the temperature of the receiving waters at the edge of the mixing zone more than 2 degrees Fahrenheit above the existing natural water temperature.

(b) Increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

J	F	M	A	M	J	J	A	S	O	N	D
38	38	43	54	65	68	68	68	63	56	48	40

(2) Rivers and streams naturally capable of supporting warmwater fish shall not receive a heat load which would warm the receiving water at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature.

(3) Rivers and streams naturally capable of supporting warmwater fish shall not receive a heat load which would warm the receiving water at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

(a) Rivers and streams north of a line between Bay City, Midland, Alma and North Muskegon:

J	F	M	A	M	J	J	A	S	O	N	D
38	38	41	56	70	80	83	81	74	64	49	39

(b) Rivers and streams south of a line between Bay City, Midland, Alma and North Muskegon, except the St. Joseph river:

J	F	M	A	M	J	J	A	S	O	N	D
41	40	50	63	76	84	85	85	79	68	55	43

(c) St. Joseph river:

J	F	M	A	M	J	J	A	S	O	N	D
50	50	55	65	75	85	85	85	85	70	60	50

(4) Non-trout rivers and streams that serve as principal migratory routes for anadromous salmonids shall not receive a heat load during periods of migration at such locations and in a manner which may adversely affect salmonid migration or raise the receiving water temperature at the edge of the mixing zone more than 5 degrees Fahrenheit above the existing natural water temperature.

R 323.1080. Special conditions

Rule 1080. To be consistent with the agreement between the United States of America and Canada on Great Lakes water quality effective April 15, 1972, the following conditions shall apply to the Michigan waters of the Great Lakes and their connecting waterways:

(a) Values of pH shall not be outside the range of 6.7 to 8.5.

(b) In Lake Erie, the level of total dissolved solids shall not be greater than 200 milligrams per liter.

(c) Filtrable iron shall not be greater than 0.3 milligrams per liter.

R 323.1082. Mixing zones.

Rule 1082. (1) A mixing zone to achieve a mixture of a point source discharge with the receiving waters shall be considered a region in which organism response to water quality characteristics is time-dependent. Exposure in mixing zones shall not cause an irreversible response which results in deleterious effects to populations of important aquatic life and wildlife. As a minimum restriction the toxic substance 96 hour TL_m for important species of fish or fishfood organisms shall not be exceeded in the mixing zone at any point inhabitable by these organisms, unless it can be demonstrated to the commission that a higher concentration is acceptable. The mixing zone at any transect of a stream shall contain not more than 25% of the cross-sectional area or volume of flow of the stream or both unless it can be demonstrated to the commission that designation of a greater area or volume of streamflow will allow passage of fish and fishfood organisms so that effects on their immediate and future populations are negligible or not measureable. Watercourses or portions thereof which, without one or more point source discharges, would have no flow except during periods of surface runoff may be considered as a mixing zone for a point source discharge. For Lake Michigan, mixing zones shall not exceed a defined area equivalent to that of a circle of radius of 1,000 feet unless the discharger can demonstrate to the commission that the defined area for a thermal discharge is more stringent than necessary to assure the protection and propagation of a balanced indigenous population of aquatic life and wildlife in the receiving water.

(2) All mixing zones established by the commission pursuant to subrule (1) shall be determined on a case-by-case basis.

R 323.1090 Application of water quality standards.

Rule 1090. (1) The water quality standards prescribed by these rules for the various designated uses of the waters of the state apply to receiving waters and are not to be considered applicable to wastewater effluents. The water quality standards shall not apply within defined mixing zones, except for those standards prescribed in rule 1050 for settleable solids, deposits,, floating solids and oil films.

(2) The accepted design streamflow to which the water quality standards as prescribed by these rules shall apply are those equal to or exceeding the 10-year recurrance of a minimum low flow average of 7-day duration, except where the commission determines that a more restrictive application is necessary to protect a particular designated use.

R 323.1091. Designated use interruption.

Rule 1091. Protection of the waters of the state designated for total body contact recreation by the water quality standards prescribed by these rules may be subject to temporary interruption during or following flood conditions or uncontrollable accidents to a sewer or wastewater treatment system. In the event of such an occurrence, full public notice thereof shall be served by the commission to those affected thereby and immediate corrective action shall be required by the commission.

R 323.1092. Dredging.

Rule 1092. The water quality standards prescribed by these rules shall not apply to dredging or construction activities within water areas where such activities occur or during the periods of time when the after effects of dredging or construction activities degrade water quality within such water areas, if the dredging operations or construction have been authorized by the United States army corps of engineers or the department. The water quality standards shall apply, however, in non-confined water areas utilized for the disposal of spoil from dredging operations, except within spoil disposal sites specifically defined by the United States army corps of engineers or the department.

R 323.1096. Determinations of compliance.

Rule 1096. Analysis of the waters of the state to determine compliance with the water quality standards prescribed by these rules shall be made according to procedures outlined in the current edition of "Standard Methods for the Examination of Water and Wastewater" as published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation, or other methods prescribed or approved by the commission and the United States environmental protection agency.

R 323.1097. Chemical applications.

Rule 1097. The application of chemicals for water resource management projects in accordance with and subject to state statutory provisions is not subject to the standards prescribed by these rules, but all projects shall be reviewed and approved by the commission prior to chemical applications.

R 323.1098. Nondegradation and water quality improvement.

Rule 1098. (1) Waters of the state in which the existing water quality is better than the water quality standards prescribed by these rules on the date when the standards become effective, shall not be lowered in quality by action of the commission unless and until it has been affirmatively demonstrated to the commission that a change in quality will not become injurious to the public health, safety or welfare; or become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being made of the waters; or become injurious to livestock, wild animals, birds, aquatic life or plants, or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish or game may be destroyed or impaired, and that a lowering in quality will not be unreasonable and against the public interest in view of the existing conditions in any waters of the state.

(2) Waters of the state which do not meet the water quality standards prescribed by these rules shall be improved to meet those standards. Where the water quality of certain waters of the state do not meet the water quality standards as a result of natural causes or conditions, no further reduction of water quality by controllable point and non-point sources shall be permitted.

R 323.1100. Designated uses, general.

Rule 1100. (1) As a minimum, all waters of the state shall be protected for agricultural uses, navigation, industrial water supply, public water supply at the point of water intake, warmwater fish and partial body contact recreation.

(2) All waters of the state designated as trout streams by the director of the department pursuant to section 8 of Act No. 165 of the Public Acts of 1929, as amended, being section 301.8 of the Michigan Compiled Laws, shall be protected for coldwater fish.

(3) All inland lakes designated or managed as trout lakes by the department and the Great Lakes and their connecting waterways shall be protected for coldwater fish.

R 323.1105. Multiple designated uses.

Rule 1105. When a particular portion of the waters of the state is designated for more than 1 use, the most restrictive water quality standards for one or more of those designated uses shall apply to that portion.

R 323.1110. Designated uses, total body contact recreation.

Rule 1110. (1) The following waters of the state, except in mixing zones prescribed by the commission, shall be protected for total body contact recreation:

(a) All Great Lakes and their connecting waterways.

(b) All inland lakes, including but not limited to those connected to the Great Lakes.

(2) The following rivers and streams and their tributaries, except in mixing zones as prescribed by the commission, shall be protected for total body contact recreation:

(a) All rivers and streams located in the Upper Peninsula.

(b) All rivers and streams located north of, but not including, the Grand and Saginaw river basins.

R 323.1115. Designated uses, impoundments and portions of streams.

