# TEMPORAL TRENDS OF COLIFORM BACTERIA

# IN

# SPENCER CREEK, HAMILTON

BY

DONNA J. LYMBURNER

A Research Paper
Submitted to the Department of Geography
in Fulfilment of the Requirements
of Geography 4C6

McMaster University
April 1991

# Abstract

Coliform bacterial pollution was studied in the Spencer Creek in Hamilton, Ontario. Data, derived from the Ontario Ministry of the Environment files in Hamilton, were used in the determination of whether distinctive temporal patterns of coliform bacterial counts and loads exist in Spencer Creek at Cootes Drive in Dundas. An initial investigation of the general streamflow trends showed that the peak flow period is during the spring snowmelt (March) and a secondary peak flow occurs in late fall due to frontal storms passing through the area. This coincides with the minimums of coliform counts and loads which consistently occur during these times of high flow, particularly March and April. Peak coliform counts and loads occur 70% of the time in late summer with varying starting times in June, July, August and September. This is attributed to the low flow and high temperature of the water in the summer. The average coliform count is 334,154 coliform bacteria per 100 mL water, well above the water quality objectives set by the Ontario Water Resources Commission for Ontario Ministry of the Environment. Approximately 80% of the coliform counts, measured in Spencer Creek in this study, were well above this water quality objective. Therefore, in terms of coliform bacteria, Spencer Creek is polluted, particularly in the summer months. This study simply points out the necessity for further study and continued water quality testing in Spencer Creek.

# Acknowledgements

The author gratefully acknowledges the helpful suggestions made by Dr. C.H. Eyles and Dr. S.B. McCann. I thank Dr. C.H. Eyles for her assistance in the initial stages of research and Dr. S.B. McCann for his advice and encouragement in redefining the project, data analysis and in the editing stages of the project. I also thank the staff at the Ontario Ministry of the Environment, West Central Regional Office in Hamilton for their contribution of the data used in this thesis.

# TABLE OF CONTENTS

1 INTRODUCTION

2 LITERATURE REVIEW

3 METHODOLOGY

4 ANALYSIS AND RESULTS

# List of Tables

# List of Figures

> "Water is the life-blood of the environment. The state of our aquatic ecosystem is a vital indicator of our economic and social well-being" (Leith, 1990). "Clear waters and clean air, green forests and fields, flights of birds and the sight of wild creatures are among the amenities that make life worth living as compared to a mere existence" (Thomas, 1972).
>
> The recent *State of the Environment Report* for Canada, 1986, included an overall environmental assessment of the response of freshwater systems to human stresses. It relates key ecological indicators - such as biotic composition, primary productivity and nutrient concentration - to loss of wetlands, sediment loading, construction of dams and diversions, and pollution from sewage contaminants (Bird and Rapport, 1986).

# 1 INTRODUCTION

## 1.1 Objectives

The primary purpose of this study is to determine if distinctive temporal patterns of water quality exist in Spencer Creek, with particular emphasis on total coliform content. The hypothesis is that temporal patterns do occur in the distribution of total coliform counts and total coliform loadings. Particularly high coliform peaks (both total counts and loading) are thought to exist in late summer months when low flow and high temperatures persist in the creek. The data for this investigation will come from Ontario Ministry of the Environment Reports on stream water quality.

## 1.2 The Importance of Studying Water Quality

Water quality means different things to different people because of its various perspectives from which they approach it. Generally, it refers to characteristics of attributes of water, good or bad, that relate to its acceptability for certain purposes or uses. A definition for pollution, given by Lamb (1985), is "the presence of materials in water that interfere unreasonably with one or more beneficial uses of it". Good water quality is the normal, unaltered state of elemental constituents in water. Departures from this state usually represent a deterioration in quality. From the public health standpoint the bacteriological quality of water is as important as the chemical quality. Thus the answer lies in the study of indicator organisms. Most often used is a group of microbes called coliforms which are organisms normal to the digestive tracts of warm-blooded animals.

## 1.3 Spencer Creek, Hamilton, Ontario

There is presently great concern over the water quality of the Great Lakes (GLWQA 1972), into one, Lake Ontario, that Spencer Creek eventually contributes its load. Thus, the approach to controlling water quality in one small tributary (Spencer Creek) eventually contributes to the control of Great Lakes water quality at the "grass roots" level. This is the approach Remedial Action Plans are taking at present. The RAP for Hamilton Harbour is presently focusing on clean-up of the harbour itself.

The water quality of Spencer Creek will be considered since it has the largest impact on the local environment. The watershed covers an area of approximately 166 $km^2$ above the testing site at Cootes Drive - Hwy. #2.

## 1.4 The Database

The data used in this report are derived from a program which is designed to provide a near continuous record of basic water quality information at specific points on rivers and inland lakes in Ontario. These particular data are made available to all those directly concerned with the quality of surface water in Southern Ontario. The present water quality monitoring program includes routine collection of water samples at specific locations from key rivers and lakes, and the subsequent analysis for various constituents which are of primary concern from a water use point of view. Each sampling station was selected, by the Ministry of the Environment, at a point thought to reasonably represent the general condition of the body of water under consideration. As it is of great importance to relate quality data to flow conditions, the sampling stations were located, where practical, in the vicinity of flow recording gauging stations.

The water quality parameters that have been determined within Spencer Creek by the Ontario Water Resources Commission: River Basin Surveys Branch (OWRC, 1964-1986) are: total phosphorus, phosphates, nitrogen, ammonium, nitrite, nitrates, dissolved oxygen, copper, nickel, zinc, lead, cadmium, chromium, pH, conductivity, stream condition and temperature (as reported by the H-W Regional office of the MOE). See Appendix for more specific information on the data not discussed in this paper.

The samples obtained at each station were collected at the same location and as nearly as possible, in the same part of the flow. In order to minimize changes caused by differences in sampling techniques, most of the bacterial samples were preserved with ice during the summer months and shipped promptly to the laboratory for examination (OWRC, 1965).

This information is used by the Ontario Ministry of the Environment to maintain surveillance over water quality and to provide supporting data for the analysis and prediction of water quality for planning and other purposes. The data are made available to any person or agency concerned with the quality of rivers and lakes.

As of 1987 the Remedial Action Plan for Hamilton Harbour has taken over the water quality testing in the lower Spencer Creek Basin. These data consist of tri-monthly estimations of various parameters. They are: dissolved oxygen, field water pH, stream condition, temperature, filtered reactive phosphate, filtered ammonium nitrogen, nitrate, nitrite, total nitrogen, iron, chromium, copper, lead, cadmium, zinc and nickel. There is no recorded streamflow data or total, streptococcal or faecal coliforms made at this site by the RAP program. Therefore these data will not be used in this discussion, although they are useful for future studies on Spencer Creek and Hamilton Harbour.

# 2 LITERATURE REVIEW

## 2.1 Water Quality Standards

A search of the scientific literature reveals that water quality standards for surface waters in general are not available. However, standards are available for waters having specific end uses. The Provincial Ministry of the Environment has established guidelines and criteria for certain types of water uses in its revised edition (1984) of "Water Management: Goals, objectives and implementation procedures of the MOE". These guidelines outline acceptable levels of various substances in both surface and groundwaters for use in agriculture, industrial, public and recreational activities. The problem in studying water quality stems from the fact that there are individual guidelines for each specific end use mentioned. Since this analysis is focusing on total coliform counts, the microbiological characteristics as they relate to health will be examined.

Water quality is judged unsafe when the total coliform count, when determined by the Membrane Filter (MF) method, persists in densities of 5 or more organisms per 100 ml. Poor water quality exists when total coliform bacteria are present above 5 organisms per 100 ml by MF tests, again and they should not occur in more than 10% of the samples submitted in any one month (PMOE, 1978). The data available from the Ministry of the Environment does not allow for an examination from this standpoint because of the small number of samples taken from the stream for many of the months in question.

A large portion of the water in the Spencer Creek watershed is used for livestock watering. These animals may be able to tolerate a fairly high level of total dissolved solids or bacteria if they are accustomed to such levels, but may be unable to tolerate a sudden change from waters with low dissolved solids or bacteria to waters with high dissolved solids or bacteria. Thus, an analysis of the changes that occur over time is necessary.

## 2.2 The Importance of Bacteriological Data

Total coliforms are natural water quality indicator organisms. Coliform organisms are normal inhabitants of soils and the intestines of man and other warm-blooded animals. They are always present in large numbers in sewage and faecal matter, and are often found in watercourses adjacent to industrial, agricultural and other pollution sources. Along with nutrients and organic materials, sewage effluent entering streams and wetlands contains large quantities of bacteria, particularly coliforms and pathogens such as *Salmonella* and

*Enterococci* (Thomas, 1972). The microbiological quality of drinking water has traditionally been viewed as the most important aspect of drinking water quality because of its association with waterborne disease. It is because of the potential health hazard to man that the presence of these organisms in surface water is highly undesirable.

Because inaccurately treated sewage and faecal matter are a primary source of disease causing organisms, a potential health hazard exists if a sanitary survey discloses that inadequately treated sewage, faecal matter or other hazardous substances are being or may be discharged into the water. The sanitary survey (bacteriological data) should consist of an on-site inspection of adjacent and upstream areas and of all water flows and potential sources of discharge. The survey should take into account the effects of rainfall, peak user loads, the danger of accidental spillage and sources from other jurisdictions (Fresenius et al., 1988). It should also be noted that high bacterial counts are further aggravated in summer months when stream flow is likely to be reduced and water temperatures are relatively high (Pickering, 1977).