Rule 1115. (1) The following impoundments and portions of streams shall be protected for total body contact recreational use:

	Name	Water Impounded	County	Location
(a)	Ada Lake	Thornapple River	Kent	From head of Ada Dam, T. 7 N., R. 10 W., Sec. 34 upstream to headwaters of Cascade Lake (48th Street).
(b)	Belleville Lake	Huron River	Wayne	T. 3 S., R. 8 E., Sec. 19 downstream to T. 3 S., R. 8 E., Sec. 24.
(c)	C. S. Mott Lake	Flint River	Genesee	T. 8 N., R. 7 E., Sec. 11, 12, 15, 16, 21.
(d)	Caley Pond	Farmer Creek	Lapeer	T. 6 N., R. 9 E., Sec. 12 and 13.
(e)	Cascade Lake	Thornapple River	Kent	Included in Ada Lake Area
(f)	Fallasberg Dam	Flat River	Kent	T. 7 N., R. 9 W., Sec. 24, 25, 26.
(g)	Ford Lake	Huron River	Washtenaw	T. 3 S., R. 7 E., Sec. 14, 15, 16, 21, 22, 23, 24
(h)	Geddes Pond	Huron River	Washtenaw	T. 2 S., R. 6 E., Sec. 26, 35, 36.
(i)	Grand River	Grand River (not impounded)	Ottawa	Eastmanville T. 7 N., R. 14 W., Sec. 10, downstream to 160th Avenue.
(j)	Grand River	Grand River (not impounded)	Kent	Plainfield Road bridge downstream to lower limits of Comstock Riverside Park, T. 8 N., R. 11 W., Sec. 31.
(k)	Holloway Reservoir	Flint River	Genesee	T. 8 N., R. 8 E., Sec. 1, 2, 11, 12, 13. T. 8 N., R. 9 E., Sec. 7, 8, 17, 18.

(l)	Ionia Recreation Area	Sessions Creek	Ionia	T. 6 N., R. 7 W., Sec. 3 N.W. 1/4 Sec. 3.
(m)	Lake Allegan	Kalamazoo River	Allegan	M-89 bridge downstream to dam - T. 2 N., R. 14 W., Sec. 10.
(n)	Lake Geneva	Looking Glass River (not impounded)	Clinton	T. 5 N., R. 2 W., Sec. 7.
(o)	Lake LeAnn	Grand River	Hillsdale	T. 5 S., R. 1 W., Sec. 3, 4, 9, 10.
(p)	Lake Victoria	Alder Creek	Clinton	T. 6 N., R. 1 W., Sec. 12, 13.
(q)	Lobdell Lake	Shiawassee River	Genesee	T. 5 N., R. 5 E., Sec. 25, 34, 35, 36.
			Livingston	T. 4 N., R. 5 E., Sec. 1 and 2.
(r)	Manitoon Lake	Unnamed Creek	Shiawassee	T. 6 N., R. 2 E., Sec. 10, 11, 14, 15.
(s)	Maple Lake	Paw Paw River	Van Buren	T. 3 S., R. 14 W., Sec. 1, 12.
(t)	Martiny Lake Flooding	S. Branch Chippewa River	Mecosta	T. 15 N., R. 8 W., Sec. 5, 6, 7, 8.
(u)	Moore's Park Impoundment	Grand River	Ingham	Waverly Road bridge downstream to dam, T. 4 N., R. 2 W., Sec. 21.
(v)	Pine Creek Reservoir	Pine Creek	Allegan	T. 1 N., R. 12 W., Sec. 7, 17, 18, 20, 21, 28, 29, 31, 32.
(w)	Ross Lake	North, Middle and South Branches Tobacco River	Gladwin	T. 17 N., R. 2 W., Sec. 1, 2, 11, 12 14. T. 17 N., R. 1 W., Sec. 5, 6, 7.
(x)	Sanford Lake	Tittabawassee River	Midland	T. 15 N., R. 1 W., Sec. 1, 2, 11, 12, 13, 14, 24. T. 16 N., R. 1 W., Sec. 11, 14, 23, 26, 35.
(y)	Secord Lake	Tittabawassee River	Gladwin	T. 19 N., R. 1 E., Sec. 2, 3, 4, 9. T. 20 N., R. 2 E., Sec. 10, 15, 20, 24, 25, 26, 29, 31, 35, 36.

(z)	Shamrock Lake	Tobacco River	Clare	T. 17 N., R. 4 W., Sec. 26.
(aa)	Shiawassee Impoundment	Shiawassee River	Shiawassee	T. 6 N., R. 3 E., Sec. 11, 14.
(bb)	Sleepy Hollow Reservoir	Maple River	Clinton	T. 6 N., R. 1 W., Sec. 3, 10, Jason Rd., downstream to dam.
(cc)	Springbrook Lake	Springbrook Creek	Shiawassee	T. 6 N., R. 2 E., Sec. 10.
(dd)	Smallwood Lake	Tittabawassee River	Gladwin	T. 18 N., R. 1 W., Sec. 1. T. 18 N., R. 1 E., Sec. 4, 9, 15, 16. T. 19N., R. 1 W., Sec. 36.
(ee)	Thompson Lake	Bogue Creek	Livingston	T. 3 N., R. 5 E., Sec. 30, 31. T. 3 N., R. 4 E., Sec. 25, 36.
(ff)	Thornapple Lake	Thornapple River	Barry	T. 3 N., R. 7 W., Sec. 19, 20, 30. T. 3 N., R. 8 W., Sec. 24, 25.
(gg)	Thread Lake	Thread Creek	Genesee	T. 7 N., R. 7 E., Sec. 19, 20.
(hh)	Webber Dam Impoundment	Grand River	Ionia	Goodwin Road downstream to dam, T. 7 N., R. 5 W., Sec. 33.
(ii)	Wiggins Lake	Cedar River	Gladwin	T. 18 N., R. 2 W., Sec. 4. T. 19 N., R. 2 W., Sec. 27, 34.
(jj)	Wildwood Lake	Thread Creek	Oakland	T. 5 N., R. 8 E., Sec. 28.
(kk)	Wixom Lake	Tittabawassee River	Gladwin	T. 17 N., R. 1 W., Sec. 36. T. 17 N., R. 1 E., Sec. 1, 2, 11, 12, 13, 14, 23, 26, 27, 33, 34, 35. T. 18 N., R. 1 E., Sec. 25, 36.
			Midland	T. 16 N., R. 1 E., Sec. 2, 3, 4. T. 16 N., R. 1 W., Sec. 1.

(2) The following streams and portions thereof shall be protected for total body contact recreational use:

	Name	County	Location
(a)	Maumee River	Branch, Lenawee and Hillsdale	All water in basin
(b)	St. Joseph River	Berrien	Napier Road to Section line between Section 1, Oronoko Twp., and Sec. 6 Berrien Township.
(c)	St. Joseph River	Berrien	Indiana-Michigan Power Company dam at Berrien Springs to north section line of Section 23, Buchanan Township.
(d)	St. Joseph River	Berrien	Township line between Buchanan and Niles Twps to sections line between Sections 15 and 16, Nil Township.
(e)	St. Joseph River	Berrien	French Paper Company dam, Niles to Michigan-Indiana border.
(f)	St. Joseph River	Cass and St. Joseph	Michigan-Indiana border to section line between Sections 26 and 27, Constantine Township.
(g)	St. Joseph River	St. Joseph	Michigan Gas and Electr Company dam at Constantine to section line between Sections 19 and 30, Lockport Township.
(h)	St. Joseph River	St. Joseph	Midland Wire Corporatio dam at Three Rivers to existing west village limits of Mendon.
(i)	St. Joseph River	St. Joseph	Existing east village limits of Mendon to Sturgeon Lake.
(j)	St. Joseph River	St. Joseph and Branch	Lowland Road to Aborgast Road, Union Township

(k)	St. Joseph River	Branch and Calhoun	Existing east city limits of Union City to existing south village limits of Burlington.
(l)	St. Joseph River	Calhoun	Existing east village limits of Burlington to section line between Sections 33 and 34, Tekonsha Township
(m)	St. Joseph River	Hillsdale	Existing east village limits of Tekonsha to section line between Sections 8 and 9, Litchfield Township.
(n)	St. Joseph River	Hillsdale	Existing east city limits of Litchfield to Genesee Mill dam.
(o)	Hickory Creek	Berrien	Mouth at St. Joseph River to section line between Sections 15 and 22, Lincoln Township.
(p)	Dowagiac River	Cass	City of Niles dam to section line between Sections 9 and 16, Pokagon Township
(q)	East Branch Dowagiac Creek	Cass	Mill pond dam to LeGrange Lake.
(r)	Christiann Creek	Cass	Michigan-Indiana border to Christiann Lake.
(s)	Portage River	St. Joseph	Existing north city limits of Three Rivers to Portage Lake.
(t)	Coldwater River	Branch	Existing east city limits of Union City to Craig Lake.

R 323.1116. Availability of documents.

Rule 1116. Documents referenced in rules 1057 and 1096 may be obtained at current costs as listed as follows:

(a) "Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, 1968" may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402, at a cost of $3.00.

(b) "Standard Methods for the Examination of Water and Wastewater" may be obtained from the American Public Health Association, 1015 Eighteenth Street, N.W., Washington, D. C., 20036, at a cost of $35.00.

APPENDIX C

FIELD AND LABORATORY TESTS

Field and Laboratory Tests

Mill Creek water samples were collected at mid-channel on the downstream side of the sampling site bridge, using a standard APHA type D.O. and BOD sampler assembly, with a special attachment on the top to hold a sterile bottle used to collect a sample for bacteriological analyses. The sampler assembly was lowered as often as necessary to collect appropriate volumes of sample. The various analyses were conducted in accordance with Standard Methods for the Examination of Water and Wastewater, 13th Edition except as otherwise noted. The specific procedures with appropriate page references to Standard Methods are as follows:

TEMPERATURE

Water temperature of each sample was determined in the field at the time of sample collection. Readings were made with a standard mercury thermometer, calibrated to tenths of a degree centrigrade which was immersed in the sampler assembly (pp. 348-349).

SPECIFIC CONDUCTANCE

Specific conductance was determined in the field at the time of collection using a Yellow Springs Instrument (YSI) Model 33 S-C-T meter. Results are reported as micromhos/cm (pp. 323-327).

pH

A Corning Model 12 Research pH meter with a glass electrode - calomel electrode system was used in the laboratory to determine the pH of all samples (pp. 276-281).

TURBIDITY

A Hach Company Model 2100 turbidimeter was used in the laboratory to determine the turbidity of each sample. Results are reported in Jackson Turbidity Unite (JTU) (pp. 349-365).

DISSOLVED OXYGEN

Dissolved oxygen content of each sample was determined using the azide modification of the Winkler method. Samples were fixed in the field at the time of collection by the addition of manganese sulfate solution, alkali - iodide - azide reagent and sulfuric acid. Final titration took place upon return to the laboratory. Results are reported in mg/l (pp. 474-488).

BIOCHEMICAL OXYGEN DEMAND

BOD samples were incubated for 5 days in a standard 20°C incubator. A Yellow Springs Instrument (YSI) Model 54 oxygen meter was used in the laboratory for initial and final dissolved oxygen measurements. The instrument was frequently calibrated against the azide Winkler procedure on test samples. Results are reported as BOD_5 in mg/l (pp. 489-495).

TOTAL COLIFORM (Membrane Filter)

M-Endo broth was used for the membrane filter media. Results are presented as counts/100 ml (pp. 678-683).

FECAL COLIFORM (Membrane Filter)

M-FC broth was used for the membrane filter media. Results are presented as counts/100 ml (pp. 684-685).

FECAL STREPTOCOCCI (Membrane Filter)

M-Enterococcus agar was used for the membrane filter media. Results are presented as counts/100 ml (pp.690-691).

TOTAL COLIFORM (Multiple-Tube Fermentation)

The presumptive test was performed using lauryl tryptose broth and the confirmed test was performed using brilliant green bile broth. Results, therefore, represent the presumptive and confirmed tests and are reported as the Most Probable Number (MPN) per 100 ml (pp. 664-668).

FECAL COLIFORM (Multiple-Tube Fermentation)

EC medium was used for the fecal coliform determination. Results are reported as MPN per 100 ml (pp. 669-672).

AMMONIA-NITROGEN

Ammonia-nitrogen concentrations were determined by the direct nesslerization method using a Bausch and Lomb Spectronic 20 and prepared calibration curves. Results are reported as mg/l N (pp. 226-230).

NITRITE-NITROGEN

The diazotization method was used to determine nitrite-nitrogen. A Spectronic 20 was used with prepared calibration curves. Results are reported as mg/l N (pp. 240-243).

ORTHOPHOSPHATE-P

The stannous chloride method was used for analysis of orthophosphate. A Spectronic 20 was used with prepared calibration curves. Results are reported as mg/l P (pp. 530-532).

NITRATE-NITROGEN

The following special procedure was used for the determination of nitrate-nitrogen:

Reagents:

1. Sodium Salicylate Reagent—0.5 gms sodium salicylate diluted to 100 ml with distilled water. Should be prepared fresh each day.
2. Sodium Hydroxide-Rochelle Reagent—100 g NaOH and 12.5 g potassium-sodium tartrate diluted to 250 ml with distilled water.
3. Concentrated Sulfuric Acid.

Procedure:

1. 10 ml of sample (filtered) is pipetted into an evaporating dish, 1 ml of sodium salicylate is added, and the solution is allowed to evaporate over a bath and to cool in a desiccator.
2. To the solid, add 1 ml of concentrated H_2SO_4. Rotate and swirl, dissolving all solid. Then let the solution stand for about 10 minutes with occasional rotation and swirling.
3. Add distilled water and pour the solution quantitatively into a 100 ml volumetric flask.
4. To the acidified solution add 7 ml of the NaOH-Rochelle reagent and dilute to 100 ml. (Let cool.)

5. After 10 minutes the yellow color can be measured at 420 mμ in a spectrophotometer.

The final reacted yellow nitrate-salicylate is very stable for long periods of time in a desiccator.

Source: Marcel Schmidt, 1969, personal communication.