In addition to the above characteristics, coliforms are plentiful and hence not difficult to find, easily detected with a simple test, generally harmless except in unusual circumstances and hardly survive longer than most known pathogens. Thus coliforms as universal indicator organisms are useful in the determination of recent pollution by wastes from warm-blooded animals and therefore the water may, but not necessarily, contain pathogenic organisms. A high coliform count is therefore suspicious and the water should not be consumed.

Measured or calculated pollutant loading values are also valuable to the wetland manager as they may indicate how threatened a wetland is by toxicity or eutrophication. The instantaneous loading value will be calculated in this study.

The only natural reducing mechanism that exists in nature to rid the water of coliforms is the wetland. There is a large land area in the Spencer Creek watershed composed of wetlands, as previously mentioned. Bacterial contamination can be reduced by these wetlands even during times of peak load (Greeson et al.). The most important mechanism for bacterial removal by wetlands is simply detention while natural dieback occurs. Many micro-organisms found in sewage effluent cannot survive for long periods of time outside of their host organism. It is also possible that protozoa present in shallow waters actively feed on bacteria, thereby speeding up the process of die-back (Brinson, 1988). In addition, root excretions of wetland plants can kill pathogenic bacteria in contaminated waters (Suffet ). Thus an indicator, such as coliform, can aid in the determination of how well a wetland is functioning as a water quality regulator. The importance of the protection of these wetlands, because of their role in water quality management, should be stressed in strict landuse policies by the Region and/or Municipality.

## 2.3 Assessment Methodology of Bacteriological Data

The Membrane Filter technique is used to obtain an approximation of the concentration of total coliform organisms. This involves filtering a sample through a sterile filter, thus capturing any coliform bacteria (Fresenius et al., 1985). The filter is then placed in a petri dish containing a sterile agar which soaks into the filter and promotes the growth of coliforms, while inhibiting other organism growth. After 24-48 hours of incubation the number of shiny black dots indicating coliform colonies is counted. If we know how many millilitres were filtered then the concentration of coliforms can be expressed in total coliform count per 100 mL. This work is usually done by the Regional Office of the Ministry of the Environment.

This MF technique is used to obtain an approximation of the concentration of total coliform organisms. Results are reported as MF count per 100 ml of sample. The objective is that the total coliform count in water should not exceed 2,400 organisms per 100 ml (OWRC, 1980).

A background count estimates the number of organisms, other than coliform, that occur in the total coliform analysis of a sample. The results are used in the interpretation of total coliform counts. High background counts are generally indicative of poor water quality. The MF technique is also used to determine the numbers of background organisms in water.

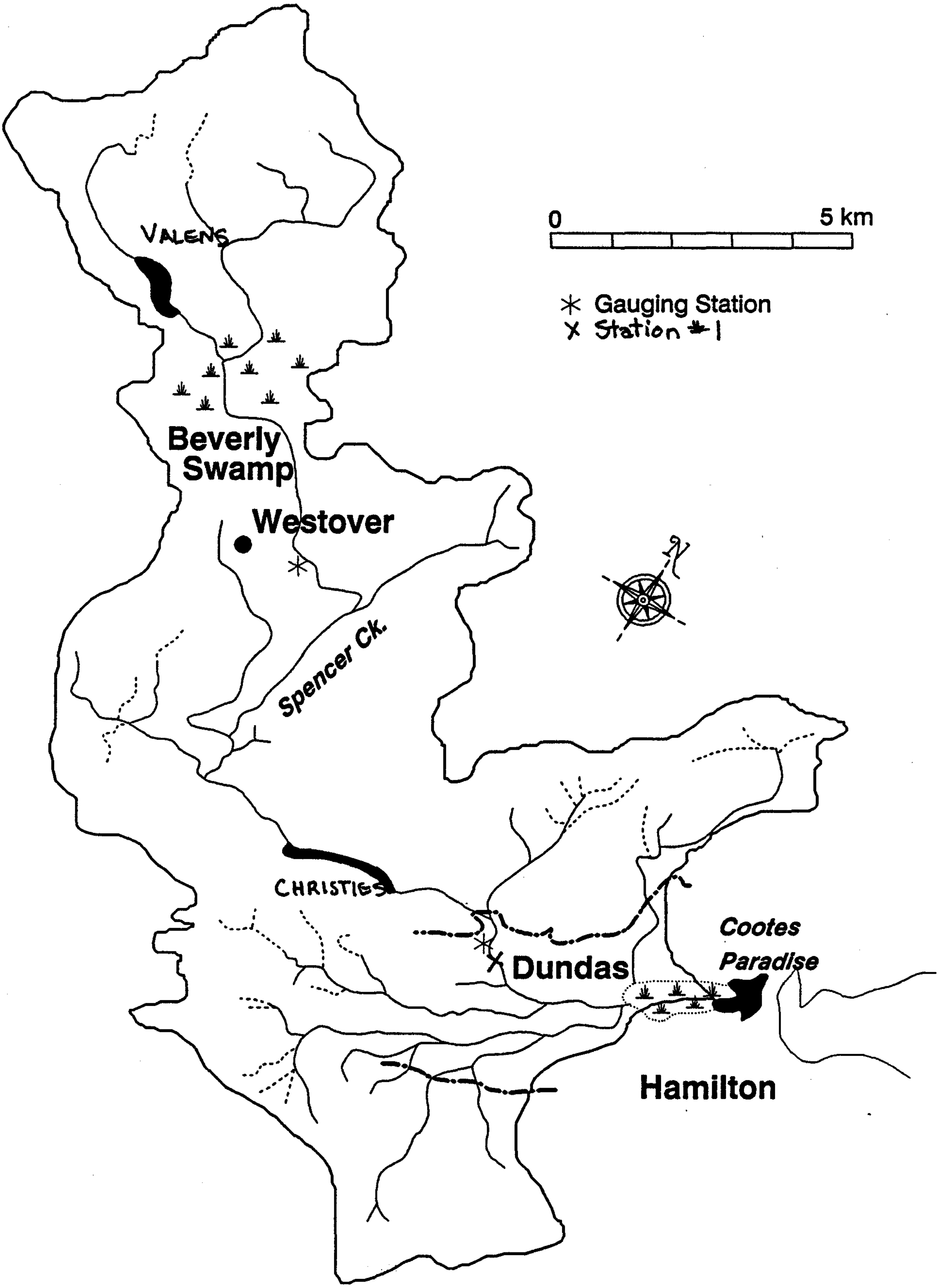
## 2.4 The Spencer Creek Watershed

As discussed in Section 1.3 the Spencer Creek watershed is an important element of the surrounding environment and ultimately has an impact on the water quality of the Great Lakes. Many smaller streams contribute to the flow of Spencer Creek, they include: Puslinch, Flamboro, Logies, Westover, West Spencer, Spring, Sydenham and Ancaster Creeks. The watershed itself is composed of a number of wetland systems all functioning as an ecosystem unit to regulate water quality and to control the flow of the creek. These include, as defined by the Hamilton-Wentworth

Environmentally Sensitive Areas (ESA) Policy: Beverly Swamp, Valen's Conservation Area, Forestry and Wildlife Area, Hayesland Forestry and Wildlife Area, Donald Farm Wetland and Christies Conservation Area (Ecologistics, 1977).

Because of the urbanization of the surrounding areas in recent years, there has become an increased need for human control over the processes of the Spencer system. Thus the dam at Christie Conservation (see Figure 1.0) area is used to control the high runoff period in the spring months. This is necessary because of the rapidly growing town of Dundas to the south. The 76 ha (full capacity) Valens reservoir was constructed primarily to augment flow through Spencer Creek during drought or regular seasonal flows (HRCA, 1980). These reservoirs also provide delayed runoff downstream during periods of intense rainfall or snowmelt. As well both Valens and Christie provide a recreation area for the population in the Hamilton-Wentworth Area.

Reservoirs may cause deterioration of water quality through several mechanisms: change from a flowing to long retention and low flow velocity increases the likelihood of algal growths and the stratification of deep impoundments during warm weather creates conditions necessary for the accumulation of certain elements (Lamb, 1985).


0
5 km
∗ Gauging Station
X Station #1
N
VALENS
Beverly Swamp
Westover
Spencer Ck.
CHRISTIES
Dundas
Cootes Paradise
Hamilton

# 3 METHODOLOGY

## 3.1 Streamflow Characteristics of Spencer Creek

Streamflow information at or near a water quality monitoring site is an important factor when interpreting and employing water quality data. Streamflow is also a useful reference when comparing water quality data for different periods of the year (eg. spring flood and summer drought), it also allows for determination of the mass of material passing a point, the load (load = streamflow x count).

Using flow data collected at the same site and time as the water quality variables, yearly hydrographs can be obtained. These of course, will only give rough estimates of the flow in Spencer Creek, but this measurement is necessary and useful in interpreting the instantaneous pollution loads (see Section 3.3).

It is first necessary to interpret the general trend of flow in the creek, ie. when the primary (highest flow) and secondary (second highest peak) peaks occur in the hydrograph. The secondary peak must represent a separate peak in the hydrograph not a continuation of the primary peak. Also, an examination of low flow or drought conditions is necessary.

These will be represented in a summary table.

Changes of streamflow over time are also an important element to consider, especially if there are any changes in the pollutant loading values over time. Therefore it is necessary to evaluate the maximum and minimum flows over the years to see if there are changes to these values. These should also be included in the summary table.