APPENDIX D

MILL CREEK WATER QUALITY DATA

MILL CREEK WATER QUALITY DATA

	Date - December 8, 1972			Date - December 15, 1972		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 **	Sta. 2 **	Sta. 3 **
Time	1:30 P.M.	2:08 P.M.	2:16 P.M.	12:28 P.M.	11:53 A.M.	11:09 AM
Temp °C	3.0	2.0	2.0	1.5	1.0	3.0
Conductivity micromhos/cm	290	290	380	460	340	420
pH	6.5	6.9	7.1	6.0	6.3	6.6
Turbidity JTU	3.0	3.5	7.5	8.4	3.5	7.0
D.O. mg/ℓ	12.8	11.9	12.6	12.4	13.0	11.8
BOD_5 mg/ℓ	3.0	1.3	2.2	1.8	1.0	1.4
Coliform, total per 100 ml (Membrane Filter)						
Coliform, Fecal per 100 ml (Membrane Filter)						
Streptococci, Fecal per 100 ml (Membrane Filter)				135	180	140
Coliform, Total per 100 ml (MPN)						
Coliform, Fecal per 100 ml (MPN)						
Runoff in cfs						

*Sta. 1 - Guenther Rd.
*Sta. 2 - Scio Church Road
*Sta. 3 - Klinger Road

**Sta. 1 - Liberty Road
**Sta. 2 - Scio Church Road
**Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - December 22, 1972			Date - January 5, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	7:53 AM	8:25 AM	8:50 AM	2:10 PM	2:50 PM	3:10 PM
Temp °C	3.0	2.0	2.5	1.5	0.0	1.0
Conductivity micromhos/cm	465	365	455	410	--	--
pH	7.4	7.3	7.2	6.3	6.5	6.5
Turbidity JTU	10.0	5.5	10.0	9.0	6.0	9.0
D.O. mg/ℓ	11.0	11.9	11.8	12.0	12.8	11.7
BOD_5 mg/ℓ	1.0	0.9	1.1	1.4	1.2	1.4
Coliform, total per 100 ml (Membrane Filter)						
Coliform, Fecal per 100 ml (Membrane Filter)						
Streptococci, Fecal per 100 ml (Membrane Filter)	160	110	130	110	180	110
Coliform, Total per 100 ml (MPN)						
Coliform, Fecal per 100 ml (MPN)						
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Scio Church Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - January 11, 1973			Date - January 15, 1973		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 *	Sta. 2 *	Sta. 3 *
Time	2:42 PM		3:12 PM	11:02 AM		11:40AM
Temp °C	1.0		0.0	3.0		3.0
Conductivity micromhos/cm	430		340	435		455
pH	6.5		6.6	7.9		7.8
Turbidity JTU	11		16	15		18
D.O. mg/ℓ	12.8		11.9	12.2		11.9
BOD_5 mg/ℓ	1.2		1.4	0.7		0.9
Coliform, total per 100 ml (Membrane Filter)						
Coliform, Fecal per 100 ml (Membrane Filter)	390		56	158		220
Streptococci, Fecal per 100 ml (Membrane Filter)	76		109	112		32
Coliform, Total per 100 ml (MPN)						
Coliform, Fecal per 100 ml (MPN)						
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Scio Church Road (discontinued)
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - January 22, 1973			Date - January 30, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	3:00 PM		3:25 PM	1:30 PM		2:00 PM
Temp °C	3.0		3.0	1.0		2.0
Conductivity micromhos/cm	345		395	410		455
pH	6.9		7.2	7.6		7.7
Turbidity JTU	54		48	17		12
D.O. mg/ℓ	11.5		11.1	12.7		12.4
BOD_5 mg/ℓ	7.2		4.8	2.8		1.3
Coliform, total per 100 ml (Membrane Filter)						
Coliform, Fecal per 100 ml (Membrane Filter)	830		425	--		--
Streptococci, Fecal per 100 ml (Membrane Filter)	1290		2900	40		26
Coliform, Total per 100 ml (MPN)	2400		3500	3500		3500
Coliform, Fecal per 100 ml (MPN)	1300		490	460		140
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Scio Church Road (discontinued)
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - February 11, 1973			Date - February 16, 1973		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 **	Sta. 2 **	Sta. 3 **
Time	11:00 AM		11:30 AM	10:20 AM	10:50 AM	11:20AM
Temp °C	0.5		1.0	1.0	-0.5	0.5
Conductivity micromhos/cm	360			420		
pH	7.7		7.8	7.7	7.8	7.8
Turbidity JTU	12		20	10	10	21
D.O. mg/ℓ	13.0		12.6	12.8	12.8	12.4
BOD_5 mg/ℓ	2.0		1.7	2.9	0.9	2.3
Coliform, total per 100 ml (Membrane Filter)	165		125	113	168	350
Coliform, Fecal per 100 ml (Membrane Filter)	43		43	50	47	180
Streptococci, Fecal per 100 ml (Membrane Filter)	18		40	42	64	115
Coliform, Total per 100 ml (MPN)	230		80	490		1300
Coliform, Fecal per 100 ml (MPN)	110		50	170		790
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Scio Church (discontinued)
*Sta. 3 - Klinger Road

**Sta. 1 - Liberty Road
**Sta. 2 - Lima Center Road
**Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - February 22, 1973			Date - March 2, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	2:00 P.M.	2:32 PM	3:04 PM	8:50 AM	9:15 AM	9:40 AM
Temp °C	0.5	-0.5	1.0	3.0	3.0	3.5
Conductivity micromhos/cm	410	410	400	380	390	400
pH	8.2	8.0	8.0	7.9	8.0	7.9
Turbidity JTU	10	12	21	25	23	19
D.O. mg/ℓ	12.8	13.6	13.5	11.4	11.8	11.3
BOD_5 mg/ℓ	3.3	0.5	1.8	3.6	3.3	3.3
Coliform, total per 100 ml (Membrane Filter)				700	390	820
Coliform, Fecal per 100 ml (Membrane Filter)	44	152	42	212	171	160
Streptococci, Fecal per 100 ml (Membrane Filter)	52	46	132	860	415	330
Coliform, Total per 100 ml (MPN)	460	1100	230	2200	2400	1300
Coliform, Fecal per 100 ml (MPN)	110	790	80	1300	490	230
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - March 6, 1973			Date - March 23, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	9:30 AM	10:00 AM	10:47 AM	8:40 AM	10:15 AM	11:10AM
Temp °C	5.0	4.5	5.5	6.0	5.0	6.5
Conductivity micromhos/cm	400	410	430	370	350	405
pH	8.2	8.2	8.1	7.9	7.9	7.9
Turbidity JTU	18	23	23	13	15	13
D.O. mg/ℓ	11.2	11.7	11.2	11.2	11.5	10.9
BOD_5 mg/ℓ	2.5	2.6	2.0	1.3	1.9	1.5
Coliform, total per 100 ml (Membrane Filter)	630	340	340	235	210	275
Coliform, Fecal per 100 ml (Membrane Filter)	90	128	175	90	60	76
Streptococci, Fecal per 100 ml (Membrane Filter)	170	145	115	72	78	38
Coliform, Total per 100 ml (MPN)	270	790	1700	460	480	330
Coliform, Fecal per 100 ml (MPN)	330	230	230	80	80	70
Runoff in cfs	105 (3-8-73)		73 (3-8-73)	111		78

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - March 29, 1973			Date - April 5, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	1:55 PM	3:20 PM	4:00 PM	2:07 PM	3:09 PM	3:55 PM
Temp °C	9.5	10.0	10.0	9.0	9.5	10.5
Conductivity micromhos/cm	450	465	485	455	465	505
pH	7.8	7.8	7.8	7.9	7.9	7.9
Turbidity JTU	11	12	13	9	11	11
D.O. mg/ℓ	10.7	11.0	10.5	11.1	11.2	11.4
BOD_5 mg/ℓ	3.1	3.0	3.2	4.6	4.6	4.4
Coliform, total per 100 ml (Membrane Filter)	325	250	158	340	510	33
Coliform, Fecal per 100 ml (Membrane Filter)	50	34	22	165	260	15
Streptococci, Fecal per 100 ml (Membrane Filter)	52	43	18	58	74	23
Coliform, Total per 100 ml (MPN)	1300	790	330	490	220	130
Coliform, Fecal per 100 ml (MPN)	260	70	130	110	270	<20
Runoff in cfs	81	--	--	59	--	44