## 3.2 Temporal Patterns

The primary purpose of this analysis is to determine if a seasonal component exists in the presence of high/low coliform counts. This can be done simply by graphing the total coliform count over time (Jan to Dec) and examining the various peaks and lows. In the case where there is a very large value ie. >800,000 coliform/100mL of sample, it is simply dropped in order to see if there is an underlying trend throughout the year which cannot be seen when a very large value distorts the graph. (It should be noted that no more than two measurements were omitted in this way for any one year (this large value however is not omitted in the discussion of the peak coliform counts)) It is then necessary to analyze the data both more qualitatively, using relative frequency data, and quantitatively using absolute values.

### 3.2.1 Relative Values

Frequency values can be taken from the graphed total coliforms versus time. The peak values, as well as minimum values and timing of these events, are recorded into a summary table showing frequencies of primary and secondary temporal peak occurrences by month, as well as the minimum count values by month.

### 3.2.2 Absolute Values

It is also necessary to compare the absolute values of the peaks and minimums, as found in Section 3.2.1, over time. In this way any changes in water quality over time can be determined. To do so the mean peak values for the different peak periods will be determined, ie. the mean coliform count for the late summer peaks. This can then be compared over the year to any other peak periods, and over time to determine if there has been any change in the absolute values of total coliform counts over the years.

## 3.3 Pollutant Loadings

Instantaneous pollutant loadings are calculated by multiplying the discharge in $m^3/s$ by the total coliform count per 100 mL (x10,000) which will give the instantaneous pollutant load in: # organisms per $m^3$ per second. This can then be analyzed as both relative frequency values and as absolute values, as the total counts were in Sections 3.2.1 and 3.2.2.

### 3.4 Background Counts

The importance of background counts has already been established so this section will consist of a direct comparison of the background counts with the total coliform counts. Are they high at the same times (ie. high during low summer flow etc.), are the numbers comparable etc.

### 3.5 Water Quality Objectives - Total Coliform

Section 2.1 states the Ontario Ministry of the Environment objectives and definitions of water quality for various end uses, and the specific levels at which total coliform counts exceed the standards for safe and tolerable uses (PMOE, 1978). Comparisons of these levels to the counts measured in Spencer Creek will reveal how "good" the water quality of the stream is in terms of total coliforms. This would be most useful in terms of the percentage time the level is above the objective, and a discussion of the temporal patterns of levels above this level.

According to the "Ministry of the Environment Water Quality Objectives" 1978, water quality is deemed unsafe if the total coliform count exceeds 5 organisms/100mL of sample and poor water quality is judged if the 100 mL sample exceeds 5 organisms 10% of the time. This is not a good level for comparison sake because at no time in the record are levels measured below 5 organisms/100mL. Levels set out by the Ontario Water Resources Commission (1964-1965) state that total coliform counts per 100 mL water sample should not exceed 2400 organisms/100 mL, after which notification of the Ministry of the Environment is required. According to the Provincial water quality objectives (PMOE, 1978) water quality is considered impaired when the total coliform mean density of water samples exceeds 1000 per 100 mL. These are better values to set as an upper limit for the levels of allowable total coliform counts in water.

# 4 ANALYSIS AND RESULTS

## 4.1 Streamflow Characteristics of Spencer Creek

Only station #1, Cootes Drive, will be discussed here as this station is a good representative of the general trends of the entire stream system. There is an obvious primary peak during the spring snowmelt period (March-April) which occurs in twelve out of the seventeen years, or 71% of the time (Table 4.1).

Table 4.1: Yearly Streamflow Summary

| YEAR | PRIM. MAX | MONTH | SECON. MAX | MONTH | MIN | MONTH | AVG |
|---|---|---|---|---|---|---|---|
| 1965 | 0.89 | MAY | 0.62 | MAR | 0.09 | JULY | 0.30 |
| 1966 | 5.24 | MAR | 1.95 | DEC | 0.05 | AUG | 1.41 |
| 1967 | 4.41 | APR | 2.67 | JUL | 0.30 | SEPT | 2.00 |
| 1968 | * | | | | | | |
| 1969 | * | | | | | | |
| 1970 | 5.90 | APR | 2.14 | NOV | 0.18 | JUN | 1.59 |
| 1971 | 5.90 | APR | 0.93 | DEC | 0.10 | AUG | 1.19 |
| 1972 | 12.20 | MAR | 3.76 | AUG | 0.34 | SEPT | 3.23 |
| 1973 | 14.40 | MAR | 1.71 | DEC | 0.06 | SEPT | 2.14 |
| 1974 | 6.00 | APR | 1.78 | NOV | 0.09 | SEPT | 2.06 |
| 1975 | 4.40 | APR | 2.55 | NOV | 0.06 | JUL | 1.50 |
| 1976 | 8.90 | MAR | 1.70 | DEC | 0.26 | SEPT | 2.50 |
| 1977 | 10.90 | DEC | 9.60 | MAR | 0.14 | AUG | 2.45 |
| 1978 | 9.67 | APR | 2.14 | JAN | 0.12 | JUL | 2.29 |
| 1979 | 5.21 | MAR | 1.92 | DEC | 0.18 | JUL | 1.37 |
| 1980 | 4.38 | MAR | 0.72 | OCT | 0.17 | AUG | 1.14 |
| 1981 | 4.35 | OCT | 2.20 | APR | 0.25 | JUN | 1.22 |
| 1982 | 5.09 | DEC | 4.23 | APR | 0.44 | SEPT | 1.84 |
| 1983 | 4.47 | DEC | 3.48 | MAR | 0.43 | SEPT | 1.72 |

* no data available

Figure 4.1, 1974, is an example of the yearly trend seen in the hydrographs with the primary peak during springmelt runoff and secondary peak in late fall. Deviations from this trend are a result of change or differences in the snow storage characteristics of the basin that winter. From Table 4.1 it can be seen that 1973, 1981 and 1982 were generally low flow years with little spring snowmelt runoff (ie. no spring peak in hydrograph). The secondary maximum peak is determined because of the effect a very large rainstorm event may have on the hydrograph, thus making streamflow in the springmelt runoff period less pronounced. This is the case in the remaining five years where the primary peak was not in the late spring (March-April). In nine of seventeen years the secondary peak flow was in late fall-winter (October-November-December) representative of frontal rainstorm events. All the minimum values for streamflow were found in the summer months (June, July, August and September). 12% if the time the minimum flow occurred in June, 24% of the time in July, and 24% in August and 40% of the time in September. From 1965 to 1977 the average primary maximum flow was approximately 7.20 $m^3/s$, and an average secondary maximum flow of 2.67 $m^3/s$. The average minimum during these same years was 0.15 $m^3/s$. From 1978 to 1983 the primary m ximum was approximately 5.50 $m^3/s$ and the secondary maximum was 2.45 $m^3/s$. The average minimum flow for these years was approximately 0.27 $m^3/s$. Therefore, since 1977 there has been a decrease in the average maximum peak value and an increase in the average minimum flow values. A quick glance at the yearly average of streamflow shows that the average fluctuated from a low of 0.304 $m^3/s$ in 1965 to a high of 3.23 $m^3/s$ in 1972 and then finally levelled off in 1979 at around 1.50 $m^3/s$ and remained here for the remaining years analyzed to 1983.

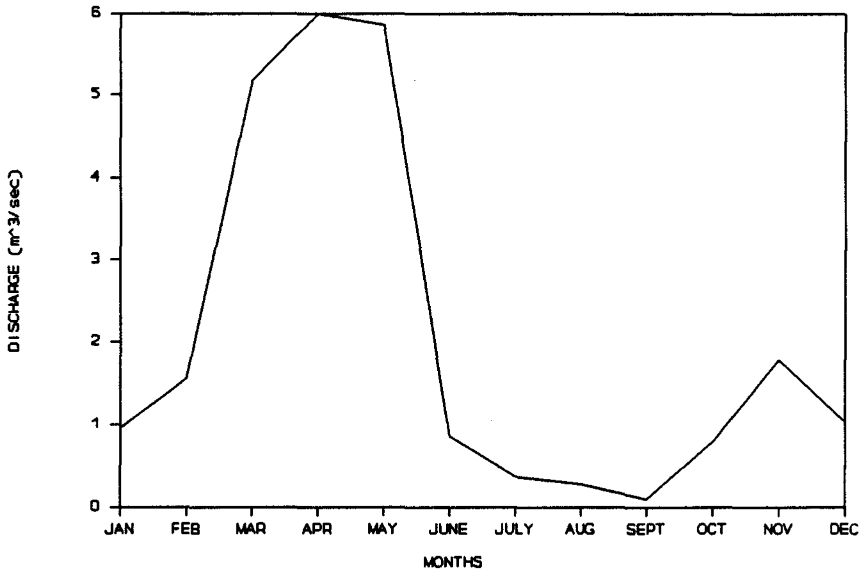


Figure 4.1: Yearly Hydrograph for Spencer Creek, 1974

## 4.2 Temporal Patterns

There is a definite trend of high coliform count in late summer (July-August-September), the start of which varies from year to year. Figure 4.2 is a representative graph of the general yearly trend of total coliform count, all data for maximums, minimums and average counts for the years is contained in Table 4.2.

Table 4.2: Total Coliform Counts For 1965 to 1983 (count per 100 mL water)

| YEAR | # SAMPLES | MAXIMUM COUNT | MONTH | MINIMUM COUNT | MONTH | AVERAGE |
|---|---|---|---|---|---|---|
| 1965 | 15 | 720 000 | JULY | 172 | MAR | 71 918 |
| 1966 | 19 | 1 700 000 | AUG | 110 | JAN | 161 344 |
| 1967 | 14 | 133 000 | JAN | 1 700 | APR | 42 836 |
| 1968 | | * | | | | |
| 1969 | | * | | | | |
| 1970 | 22 | 1 690 000 | DEC | 164 | MAR | 103 088 |
| 1971 | 23 | 144 000 | JULY | 304 | MAR | 22 088 |
| 1972 | 17 | 140 000 | AUG | 212 | MAR | 24 549 |
| 1973 | 11 | 15 000 | NOV | 288 | JUN | 4 818 |
| 1974 | 12 | 14 300 | NOV | 1 000 | APR | 5 492 |
| 1975 | 11 | 950 000 | SEPT | 200 | APR | 146 765 |
| 1976 | 10 | 25 000 | SEPT | 212 | NOV | 6 006 |
| 1977 | 14 | 440 000 | NOV | 1 300 | APR | 51 721 |
| 1978 | 14 | 2 100 000 | MAR | 410 | DEC | 233 629 |
| 1979 | 12 | 280 000 | MAY | 300 | MAR | 30 027 |
| 1980 | 12 | 230 000 | AUG | 180 | MAY | 22 757 |
| 1981 | 12 | 88 000 | JULY | 310 | MAR | 15 268 |
| 1982 | 12 | 190 000 | AUG | 140 | MAR | 24 025 |
| 1983 | 6 | 71 000 | JULY | 940 | JAN | 15 273 |
| 1984 | 5 | 15 000 | MAY | 1 000 | NOV | 6 620 |
| | | AVG.= 496 921 | | AVG.=1 018 | | |

* no data available

Figure 4.2, 1982, has its peak coliform count in August of 190,000 organism per 100 mL of water sample. The secondary maximum count occurs in January with a count of 19,000 organisms per 100 mL water sample. The minimum occurs in March and has a value of 140 organisms per 100 mL water.

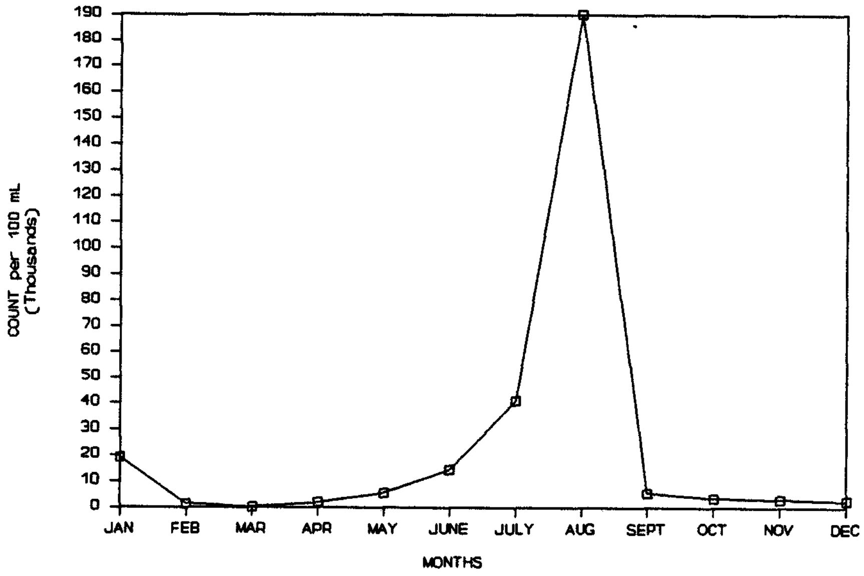


Figure 4.2: Total Coliform Count - 1982

The highest frequencies of primary and secondary peaks occurs in the late summer months (see Table 4.3), a high frequency of peak counts also occur in November. The average yearly maximum coliform count is approximately 496,961 organisms per 100 mL.

Table 4.3: Frequency Distribution of Primary and Secondary Maximum and Minimum Total Coliform Counts by Month (From 15 years of reliable data 1965-67, 1970-1982)

| MONTH | PRIMARY MAX. | SECONDARY MAX | TOTAL # PEAKS (Prim + Secon) | MIN. |
|---|---|---|---|---|
| JAN | 1 | 1 | 2 | 1 |
| FEB | 0 | 2 | 2 | 0 |
| MAR | 0 | 2 | 2 | 7 |
| APR | 0 | 1 | 1 | 4 |
| MAY | 1 | 0 | 1 | 1 |
| JUNE | 0 | 0 | 0 | 1 |
| JULY | 3 | 2 | 5 | 0 |
| AUG | 4 | 0 | 4 | 0 |
| SEPT | 2 | 2 | 4 | 0 |
| OCT | 0 | 3 | 3 | 0 |
| NOV | 3 | 2 | 5 | 1 |
| DEC | 1 | 0 | 1 | 0 |

At no time during the late summer does a minimum total coliform count occur. The highest frequency, eleven out of fifteen years, of minimum yearly counts of coliform occurs in the spring snowmelt period (March-April) (see Table 4.3). The average yearly minimum coliform counts is 1,018 organisms per 100 mL.

The average peak value, including both primary and secondary peak counts, is 334,154 organisms per 100 mL of water. Since 1979 all of the peak coliform count were below this average. This may indicate an increased condition of the water quality in Spencer Creek in terms of total coliform bacteria. Perhaps increased awareness of the potential inputs of coliform bacteria and other nutrients into the stream has caused this decrease. Through land stewardship programs currently being promoted in the Spencer Creek watershed, development control ie. ESA policy (RMHW Official Plan 1980) etc., such things as minimizing livestock access to the stream and teh establishment of buffer zones have all been brought to the attention, not only of planning officials but also the private landowners. All of these programs are designed for the purpose of protecting the wetland areas and to reduce point and non-point source pollution.

## 4.3 Pollutant Loadings

Like the total coliform count, the highest frequency of peak loading values occurrs in the late summer (July and August), and again in November, see Table 4.5. For twelve out of fifteen years a peak, either primary or secondary, was seen in the late summer months (June to September). The highest frequency of minimum loading values occurrs in March, the springmelt runoff period. For six years out of fifteen, a minimum load occurred in either March or April. This general trend can be seen in a representative graph, Figure 4.3: Coliform Loading - 1982.

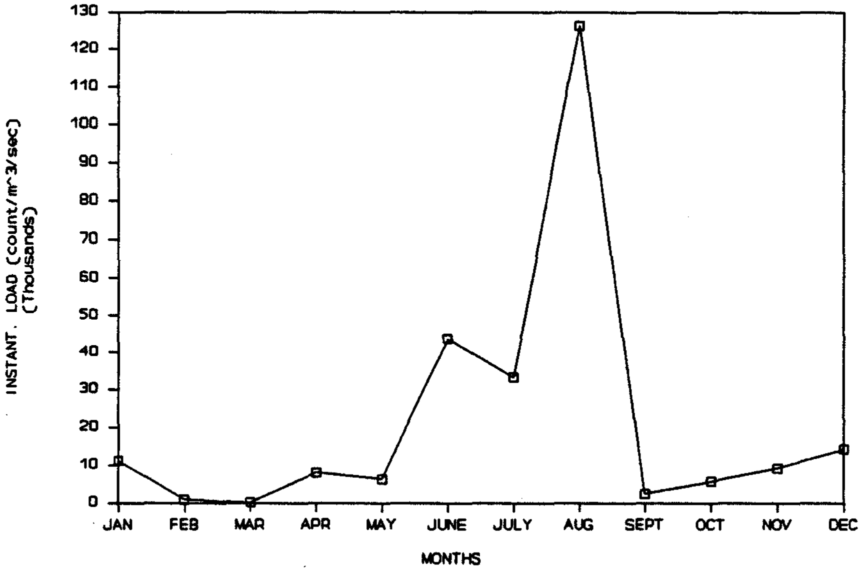


Figure 4.3: Instantaneous Coliform Loading - 1982

The average instantaneous load has decreased and levelled off since 1978. A high of 3.43 billion organisms per $m^3$ per second in 1978 decreased to an average yearly instantaneous load of 138.9 million organisms per $m^3$ per second during the years 1979 to 1983. The average of all years (1965 to 1983) was 620 million organism per $m^3$ per second, the average from 1965 to 1978 was 820 million organisms per $m^3$ per second and from 1979 to 1983 an average load of 138 million per $m^3$ per second was found. Both the maximum and minimum load values have changed, exhibiting the same general pattern as the average loading values. The maximum average load for all years (1965 to 1983) is 6.94 billion organisms per $m^3$ per second, from 1965 to 1978 the average maximum load was 9.46 billion organisms per $m^3$ per second and from 1979 to 1982 the average maximum was 890 million organisms per $m^3$ per second. The average minimum loadings don't show as great a fluctuation as the average and the maximums although the same general trend exists with an increase in the average minimums since 1978.