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - April 12, 1973			Date - April 27, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	1:45 PM	2:45 PM	3:15 PM	9:20 AM	10:30 AM	11:10AM
Temp °C	9.0	9.0	9.0	9.5	9.5	9.5
Conductivity micromhos/cm	470	485	485	480	480	480
pH	8.1	8.0	8.0	7.9	7.9	7.9
Turbidity JTU	7	7	8	11	12	12
D.O. mg/ℓ	12.3	12.2	12.4	9.7	10.3	10.4
BOD_5 mg/ℓ	1.2	1.4	1.7	0.7	0.7	0.9
Coliform, total per 100 ml (Membrane Filter)	365	395	158	275	240	660
Coliform, Fecal per 100 ml (Membrane Filter)	64	104	12	130	88	118
Streptococci, Fecal per 100 ml (Membrane Filter)	30	42	40	100	102	76
Coliform, Total per 100 ml (MPN)	700	490	490	1700	1700	2400
Coliform, Fecal per 100 ml (MPN)	80	220	80	110	310	40
Runoff in cfs	54	--	44	42	--	37

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - May 4, 1973			Date - May 13, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	5:20 PM	6:10 PM	6:50 PM	10:00 AM	11:10 AM	11:50AM
Temp °C	10.5	10.0	10.0	11.5	11.5	11.0
Conductivity micromhos/cm	455	475	475	---	---	---
pH	8.1	8.1	8.1	7.8	7.9	7.9
Turbidity JTU	7	8	8	7	7	6
D.O. mg/ℓ	11.4	11.3	11.4	9.8	10.4	10.9
BOD_5 mg/ℓ	1.4	1.5	0.4	1.9	1.7	1.2
Coliform, total per 100 ml (Membrane Filter)	460	324	240	620	2740	520
Coliform, Fecal per 100 ml (Membrane Filter)	80	60	38	68	192	46
Streptococci, Fecal per 100 ml (Membrane Filter)	102	100	104	118	162	162
Coliform,Total per 100 ml (MPN)						
Coliform,Fecal per 100 ml (MPN)						
Runoff in cfs	38		32	31		28

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - May 17, 1973			Date - May 25, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	5:00 PM	6:10 PM	6:55 PM	12:45 PM	1:20 PM	1:50PM
Temp °C	12.0	12.0	12.0	12.5	12.0	12.0
Conductivity micromhos/cm	490	500	510	700	700	690
pH	8.4	8.2	8.2	7.8	8.0	8.0
Turbidity JTU	5.6	5.8	7.5	9.5	13	7.5
D.O. mg/ℓ	12.7	11.6	12.1	7.6	7.6	7.5
BOD_5 mg/ℓ	1.5	1.0	2.2	2.2	1.6	1.7
Coliform, total per 100 ml (Membrane Filter)	260	530	150	760	650	1460
Coliform, Fecal per 100 ml (Membrane Filter)	14	16	16	185	109	221
Streptococci, Fecal per 100 ml (Membrane Filter)	140	57	46	475	400	415
Coliform, Total per 100 ml (MPN)	--	--	--	2200	1800	5400
Coliform, Fecal per 100 ml (MPN)	--	--	--	460	430	940
Runoff in cfs	24	--	21	66	--	51

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - May 29, 1973			Date - June 6, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	11:10 AM	12:00	1:30 PM	11:30 AM	12:40 PM	1:15 PM
Temp °C	14.0	14.0	14.0	18.5	18.0	18.0
Conductivity micromhos/cm	680	690	640	680	665	690
pH	7.9	7.7	7.8	8.3	8.3	8.3
Turbidity JTU	17	18	14	20	32	22
D.O. mg/ℓ	7.7	7.8	7.7	7.0	7.1	7.4
BOD_5 mg/ℓ	1.2	1.5	1.3	2.0	2.1	1.9
Coliform, total per 100 ml (Membrane Filter)	2400	1240	2400	6400	4500	6000
Coliform, Fecal per 100 ml (Membrane Filter)	600	680	440	550	680	2520
Streptococci, Fecal per 100 ml (Membrane Filter)	1430	2140	2710	2500	1800	3600
Coliform, Total per 100 ml (MPN)	5400	9200	16,000	9200	16,000	9200
Coliform, Fecal per 100 ml (MPN)	1100	1700	700	490	2200	2400
Runoff in cfs	111	--	91	54	--	54

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - June 13, 1973			Date - June 22, 1973		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 *	Sta. 2 *	Sta. 3 *
Time	10:20 AM	11:00 AM	11:20 AM	9:45 AM	10:18 AM	10:30 AM
Temp °C	20.0	21.0	20.0	18.0	19.5	19.0
Conductivity micromhos/cm	690	655	705	600	630	640
pH	8.4	8.4	8.5	8.0	8.1	8.2
Turbidity JTU	18	15	13	14	27	29
D.O. mg/ℓ	7.8	8.5	8.9	7.2	8.2	8.7
BOD_5 mg/ℓ	1.9	1.4	2.1	2.7	2.7	2.1
Coliform, total per 100 ml (Membrane Filter)	230	1500	3200	6500	6100	3000
Coliform, Fecal per 100 ml (Membrane Filter)	80	440	390	510	660	480
Streptococci, Fecal per 100 ml (Membrane Filter)	810	760	870	650	810	730
Coliform, Total per 100 ml (MPN)	490	9200	2400	5400	9200	5400
Coliform, Fecal per 100 ml (MPN)	230	230	490	330	460	1400
Runoff in cfs	24	--	24	23	--	21

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - June 28, 1973			Date - July 3, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	2:23 PM	3:05 PM	3:25 PM	9:53 AM	10:45 AM	11:25 AM
Temp °C	19.5	19.0	19.5	21.0	21.0	21.5
Conductivity micromhos/cm	390	470	610	390	390	410
pH	7.9	7.8	7.6	7.1	7.4	7.3
Turbidity JTU	330	320	52	100	85	75
D.O. mg/ℓ	7.2	7.9	8.1	6.0	5.8	5.1
BOD_5 mg/ℓ	4.4	3.7	2.8	3.9	3.5	3.6
Coliform, total per 100 ml (Membrane Filter)	13,000	16,200	5800	42,000	43,000	ł1,000
Coliform, Fecal per 100 ml (Membrane Filter)	3800	6100	1500	5400	6300	2900
Streptococci, Fecal per 100 ml (Membrane Filter)	--	--	9500	24,000	35,000	36,000
Coliform, Total per 100 ml (MPN)	>24,000	>24,000	16,000	24,000	24,000	24,000
Coliform, Fecal per 100 ml (MPN)	16,000	5400	3500	13,000	13,000	13,000
Runoff in cfs	127	--	56	209	--	150

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - July 11, 1973			Date - July 17, 1973		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 *	Sta. 2 *	Sta. 3 *
Time	9:30 AM	10:35 AM	10:45 AM	10:08 AM	11:05 AM	11:22 AM
Temp °C	19.0	19.5	19.0	17.0	17.8	17.8
Conductivity micromhos/cm	670	650	690	600	620	630
pH	8.3	8.4	8.3	8.4	8.4	8.5
Turbidity JTU	32	32	17	19	14	10
D.O. mg/ℓ	7.5	7.7	8.0	9.5	9.5	11.0
BOD_5 mg/ℓ	1.4	1.4	1.2	2.2	2.3	1.4
Coliform, total per 100 ml (Membrane Filter)	6700	5300	5000	5100	4300	6300
Coliform, Fecal per 100 ml (Membrane Filter)	770	800	600	690	550	430
Streptococci, Fecal per 100 ml (Membrane Filter)	1800	1700	1700	900	740	720
Coliform, Total per 100 ml (MPN)	9200	1100	16,000	3500	2400	9200
Coliform, Fecal per 100 ml (MPN)	3500	490	790	790	1100	1100
Runoff in cfs	32	--	29	19	--	18