Table 4.4: Instantaneous Coliform Loadings (counts/$m^3$/sec)

| YEAR | MAXIMUM LOAD (x10,000) | MONTH | MINIMUM LOAD (x10,000 | MONTH | AVERAGE (x10,000) |
|---|---|---|---|---|---|
| 1965 | 67 248 | JULY | 107 | MAR | 11 913 |
| 1966 | 83 776 | MAR | 482 | APR | 23 470 |
| 1967 | 199 500 | JAN | 7 361 | APR | 58 524 |
| 1968 | * | | | | |
| 1969 | * | | | | |
| 1970 | 3 619 980 | DEC | 358 | FEB | 175 798 |
| 1971 | 40 469 | JUNE | 396 | OCT | 8 091 |
| 1972 | 526 960 | AUG | 2 591 | MAR | 50 581 |
| 1973 | 180 944 | MAR | 118 | SEPT | 18 567 |
| 1974 | 25 454 | NOV | 410 | SEPT | 6 574 |
| 1975 | 1 633 920 | NOV | 81 | JULY | 187 780 |
| 1976 | 17 625 | MAY | 256 | NOV | 5 374 |
| 1977 | 972 400 | NOV | 585 | JUNE | 96 004 |
| 1978 | 3 922 800 | MAR | 112 | JULY | 342 647 |
| 1979 | 165 760 | MAY | 608 | JUNE | 18 410 |
| 1980 | 44 850 | AUG | 228 | DEC | 6 260 |
| 1981 | 70 488 | JULY | 353 | MAR | 12 753 |
| 1982 | 126 350 | AUG | 116 | MAR | 21 794 |
| 1983 | 41 748 | JULY | 1 335 | JAN | 10 249 |

* no data available

Table 4.5: Frequency Distribution of Coliform Loadings by Month

| MONTH | PRIMARY MAX. | SECONDARY MAX | TOTAL # PEAKS (Prim + Secon) | MIN. |
|---|---|---|---|---|
| JAN | 1 | 0 | 1 | 0 |
| FEB | 0 | 3 | 3 | 1 |
| MAR | 2 | 1 | 3 | 4 |
| APR | 0 | 0 | 0 | 2 |
| MAY | 2 | 0 | 2 | 0 |
| JUNE | 1 | 0 | 1 | 1 |
| JULY | 2 | 2 | 4 | 2 |
| AUG | 3 | 2 | 5 | 0 |
| SEPT | 0 | 2 | 2 | 2 |
| OCT | 0 | 2 | 2 | 1 |
| NOV | 3 | 2 | 5 | 1 |
| DEC | 1 | 1 | 2 | 1 |

## 4.4 Background Counts

Background organism counts were available for only five years, 1979 to 1983. In four of the five years, or 80% of the time, the primary background count (peak) (Table 4.6) coincided with the primary peak of total coliform (Table 4.2). This was also true of the minimum counts which also coincided 80% of the time with the total coliform counts. The secondary peaks did not coincide at all. Figures 4.4 (1981) and 4.5 (1982) show how the background and total coliform counts are related. When one is high the other is high as well. No numerical relationship exists, just the fact that the counts are both high at the same time indicates that the water quality at those times is particularly poor. As is obvious the background counts are much higher than the total coliform counts, this is because of the larger number of organisms in the background count, these are not separated or identified.

Table 4.6: Summary Table of Background Counts (count per 100 mL water)

| YEAR | PRIM. MAX | MONTH | SEC. MAX | MONTH | MIN | MONTH |
|---|---|---|---|---|---|---|
| 1979 | 1 400 000 | MAY | 255 000 | OCT | 300 | MAR |
| 1980 | 1 900 000 | AUG | 18 000 | MAR | 4 200 | DEC |
| 1981 | 640 000 | AUG | 28 000 | NOV | 770 | MAR |
| 1982 | 3 400 000 | AUG | 49 000 | NOV | 760 | MAR |
| 1983 | 1 200 000 | JUL | * | | 3 000 | JAN |

* no secondary peak

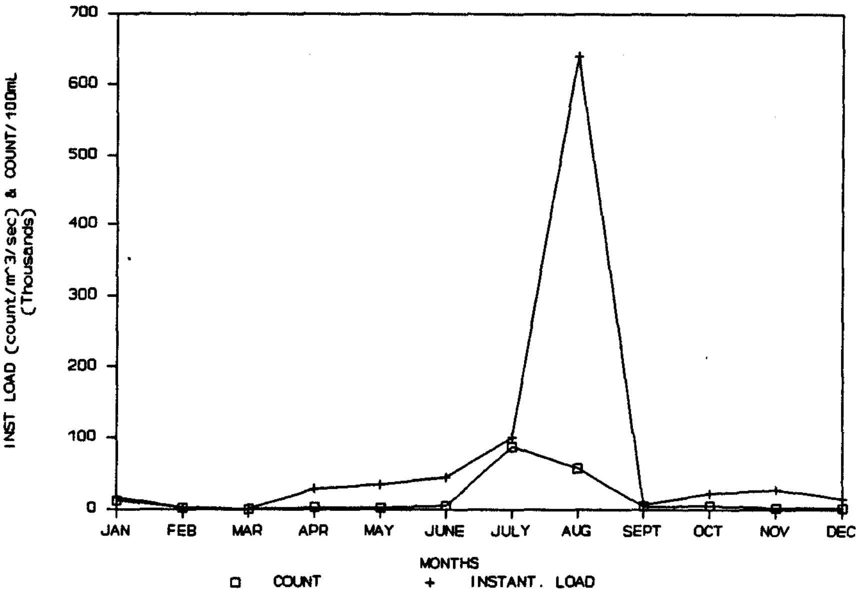


Figure 4.4: Total Coliform Count and Background Count - 1981

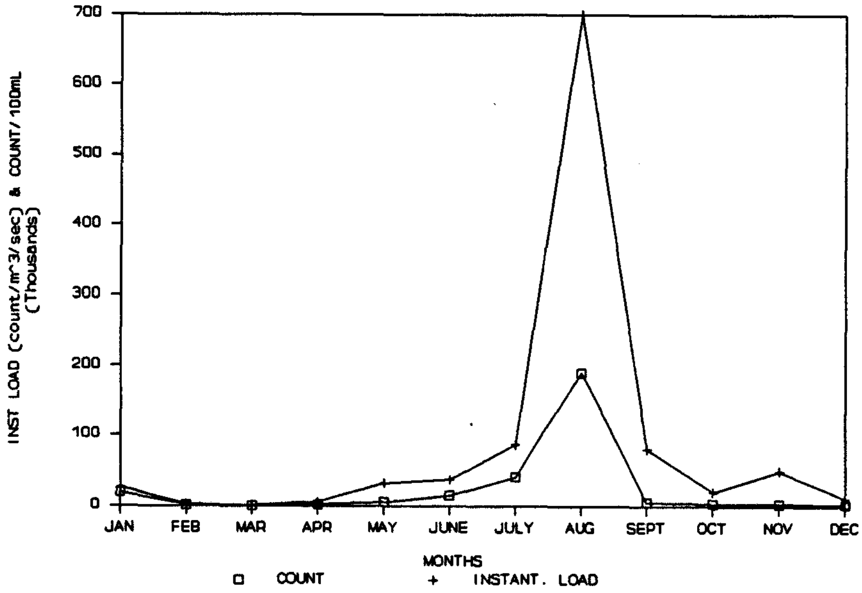


Figure 4.5: Total Coliform Count and Background Count - 1982

## 4.5 Water Quality Objectives - Total Coliform

According to the 1965 Ontario Water Resources Commission, total coliform counts per 100 mL water sample should not exceed 2,400 organisms per 100 mL. Table 4.7 shows the exceedance of this objective by an average of 57.82 %. This is very high considering this objective. According to the most recent provincial water quality objectives however (OMOE, 1978), water quality is considered impaired when the total coliform count exceeds just 1,000 organisms per 100 mL water. Table 4.7 shows that on the average this occurs 79.29 % of the time. This does not represent good water quality in terms of total coliform counts. Although there are no objectives for background counts, their high counts do coincide with high coliform counts and instantaneous coliform loadings. The presence of high background counts simply confirms the conclusion that the bacterial water quality of Spencer Creek is very poor, especially during the late summer starting in June through July, August and September.

Table 4.7: Exceedance of Water Quality Objectives

| YEAR | #/100 mL > 2400 | # SAMPLES | % > 2400 | #/100 mL > 1000 | % > 1000 |
|---|---|---|---|---|---|
| 1965 | 13 | 15 | 87 | 13 | 87 |
| 1966 | 10 | 19 | 53 | 12 | 63 |
| 1967 | 13 | 14 | 93 | 14 | 100 |
| 1970 | 14 | 22 | 64 | 15 | 68 |
| 1971 | 15 | 23 | 65 | 16 | 70 |
| 1972 | 8 | 17 | 47 | 13 | 76 |
| 1973 | 5 | 11 | 45 | 7 | 64 |
| 1974 | 6 | 12 | 50 | 11 | 92 |
| 1975 | 5 | 11 | 45 | 8 | 73 |
| 1976 | 4 | 10 | 40 | 6 | 60 |
| 1977 | 11 | 14 | 79 | 14 | 100 |
| 1978 | 8 | 14 | 57 | 12 | 86 |
| 1979 | 6 | 12 | 50 | 9 | 75 |
| 1980 | 5 | 12 | 42 | 8 | 67 |
| 1981 | 7 | 12 | 58 | 11 | 92 |
| 1982 | 9 | 12 | 75 | 11 | 92 |
| 1983 | 2 | 6 | 33 | 5 | 83 |
| | | AVG | 57.82% | AVG | 79.29% |

## 5 CONCLUSION

In conclusion it has been shown that a temporal pattern exists in the presence of coliform bacteria in the water of Spencer Creek. This pattern is related to the general flow patterns of the creek. During the springmelt runoff period (March) of high flow, the water quality is quite good, total coliform, instantaneous coliform loading and background counts are all at a minimum and are generally below the objective set out by the Ministry of the Environment for Ontario stream water quality. The summer months (June, July, August and September) are a time of low flow and high temperatures, conditions in which coliform bacteria thrive. Total coliform, instantaneous coliform loads and background counts all reach their maximum yearly values during these months.

With almost an 80% exceedance of the present water quality objectives in the water of Spencer Creek, one can't but wonder whether an exceedance by more than a billion organisms can ever be eradicated. However, it was found that, although the objectives are far from being met during the peak summer months, the general trend of water quality has been improving since 1978. It is during these months too, that humans come in greater contact with the water of the creek. Both Christies and Valen's Conservation Areas promote recreational use of their reservoirs into and out of which the water of Spencer Creek flows. During the warm months as well, the length of the entire creek is used more frequently by both humans, especially children, and livestock. It is therefore necessary to continue this type of water quality monitoring, but more in-depth studies of the actual water quality parameters and their changes and trends needs to be addressed.

# BIBLIOGRAPHY

Bird, P.M. and D.J. Rapport for Environment Canada (1986).State of the Environment Report for Canada. Ottawa: Supply and Services, Canada.

Brinson, M.M. (1988). Strategies for assessing the cumulative effects of wetland alteration on water quality in: Environmental Management, Vol. 12, No. 5, pp. 655-662.

Canadian Environmental Assessment Research Council (1986). Cumulative Effects Assessment: A Context for Further Research and Development.

Canadian Environmental Assessment Research Council (1986). Cumulative Effects Assessment in Canada: An Agenda For Action and Research.

Canadian Society of Environmental Biologists (1987). Conservation Strategies in Canada.

Carolinian Canada, Identification Subcommittee (1985). Critical Unprotected Natural Areas in the Carolinian Life Zone of Canada: Final Report.

Department of Fisheries and Oceans (1986). Policy For the Management of Fish Habitat.

Dunster, K. J. (1987). Rethinking Regions: An Ecological Approach to Landscape Conservation.

Ecologistics Limited 1976. Hamilton-Wentworth Region Environmentally Sensitive Areas Study.

Environment Canada (1972). The Great Lakes Water Quality Agreement.

Fresenius, W., K.E. Quentin and W. Schneider (eds.) (1988). Water Analysis: A practical guide to physico-chemical, chemical and microbiological water examination and quality assurance. Springer-Verlag, Germany. pp. 772-780.

Greeson, P.E., J.R. Clark and J.E. Clark (eds.) Wetland Functions and Values: The State of our Understanding. American Water Resources Association, Minneapolis Minnesota.

Hamilton Region Conservation Authority (1973). A Sanitary Survey of the Creeks in the HRCA.

Hamilton Region Conservation Authority (1972). Sixth Annual Pollution Survey of the Creeks in the HRCA.

Hamilton Region Conservation Authority (1980). Valen's Conservation Area: Master Plan.

Hamilton-Wentworth Region (1980). Official Plan of the Hamilton-Wentworth Region.

Hemond, H.F. and J. Benoit (1988). Cumulative impacts on water quality functions of wetlands in: Environmental Management, Vol. 12, No. 5, pp. 639-653.

Klein, R.D. and J.W Gracie (1980). An Integrated Watershed Management Policy. Maryland Save Our Streams, Maryland Wildlife Administration, Maryland Department of Natural Resources and the Maryland Chapter of Trout Unlimited.

Lamb, J.C. III (1985). Water Quality and Its Control. John Wiley and Sons Ltd.

Leith, D.M. (1990). Editorial: Swimmable beaches and edible fish. in: Alternatives. Vol. 17, No. 3, pp. 1.

McDaniel, T.W., C.T. Hunsaker and J.J. Beauchamp (1987). Determining regional water quality patterns and their ecological relationships in: Environmental Management, Vol. 11, No. 4 pp. 507-518.

Ontario Water Resources Commission (1964-1990). Water Quality Data, compiled by : River Basin Surveys Water Quality Surveys Branch, Division of Sanitary Engineering. Volumes I to XXIV.

Pickering, W.F. (1977). Pollution Evaluation: The Qualitative Aspects, Environmental Science and Technology Series Vol. 2.

Provincial Ministry of the Environment (1978). Water Management: Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. revised 1984.

Regional Municipality of Hamilton-Wentworth (1980). Region of Hamilton-Wentworth Official Plan.

Sadler, B. (1990). Sustainable development and water resource management. in: Alternatives: Vol.17, No.3 pp.14-24.

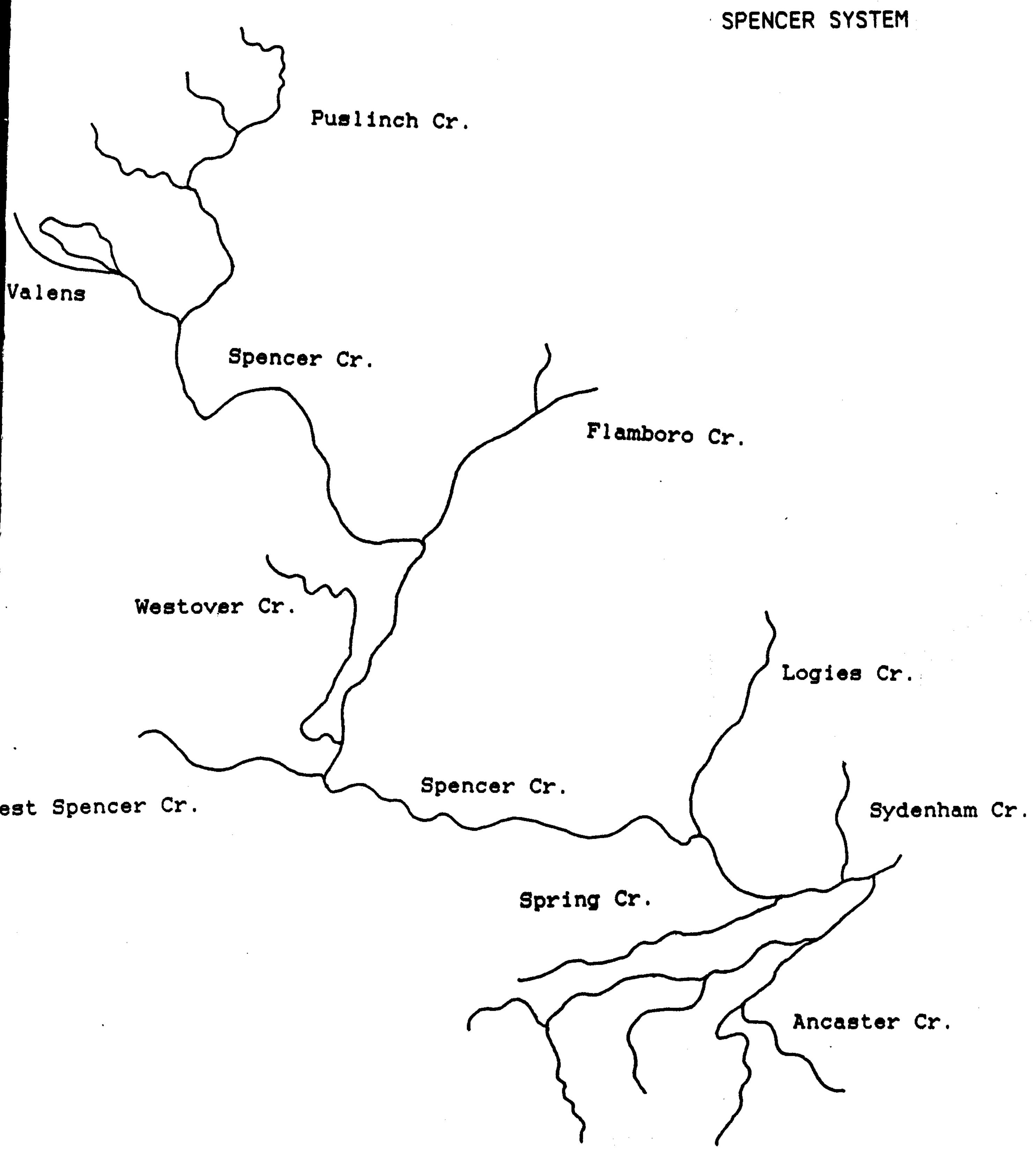
Schaenman, P.S. and T. Muller (1974). Measuring Impacts of Land Development: An Initial Approach. The Urban Institute, Washington, D.C.

Suffet, I.H. (ed.) Fate of Pollutants in the Air and Water Environments. John Wiley and Sons, New York.

Thomas, W.A. (ed.) (1972). Indicators of the Environmental Quality. Proceedings of a symposium held during AAAs meetings in Philadelphia Dec. 1971. Plenum Press, New York, London.

World Commission on Environment and Development (WCED) (1988). Our Common Future, New York: Oxford University Press.

# APPENDIX


SPENCER SYSTEM
Puslinch Cr.
Valens
Spencer Cr.
Flamboro Cr.
Westover Cr.
Logies Cr.
est Spencer Cr.
Spencer Cr.
Sydenham Cr.
Spring Cr.
Ancaster Cr.

## A. ANALYSES AND MEASUREMENTS CONDUCTED AT THE SAMPLING SITE

### Stream Condition

The physical condition of the body of water is described from an on-site examination at the time of sampling and is represented by a one-digit number from one to zero as follows:

1. Stream dry
2. Frozen to stream bed
3. Stream in flood condition
4. Sampled through ice
5. Suspended algae
6. No apparent algae
7. Profuse weed growth
8. Normal weed growth
9. Oil scum or floating matter
10. Objectionable odours.

Under some circumstances a combination of up to three of the above conditions may be shown for a given sample at an individual station.

### Streamflow

Streamflow information at or near a water quality monitoring site is an important factor when interpreting and employing water quality data. The product of streamflow and concentration defines the mass of material passing a point. Streamflow is also a useful reference when comparing water quality data for different periods of the year (e.g. spring flood vs summer drought).