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - July 24, 1973			Date - July 26, 1973		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 *	Sta. 2 *	Sta. 3 *
Time	9:30 AM	9:55 AM	10:20 AM	11:45 AM	12:15 AM	12:40 PM
Temp °C	19.0	19.0	19.2	20.5	20.2	19.8
Conductivity micromhos/cm	650	650	650	650	660	660
pH	8.3	8.3	8.4	8.3	8.4	8.3
Turbidity JTU	48	28	12	18	45	18
D.O. mg/ℓ	8.2	8.9	8.3	7.9	8.0	7.9
BOD_5 mg/ℓ	3.3	3.2	1.3	1.9	3.6	2.7
Coliform, total per 100 ml (Membrane Filter)	9600	6800	4800	6600	8600	5700
Coliform, Fecal per 100 ml (Membrane Filter)	920	740	520	1280	1580	1500
Streptococci, Fecal per 100 ml (Membrane Filter)	1400	1200	1200	5500	5300	7500
Coliform, Total per 100 ml (MPN)	9200	16,000	9200	5400	9200	16,000
Coliform, Fecal per 100 ml (MPN)	1700	330	2200	3500	1300	2200
Runoff in cfs	--	--	--	18	--	18

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - July 30, 1973			Date - August 2, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	10:05 AM	11:10 AM	12:30 PM	9:20 AM	10:20 AM	10:40AM
Temp °C	18.5	19.0	19.0	18.5	18.5	18.5
Conductivity micromhos/cm	630	640	670	620	625	625
pH	8.2	8.2	8.2	8.2	8.2	8.2
Turbidity JTU	31	34	20	35	27	21
D.O. mg/ℓ	7.4	7.2	7.3	7.2	7.3	7.0
BOD_5 mg/ℓ	2.6	2.4	2.3	3.0	2.1	2.2
Coliform, total per 100 ml (Membrane Filter)	9600	9200	8000	9600	4300	5000
Coliform, Fecal per 100 ml (Membrane Filter)	640	580	660	412	240	550
Streptococci, Fecal per 100 ml (Membrane Filter)	1980	1600	1600	1960	1500	1360
Coliform, Total per 100 ml (MPN)	16,000	16,000	5400	9200	3500	16,000
Coliform, Fecal per 100 ml (MPN)	790	790	1700	790	490	460
Runoff in cfs	35	--	29	39	--	37

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - August 6, 1973			Date - August 9, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	9:20 AM	10:25 AM	10:50 AM	9:10 AM	10:15 AM	11:10 AM
Temp °C	19.0	19.5	19.0	21.8	21.5	21.5
Conductivity micromhos/cm	675	680	675	690	680	680
pH	8.2	8.3	8.3	8.4	8.5	8.4
Turbidity JTU	37	25	22	32	21	12
D.O. mg/ℓ	7.8	8.1	8.0	8.0	7.9	7.2
BOD_5 mg/ℓ	3.2	3.1	1.6	5.4	1.7	1.2
Coliform, total per 100 ml (Membrane Filter)	6200	4900	2300	12,200	6600	6000
Coliform, Fecal per 100 ml (Membrane Filter)	540	430	530	650	800	550
Streptococci, Fecal per 100 ml (Membrane Filter)	1160	920	1060	1900	1180	1800
Coliform, Total per 100 ml (MPN)	9200	3500	>24,000	16,000	5400	2200
Coliform, Fecal per 100 ml (MPN)	490	490	790	2200	1300	1400
Runoff in cfs	23	--	19	19	--	17

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - August 14, 1973			Date - August 16, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	9:27 AM	10:25 AM	10:45 AM	9:45 AM	10:50 AM	11:45 AM
Temp °C	18.5	18.0	17.5	17.8	18.0	18.0
Conductivity micromhos/cm	650	660	650	640	640	630
pH	8.0	8.0	7.9	8.0	8.0	8.0
Turbidity JTU	25	19	18	30	21	16
D.O. mg/ℓ	7.0	7.7	7.7	8.0	8.5	9.9
BOD_5 mg/ℓ	2.2	2.2	1.7	3.8	1.5	1.3
Coliform, total per 100 ml (Membrane Filter)	5900	5200	5300	780	4200	2200
Coliform, Fecal per 100 ml (Membrane Filter)	380	340	400	620	260	220
Streptococci, Fecal per 100 ml (Membrane Filter)	1180	1160	900	2600	580	860
Coliform, Total per 100 ml (MPN)	16,000	5400	3500	13,000	4900	1300
Coliform, Fecal per 100 ml (MPN)	2400	790	790	3500	790	330
Runoff in cfs	24	--	23	22	--	18

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - August 20, 1973			Date - Sept. 5, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	10:30 AM	10:40 AM	11:00 AM	11:20 AM	12:00	12:30 AM
Temp °C	19.0	19.5	19.0	21.0	20.5	20.0
Conductivity micromhos/cm	580	470	610	650	650	650
pH	7.8	7.8	7.8	8.3	8.3	8.3
Turbidity JTU	95	240	52	9.2	7.8	7.4
D.O. mg/ℓ	6.9	7.2	7.6	8.0	8.7	9.2
BOD_5 mg/ℓ	4.7	4.4	2.8	0.7	0.7	0.8
Coliform, total per 100 ml (Membrane Filter)	150,000	220,000	54,000	4200	3400	3000
Coliform, Fecal per 100 ml (Membrane Filter)	9600	8600	1900	300	280	240
Streptococci, Fecal per 100 ml (Membrane Filter)	59,000	127,000	23,000	1400	700	1100
Coliform, Total per 100 ml (MPN)	35,000	92,000	54,000	5400	790	3500
Coliform, Fecal per 100 ml (MPN)	7900	17,000	3300	1300	490	490
Runoff in cfs	--	--	--	--	--	--

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - September 14, 1973			Date - September 19, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	2:17 PM	2:41 PM	3:05 PM	2:15 PM	2:33 PM	2:50 PM
Temp °C	17.0	16.5	17.0	14.0	13.0	13.5
Conductivity micromhos/cm	590	590	600	500	530	520
pH	8.4	8.5	8.4	8.0	8.2	7.6
Turbidity JTU	7.1	6.2	7.2	6.5	7.6	7.1
D.O. mg/ℓ	10.6	10.3	10.6	10.1	11.0	11.1
BOD_5 mg/ℓ	0.7	0.5	0.5	0.8	0.8	1.0
Coliform, total per 100 ml (Membrane Filter)	1200	960	840	940	1700	1200
Coliform, Fecal per 100 ml (Membrane Filter)	40	65	110	110	140	220
Streptococci, Fecal per 100 ml (Membrane Filter)	520	370	290	730	350	470
Coliform, Total per 100 ml (MPN)	2200	1300	1700	1100	3500	2400
Coliform, Fecal per 100 ml (MPN)	490	220	830	220	490	220
Runoff in cfs	--	--	--	--	--	--

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - September 27, 1973			Date - October 4, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	2:20 PM	2:45 PM	3:06 PM	10:50 AM	11:10 AM	11:28 AM
Temp °C	19.0	20.0	19.0	22.0	22.0	23.0
Conductivity micromhos/cm	600	600	600	590	590	590
pH	8.0	8.2	8.3	7.5	7.2	7.6
Turbidity JTU	7.1	11	8.5	11	12	11
D.O. mg/ℓ	10.8	10.9	11.3	8.9	9.2	9.1
BOD_5 mg/ℓ	2.4	1.3	1.2	1.5	1.6	1.2
Coliform, total per 100 ml (Membrane Filter)	620	860	570	880	3400	1260
Coliform, Fecal per 100 ml (Membrane Filter)	180	140	170	260	270	320
Streptococci, Fecal per 100 ml (Membrane Filter)	760	420	400	1480	1280	1060
Coliform, Total per 100 ml (MPN)	5400	790	270	330	790	1100
Coliform, Fecal per 100 ml (MPN)	490	230	130	230	330	790
Runoff in cfs	--	--	--	--	--	--