Flows in many of the streams sampled are measured by the Canada Department of Fisheries and Environment - Water Survey of Canada. In a number of other instances, they are obtained by Ontario Ministry of the Environment personnel.

### Temperature

Water temperature is an important factor when a number of water quality parameters are being evaluated. Temperature directly affects the solubility of gases (e.g. dissolved oxygen) and significantly affects biological and chemical reaction rates.

Temperature is measured at the sampling site with an electronic thermistor or a mercury thermometer.

### Dissolved Oxygen

Dissolved oxygen in water originates directly from the atmosphere or through photosynthesis in aquatic plants. Ample dissolved oxygen is necessary to maintain satisfactory conditions for fish and other biological life in water. Organic wastes and some inorganic materials exert, upon decomposition, an oxygen demand which may deplete the dissolved oxygen below levels required by aquatic life.

Dissolved oxygen is measured at the sampling site with an electronic meter or by a chemical titration.

## B. BACTERIOLOGICAL EXAMINATION

### Total Coliform

The Membrane Filter (MF) technique is used to obtain an approximation of the concentration of total coliform organisms. These organisms are normal inhabitants of soils and the intestines of man and other warm-blooded animals. They are always present in large numbers in sewage and fecal mattter, and are often found in watercourses adjacent to industrial, agricultural and other pollution sources.

Results are reported as MF count per 100 ml of sample.

### Background Count

The background count estimates the number of organisms, other than coliforms, that occur in the total coliform analysis of a sample. The results are used in the interpretation of total coliform counts. High background counts are generally indicative of poor water quality.

### Fecal Coliform and Fecal Streptococcus (Enterococcus) Organisms

Fecal coliform and Enterococcus organisms are generally found in the alimentary tract of warm-blooded animals. They are indicative of sanitary waste intrusion and/or fecal contamination from warm-blooded animals.

### Pseudomonas aerugenosa

Pseudomonas aeruginosa are pathogens that can be readily isolated from sewage. These organisms can be frequently found in bathing waters and are the major etiological agent in otitis externa (ear aches) and other skin infections.

## C. CHEMICAL AND PHYSICAL ANALYSES

### Biochemical Oxygen Demand (BOD)

In itself, BOD is not a pollutant and presents no direct harm to the aquatic environment. It is, however, a measure of the unstable organic matter present in water which, through aerobic decomposition, oxidizes to a stable inorganic form utilizing the oxygen resources of a watercourse. The level of BOD is an important parameter in assessing the potential effects of pollutants on the concentration of dissolved oxygen in water.

Five-day biochemical oxygen demand ($BOD_5$) is a laboratory measurement of the amount of oxygen consumed in a sample incubated for five days at 20°C.

## Total Phosphorus

Phosphorus is a primary nutrient for plant and animal life and like nitrogen passes through cycles of decomposition and photosynthesis. This element is commonly found in nature in the form of inorganic phosphates and organically bound phosphorus. Total phosphorus includes orthophosphate, condensed phosphates and organically bound phosphorus in both the dissolved and particulate form. Untreated or treated sewage, some industrial wastes and agriculatural and urban drainage contain significant concentrations of phosphorus.

Although there is no firm criterion for phosphorus, it is generally considered that to prevent biological nuisances, total phosphorus should not exceed 0.03 mg/l in a flowing stream or 0.020 mg/l where waters enter a lake or standing body of water.

## Filtered Reactive Phosphate

Filtered reactive phosphate is that phosphorus which passes through a 1-2 micrometre filter and responds to a colorimetric orthophosphate determination. It is a combination of simple orthophosphate and readily hydrolized phosphate primarily in the dissolved form.

Filtered reactive phosphate is generally considered to be readily available for aquatic plant growth.

## Filtered Ammonia Nitrogen

Filtered ammonia nitrogen (ammonia $NH_3$ + ammonium $NH_4^+$) is the soluble product in the anaerobic decomposition of nitrogenous organic matter. It is also formed when nitrites and nitrates are reduced either biologically or chemically. Small amounts of ammonia nitrogen may be taken out of the atmosphere by rain water.

Rivers which are considered unpolluted generally have filtered ammonia levels of less than 0.1 mg/L.

## Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen is a measure of the total nitrogenous matter present, excluding nitrate and nitrite. The total Kjeldahl nitrogen concentration, less the ammonia nitrogen concentration, gives a measure of the organic nitrogen present.

Ammonia and organic nitrogen are important in assessing the availability of nitrogen for biochemical utilization. In unpolluted rivers, the normal range for total Kjeldahl nitrogen is 0.1 to 0.5 mg/L.

## Filtered Nitrite

Nitrite is an intermediate oxidation product of ammonia and also an intermediate form in the denitrification process from nitrate to nitrogen gas. The significance of nitrites, therefore, varies with their amount, source and relation to other constituents of samples (notably the relative magnitude of ammonia and nitrate present).

Since nitrite is rapidly and easily converted to nitrate, its presence in concentrations greater than a few micrograms per litre is generally indicative of active biological processes in the water.

## Filtered Nitrate

Nitrate is the end product of the stabilization of organic nitrogen which occurs primarily through aerobic biochemical processes. Nitrate is usually found in polluted waters that have undergone some degree of self-purification. Nitrates can also occur in watercourses intercepting drainage from fertilized agricultural areas.

Nitrogen in the form of nitrate is readily utilized by aquatic plants and algae. In unpolluted rivers, the nitrate nitrogen concentration is generally less than 0.5 mg/L.

## Inorganic Nitrogen

Inorganic nitrogen is a calculated value and represents the sum of the concentrations of filtered ammonia nitrogen and filtered (nitrate + nitrite) nitrogen.

## Organic Nitrogen

Organic nitrogen is a calculated value and represents the difference of the concentrations of total Kjeldahl nitrogen and filtered ammonia nitrogen.

## Total Nitrogen

Total nitrogen is a calculated value and represents the sum of the concentrations of total Kjeldahl nitrogen and filtered (nitrate + nitrite) nitrogen. Nitrogen is a common constituent of decomposition products, treated sewage, fertilizers and industrial discharges. Nitrogen compounds are present in most plant and animal materials.

## Solids

Total, suspended and dissolved solids are presented as separate parameters in this report. The solids analyses are gross measurements of the amounts of particulate matter and dissolved materials found in water. Solids enter the watercourse from virtually every source, the most familiar being sewage treatment plant effluents, municipal storm drainage, industrial discharges and erosion.

Solids significantly affect water uses. Highly turbid water is undesirable for municipal and industrial supply, fish and aquatic life, recreation and aesthetics. Suspended solids can also transport significant quantities of organic and inorganic trace contaminants.

## Conductivity

The conductivity test provides a measure of the electrolytic properties of water. The presence of dissolved ions (in solution) such as chlorides, sulphates and calcium, renders water conductive. Conductance, the reciprocal of resistance, is recorded in the unit mho and in order to avoid inconvenient decimals, data are reported in micromhos per cubic centimetre. In many waters there is a direct linear relationship between dissolved solids concentrations and conductivity.

Conductivity serves as a control parameter and is an excellent indicator of water-quality changes since it is relatively sensitive to variations in dissolved-solids concentrations.

## Turbidity

The turbidity of water is attributable to suspended and colloidal matter such as micro-organisms, detritus, clay and other mineral substances which reduce clarity and diminish the penetration of light.

Turbidity is undesirable in surface waters used for domestic and industrial supply and for recreation. Often some of the suspended matter has to be removed to prevent interference with disinfection processes and abrasion to equipment. By interfering with the penetration of light, turbidity can seriously affect aquatic biological communities.

## Chlorides

Chlorides are found in practically all natural waters. They may be of natural mineral origin but in general the largest contributions can be traced to domestic sewage discharge, municipal storm drainage, road salting, and industrial wastes.

While not harmful to health in moderate quantities, high concentrations of chlorides make water unfit for municipal and industrial supplies and livestock watering. In addition to imparting an objectionable taste to water, high chloride levels are responsible for increased corrosiveness of water. Furthermore, chloride, being toxic to many plants, may render water undesirable for irrigation.

## Sulphate

Sulphates may occur naturally in waters and may be contained in industrial wastes. They are produced from the final oxidation stage of sulphides, sulphites and thiosulphates. Sulphates, under anaeorbic conditions, can be reduced to hydrogen sulphide which is malodorous (the odour of rotten eggs) and highly corrosive.

High concentrations (between 150 and 500 mg/l) in drinking water may be cathartic to humans.

## Unfiltered Reactive Silicate

Silicon occurs in sand or quartz as silica and as silicates in feldspar, kaolinite and other minerals. Silicon dioxide, or silica, is insoluble in waters or acids, except hydrofluoric acid, but it may occur in natural waters as finely divided or colloidal suspended matter. Silica is widely employed in industry for making glass, silicates, ceramics, abrasives, enamels, petroleum products, etc.

In concentrations found in natural or treated waters, silica or silicates have no adverse physiological effects. Silicates are essential to the growth of many aquatic organisms.

The data which appear under the heading "Reactive Silicate" should properly be referred to as "Unfiltered Reactive Silicate" and are reported as Silicon (Si). Data in this series of publications prior to 1975 were reported as Silica ($SiO_2$).

Acidity in surface or ground waters may be attributable to natural causes, such as humic acids extracted from swamps or peat beds, or industrial wastes such as pickling liquors, effluent from the manufacture of explosives, acid mine drainage or sulfite waste liquors. It may also be affected by atmospheric inputs.

Acidity is best interpreted in conjunction with the pH and alkalinity, as well as any other analyses which identify the acidic components of water.