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - October 10, 1973			Date - October 17, 1973		
	Sta. 1*	Sta. 2*	Sta. 3*	Sta. 1*	Sta. 2*	Sta. 3*
Time	2:45 PM	3:00 PM	3:22 PM	2:50 PM	3:12 PM	3:30 PM
Temp °C	20.0	20.0	19.5	11.0	11.0	12.5
Conductivity micromhos/cm	590	600	610	500	510	510
pH	7.6	8.2	8.4	7.4	8.2	8.3
Turbidity JTU	8.6	8.4	9.4	7.4	7.4	7.3
D.O. mg/ℓ	10.5	10.4	10.6	12.2	11.9	12.4
BOD_5 mg/ℓ	0.8	0.8	0.8	1.1	1.2	0.6
Coliform, total per 100 ml (Membrane Filter)	820	1020	1220	460	420	820
Coliform, Fecal per 100 ml (Membrane Filter)	88	145	196	78	78	590
Streptococci, Fecal per 100 ml (Membrane Filter)	780	480	620	670	300	340
Coliform, Total per 100 ml (MPN)	1700	790	790	490	700	2400
Coliform, Fecal per 100 ml (MPN)	700	230	330	110	210	1300
Runoff in cfs	--	--	--	--	--	--

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - October 24, 1973			Date - October 31, 1973		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 *	Sta. 2 *	Sta. 3 *
Time	2:15 PM	2:35 PM	2:55 PM	2:30 PM	2:45 PM	3:05 PM
Temp °C	11.5	12.0	12.5	12.0	11.0	11.0
Conductivity micromhos/cm	500	500	510	500	510	500
pH	7.8	8.2	8.3	7.6	8.1	8.3
Turbidity JTU	7.1	6.7	6.9	7.1	8.3	8.7
D.O. mg/ℓ	11.9	12.1	12.2	9.0	10.4	10.4
BOD_5 mg/ℓ	1.5	0.7	0.8	1.3	1.1	0.9
Coliform, total per 100 ml (Membrane Filter)	1020	600	1120	800	900	3500
Coliform, Fecal per 100 ml (Membrane Filter)	66	36	260	180	94	1330
Streptococci, Fecal per 100 ml (Membrane Filter)	310	215	275	570	430	2820
Coliform, Total per 100 ml (MPN)	490	330	330	1100	330	1700
Coliform, Fecal per 100 ml (MPN)	130	80	330	170	230	3500
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

	Date - Nov. 7, 1973			Date -		
	Sta. 1 *	Sta. 2 *	Sta. 3 *	Sta. 1 *	Sta. 2 *	Sta. 3 *
Time	2:25 PM	2:45 PM	3:05 PM			
Temp °C	5.5	4.8	6.0			
Conductivity micromhos/cm	450	450	470			
pH	7.7	8.1	8.2			
Turbidity JTU	8.3	7.6	10.0			
D.O. mg/ℓ	12.7	13.4	12.5			
BOD_5 mg/ℓ	0.9	0.9	1.1			
Coliform, total per 100 ml (Membrane Filter)	1040	560	580			
Coliform, Fecal per 100 ml (Membrane Filter)	176	70	54			
Streptococci, Fecal per 100 ml (Membrane Filter)	275	250	150			
Coliform, Total per 100 ml (MPN)	230	490	230			
Coliform, Fecal per 100 ml (MPN)	130	140	130			
Runoff in cfs						

*Sta. 1 - Liberty Road
*Sta. 2 - Lima Center Road
*Sta. 3 - Klinger Road

MILL CREEK WATER QUALITY DATA

March 6, 1973	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9
Time	9:30 AM	10:00AM	10:47 AM	10:20 AM	11:07 AM	12:10 PM	12:30 PM	11:50AM	11:30 AM
Temp °C	5°	4.5	5.5	5.5	6.5	--	--	--	6.0
Conductivity micromhos/cm	400	410	430	420	405	--	--	--	250
pH	8.2	8.2	8.1	8.2	8.2	8.1	8.1	8.2	8.1
Turbidity JTU	18	23	23	15	22	7	4	6	4
D.O. mg/ℓ	11.2	11.7	11.2	11.5	11.8	11.3	11.4	11.2	12.1
BOD_5 mg/ℓ	2.5	2.6	2.0	2.3	1.7	1.6	2.2	1.9	1.7
Coliform, total per 100 ml (Membrane Filter)	630	340	340	450	130	130	102	38	46
Coliform, Fecal per 100 ml (Membrane Filter)	90	128	175	158	12	58	8	4	2
Streptococci, Fecal per 100 ml (Membrane Filter)	170	145	115	105	42	72	40	54	40
Coliform, Total per 100 ml (MPN)	270	790	1700	3500	230	1300	330	170	330
Coliform, Fecal per 100 ml (MPN)	330	230	230	230	50	130	50	50	20
Runoff in cfs									

MILL CREEK WATER QUALITY DATA

July 11, 1973	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9
Time	9:30 AM	10:35AM	10:45 AM	11:24 AM	11:42AM	11:55AM	12:05 PM	12:25 PM	12:40 PM
Temp °C	19	19.5	19	18.7	19	18.7	17	19.8	22.2
Conductivity micromhos/cm	670	650	690	690	650	700	650	610	450
pH	8.3	8.4	8.3	8.3	8.6	8.0	8.2	8.3	8.3
Turbidity JTU	32	32	17	24	30	7	10	37	25
D.O. mg/ℓ	7.5	7.7	8.0	8.1	8.2	7.1	9.0	7.5	7.2
BOD_5 mg/ℓ	1.4	1.4	1.2	2.7	1.2	1.6	1.8	4.0	2.1
Coliform, total per 100 ml (Membrane Filter)	6700	5300	5000	7200	1200	7200	4400	5700	1420
Coliform, Fecal per 100 ml (Membrane Filter)	770	800	600	450	280	390	360	1220	150
Streptococci, Fecal per 100 ml (Membrane Filter)	1800	1700	1700	1800	1280	1400	1420	3800	940
Coliform, Total per 100 ml (MPN)	9200	1100	16,000	9200	5400	9200	9200	16,000	2400
Coliform, Fecal per 100 ml (MPN)	3500	490	790	1100	2200	2200	9200	1700	2400
Runoff in cfs	32		29						

APPENDIX E

U.S. GEOLOGICAL SURVEY WATER QUALITY DATA

[illegible] field and laboratory determinations at water-quality monitoring sites in Washtenaw C[illegible]
Analyses for nitrogen and phosphorus species, bacteria, BOD, and MBAS by Washtenaw County He[illegible]
Department, other field determinations by U.S. Geological Survey. Coding for visual observation[illegible]
0--not present; 1--mild, 25%; 2--moderate, 25- 50%; 3--serious, 50- 75%; 4--extreme, 75-100%.

STATION	DATE	TIME	DIS-CHARGE (CFS)	TOTAL NITRITE (N) (MG/L)	TOTAL AMMONIA NITROGEN (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL ORTHO PHOS-PHORUS (P) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	[illegible] (MICRO-MHOS)	[illegible]
4173150 MILL CREEK AT MANCHESTER ROAD NEAR SYLVAN	71-08-18	0940	--	.015	.42	.20	.005	.023	560	7.9
	10-27	1230	--	.028	.64	1.4	.025	.026	650	7.9
	12-16	0900	--	.019	.54	.20	.22	.26	730	7.3
	72-03-08	0935	--	.015	.15	.08	.049	.081	625	7.9
	04-25	1205	--	.017	.05	.10	.046	.055	650	8.1
	06-21	1110	--	.004	.56	.04	.18	.18	640	8.0
	08-24	1515	--	.015	.32	.02	.042	.046	580	8.4
	11-02	1230	--	.001	.46	1.5	.078	.12	700	7.5
	73-01-03	1100	--	.006	.15	1.4	.010	.023	770	7.7
	03-15	1515	--	.006	.27	.10	.29	.30	650	7.9
	05-09	1240	--	.004	.27	.06	.039	.10	700	7.9
	07-10	1355		.003	1.0	.40	.15	.18	720	7.7
	MAXIMUM			.028	1.0	1.5	.29	.30	770	8.4
	MINIMUM			.001	.05	.02	.005	.023	560	7.3
	MEAN			.011	.40	.46	.095	.116	665	7.0
4173254 MILL CREEK AT JERUSALEM ROAD NEAR LIMA CENTER	71-08-18	1555	--	.009	.56	.00	.068	.068	620	7.9
	10-27	1045	--	.024	.42	.60	.017	.027	700	7.5
	12-15	1245	--	.035	.15	.30	.026	.026	750	8.1
	72-03-08	1030	--	.024	.27	.10	.046	.052	580	8.3
	04-25	1115	--	.019	.12	.40	.026	.033	700	7.9
	06-21	0930	--	.008	.65	.04	.28	.28	650	6.5
	08-25	1250	--	.008	.83	.04	.19	.25	700	8.2
	11-02	1330	--	.010	.68	.50	.22	.24	860	7.7
	73-01-03	1210	--	.012	.42	5.3	.010	.013	620	7.6
	03-16	1600	--	.004	.51	.06	.052	.085	660	7.7
	05-09	1205	--	.001	.20	.20	.016	.082	675	7.8
	07-10	1245	--	.004	1.0	.90	.065	.078	675	7.7
	08-22	1330	--	.008	.68	.06	.062	.088	720	7.9

STATION	TEMP-ERATURE (DEG C)	DISSOLVED OXYGEN (MG/)	DISSOLVED OXYGEN PER-CENT SATUR-ATION	BIO-CHEM-ICAL OXYGEN DEMAND (MG/L)	TOTAL COLI-FORM (MPN)	FECAL COLI-FORM (MPN)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L)	AIR TEMP-ERATURE (DEG C)	VISUAL OBSERVATIONS: ICE COVER	TUR-BID-ITY	OIL	ALGAE
04173150	15.0	9.6	97	2.1	46,000	400	.00	28.0	--	0	0	0
	15.5	9.3	96	3.7	24,000	1,100	.00	16.5	--	1	0	0
	4.[illegible]	11.6	[illegible]	.1	7,500	2,300	.00	3.0	0	2	0	0
	.0	13.2	95	.2	930	30	.00	-3.0	0	1	0	0
	9.5	11.4	103	1.4	90	40	.00	18.0	--	1	0	1
	14.0	9.3	92	1.4	9	4	.00	13.0	--	1	0	1
	24.5	7.6	94	1.4	4,300	2,000	.10	29.0	--	1	0	0
	11.0	9.4	87	1.4	110,000	400	.20	22.5	--	4	0	0
	1.5	11.6	88	1.7	9,300	90	.00	.5	--	2	0	0
	11.0	9.9	92	[illegible]	110,000	7,[illegible]00	.00	16.0	--	2	0	0
	16.0	9.0	93	3.4	4,000	4,000	.00	16.0	--	2	0	1
	23.5	7.0	85	2.0	1,100,000	75,000	.00	28.0		2	0	0
MAXIMUM	24.5	13.2	103	3.7	1,100,000	75,000	.20	29.0				
MINIMUM	.0	7.0	85	.1	9	4	.00	.5				
MEAN	12.1	9.9	93	1.7	120,000	7,700	.03	15.6				
04173254	24.0	10.4	127	2.1	15,000	4,300	.00	34.5	--	0	0	1
	15.0	9.6	97	1.5	9,300	400	.00	18.0	--	1	0	0
	6.0	11.2	92	.6	4,300	400	.00	11.0	0	2	0	0
	.0	12.8	90	1.5	24,000	110	.20	-7.0	1	2	0	0
	6.0	11.8	98	2.0	230	230	.00	17.5	--	1	0	0
	17.5	7.1	76	1.1	9	3	.00	11.5	--	1	0	1
	23.0	9.7	117	.0	7,500	900	.00	29.0	--	2	0	0
	11.0	10.0	93	3.5	46,000	1,500	.00	22.0	--	3	0	0
	1.0	11.1	80	2.9	46,000	430	.00	3.5	--	4	0	0
	11.0	9.4	87	1.4	240,000	1,500	.00	14.0	--	2	0	0
	14.0	9.9	98	4.2	43,000	4,000	.00	22.0	--	3	0	0
	21.0	6.7	77	5.1	6,400,000	110,000	.00	27.0	--	3	0	0
	17.0	11.4	82	2.3	1,100,000	[illegible]	.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LABORATORY AVANLYSIS BY U.S. GEOLOGICAL SURVEY

SITE NUMBER	STATION NUMBER	STATION	DATE OF SAMPLE	SILICA (SIO2) (MG/L)	IRON (FE) (UG/L)	MAN-GANESE (MN) (UG/L)	CAL-CIUM (CA) (MG/L)	MAG-NE-SIUM (MG) (MG/L)	SODIUM (NA) (MG/L)	PO-TAS-SIUM (K) (MG/L)
	04173150	MILL CREEK AT MANCHESTER RD.	71-08-18	12	30	0	74	21	14	1.4
			72-04-25	13	780	99	100	17	19	2.0
			72-11-02	12	.10	4	100	22	18	2.6
			73-03-15	7.4	610	11	78	30	20	2.2
	04173254	MILL CREEK AT JERUSALEM RD.	71-08-18	16	30	0	95	20	11	2.2
			72-04-25	12	710	100	110	24	9.0	2.9
			72-11-02	9.0	20	31	94	21	11	3.1
			73-03-15	5.6	0	22	85	32	7.5	3.8
			73-08-22	10	--	--	120	24	12	2.2

	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	ALKA-LINITY AS CACO3 (MG/L)	SULFATE (SO4) (MG/L)	CHLO-RIDE (CL) (MG/L)	FLUO-RIDE (F) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	HARD-NESS (CA, MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (JTU)
04173150	284	0	233	34	30	.3	342	270	37	5	1
	[illegible]	[illegible]	194	96	[illegible]	.3	462	320	130	15	8
	270	0	221	89	46	.2	457	340	120	15	75
	270	0	221	73	45	.3	420	320	98	20	25
04173254	348	0	285	48	16	.5	385	320	34	15	10
	233	0	191	150	23	.4	503	370	180	33	11
	270	0	221	74	--	.2	409	320	100	20	8
	242	0	198	110	26	.3	374	340	150	35	25
	368	0	302	65	26	.3	450	400	95	35	7

STATION NUMBER	STATION NAME	DATE OF SAMPLE	DIS-SOLVED ARSENIC (AS) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED SELE-NIUM (SE) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
04173150	MILL CREEK	71-08-18	6	0	0	1	1.0	--	--	--
		72-11-02	10	0	0	16	<.5	--	--	--
04173254	MILL CREEK	71-08-18	3	0	0	0	<.5	--	--	--
		72-11-02	6	0	0	17	1.3	0	0	40
		73-08-22	10	0	0	0	<.5	--	--	--