## Filtered Alkalinity

Alkalinity is a measure of a water's capacity to neutralize an acid. The alkalinity of natural waters is caused by three major classes of materials which may be ranked in order of their effect on pH as follows:

1. Hydroxides (rarely present in Ontario)
2. Carbonates
3. Bicarbonates and other salts of weak acids

The alkalinity of water has little sanitary significance but is of importance in water and waste treatment practices. Waters with high alkalinity are undesirable because of their associated excessive hardness.

## pH

The symbol pH is used to designate the logarithm (base 10) of the reciprocal of the hydrogen-ion concentration. It is an index of the acidity or alkalinity of the solution. The practical pH range extends from 0, very acidic, to 14, very alkaline, with the middle value of pH 7 corresponding to exact neutrality at 25°C.

The pH is important in determining the treatment of water supplies.

## Total Iron

Iron is one of the most abundant elements in the earth's crust and it is a constituent of many industrial wastes.

When sufficient iron is added to water in the form of salts (chlorides, nitrates, sulphates), ferrous to ferric precipitates (iron hydroxides) tend to form, causing low pH values which are toxic to aquatic life. Iron in water may also result in the growth of iron bacteria causing unpalatable tastes, discolouration of clothes and plumbing fixtures, and the formation of scales in water mains.

## Phenols

The phenolic compounds, collectively referred to as phenols, are those hydroxyl derivatives of benzene or its condensed nuclei, which are determined by the 4-amino antipyrene method. The results are reported in micrograms per litre. Phenols are present in waste flows from many industrial processes and may also be released from aquatic plants and decaying vegetation.

Depending on the concentration, the presence of phenolic compounds may be toxic to fish, or may taint the flesh of fish. Phenols in very minute concentrations will combine with chlorine to produce tastes and odours which are usually described as medicinal or chemical.

## Hardness

Water hardness relates to a water's capability to produce lather from soap. The higher the hardness, the less lather will be formed. Hardness in water is caused by dissolved divalent metal ions, calcium and magnesium being the most common. Natural hardness occurs most frequently in limestone areas. The limestone is dissolved by contact with ground and surface water and releases calcium ions and traces of contaminant metals.

Hard water, though not considered a health hazard, is undesirable for industrial and domestic water supplies because it has a number of detrimental effects, the most common being the formation of scale in boilers, pipes and water heaters; excessive soap consumption in home and commercial laundering; and adverse affects in textile, plating and canning industries.

Results appear under either the heading "Hardness" or "Calculated Hardness", depending on the anlaytical procedure. The former results are obtained through titration with EDTA (ethylenediaminetetra-acetic acid), the latter by calculation from magnesium (Mg) and calcium (Ca) results determined by AAS (Atomic Absorption Spectrophotometry).

## Calcium

Calcium is relatively abundant in the earth's crust and readily soluble in water so that calcium salts and calcium ions are among the most commonly encountered substances in water. They may result from the leaching of soil and may be contained in sewage and industrial wastes.

Excessive calcium and magnesium in drinking water have been implicated as factors predisposing to the formation of concretions in the body, such as kidney, or bladder stones. On the other hand, there is also evidence of adverse physiological effects from an insufficiency of calcium in water. The calcium ion is a major contributor to hardness and is often responsible for boiler scale deposits on cooking utensils and excessive soap requirements in washing and laundering. Where water is used for irrigation, calcium is beneficial to plant growth.

## Magnesium

Magnesium is an abundant element and a common constituent of natural waters. Magnesium ranks with calcium as a major cause of hardness.

The effects of magnesium in water used for consumption and irrigation are generally the same as those of calcium. Magnesium is considered relatively non-toxic to man and not a public health hazard because before toxic concentrations are reached in water, the taste becomes quite unpleasant.

## Colour

Colour in water may be of natural mineral or vegetable origin caused by metallic substances such as iron and manganese compounds, humus material, peat, tannins, algae, weeds, and protozoa. Waters may also be coloured by inorganic or organic soluble wastes from industries, such as steelworks, mining, refining, pulp and paper, chemicals, and others. Returned irrigation water also contributes to colour.

Colour from natural origin is not considered harmful from a health standpoint. However, in domestic water, colour is undesirable from aesthetic considerations.

## Potassium

Potassium occurs in many minerals and potassium salts exist in natural waters as a result of contact with potassium-bearing soils and the introduction of certain industrial wastes. The common salts of potassium are highly soluble in water. They resist separation from water by natural processes other than evaporation.

Although in limited concentrations potassium is an essential nutrient, excessive amounts of certain potassium salts in drinking water have detrimental effects on human digestive and nervous systems.

## Sodium

Sodium salts are common to all natural waters and may be present in high concentrations in wash waters softened by exchanging calcium and magnesium ions for sodium. Sodium is also found in many industrial process effluents, domestic wastes and salts used in road de-icing.

The presence of sodium salts in drinking water may present a health hazard to a person with circulatory, renal and cardiac problems and may cause digestive problems in animals and otherwise healthy human beings. Concentration of salts such as sodium chloride impart objectionable tastes and may render water unpalatable.

## Total Organic Carbon (TOC)

Total organic carbon (TOC), the most significant carbon measurement from a water-quality assessment viewpoint, is the arithmetic difference between total carbon (TC) and total inorganic carbon (TIC).

Total organic carbon usually has a direct relationship with Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values, but the relationship varies with the composition of the organic material present. The carbon tests are rapid and suitable for the evaluation of organic pollution levels, assessment of waste treatment efficiencies and to a limited extent, the potential demand of a waste discharge on the oxygen resources of a water body.

## Chemical Oxygen Demand (COD)

The chemical oxygen demand is used in measuring the strength of sewage and industrial wastes. The major advantage of this test is that laboratory results can be obtained in about three hours compared to five days for the five-day biochemical oxygen demand test. The chief limitation of the COD analysis is its inability to differentiate between biologically oxidizable and biologically inert organic matter. The COD almost always exceeds the biochemical oxygen demand.

## Solvent Extractables

The solvent extractable test measures the total quantity of substances present in a water sample that is readily soluble in an appropriate organic solvent. Such substances include fatty acids, petroleum products, oils, and greases, resins, etc. They are generally found in effluents of oil refineries, meat packing plants, slaughter houses, dairies, canneries, and a variety of other industries.

Solvent soluble materials greatly increase the oxygen depletion rate in receiving waters and will hinder oxygen exchange with the atmosphere by forming slicks.

## Arsenic

Arsenic may occur to a small extent naturally, mostly as sulphides and as arsenides of metals. Elemental arsenic is insoluble in water but many of the arsenates are highly soluble. Highest levels of arsenic in Ontario are found in watercourses downstream of wastewater discharges from metal smelting operations.

Arsenic is very toxic to humans and the trivalent forms are largely retained in the body tissues. Low concentrations of arsenic stimulate plant growth but higher concentrations destroy chlorophyll in the foliage.

## Mercury

Mercury may occur naturally as a free metal or as mercuric salts, the most common being cinnabar, HgS. Both elemental mercury and HgS are insoluble in water and are not likely to occur as water pollutants. Many synthetic organic salts of mercury are used commercially and these salts are highly soluble in water.

Mercury is cumulative and toxic to humans, and can be concentrated and transferred up the food chain to a point where commercial and game fish may become unsuitable for human consumption. Micro-organisms can methylate inorganic mercury under both aerobic and anaerobic conditions to produce a more toxic substance.

## Aluminium

Aluminium occurs in many rocks and ores but never as a pure metal in nature. In streams, the presence of aluminium ions may result from industrial wastes or more likely from wash water from water treatment plants.

Aluminium in a public water supply is not considered a public health problem, since no evidence has been found to prove that aluminium in water supplies is harmful to human beings.

## Chromium

Few waters contain chromium from natural sources since chromium is generally present in rocks and soils as insoluble chromic oxide which is strongly sorbed to particulate matter. Chromate or dichromate salts are used extensively in metal pickling and plating operations, in anodizing aluminium, in the leather industry as a tanning agent, and in the manufacture of paints, dyes, explosives, ceramics, paper and many other substances. Chromic or chromite salts on the other hand, are used much less extensively being employed as mordants in textile dyeing, in the ceramic and glass industry and in photography. Chromium compounds may be present in wastes from many of the foregoing industries or may be discharged in chromium-treated cooling waters where the chromium is used as a corrosion inhibitor.

There is no evidence that chromium salts are essential or beneficial to human nutrition. Salts of trivalent chromium are not considered to be physiologically harmful; however, large doses of chromates lead to corrosive effects in the intestinal tract and to nephritis. Both the chromic and chromate ions are toxic to plants and interfere with the uptake of essential elements.

## Copper

Copper salts occur in natural surface waters in trace concentrations and may occur in industrial waste discharges. Copper is used as an algicide for the control of undesirable algae growth and in the treatment of soils as a fungicide and a pesticide.

Copper compounds are toxic to plants and aquatic life. Prolonged ingestion may cause liver damage in man.

## Lead

Some natural waters contain lead in solution. Lead may be introduced into water as a constituent of various wastes including industrial and mining effluents, lead plumbing and automobile exhaust. Certain lead salts, such as acetate and chloride, are readily soluble. However, lead which occurs in the carbonate, hydroxide and sulphate forms is sparingly soluble and will not remain long in natural waters.

Lead is a cumulative poison that tends to be deposited in the bone. The intake that can be regarded as safe cannot be stated definitely because the sensitivity of individuals to lead differs considerably. Studies on fish indicate that in water containing lead salts, a film of coagulated mucus forms over the gills and then the entire body, probably as a result of a reaction between lead and an organic constituent of mucus. The fish then die of suffocation. The toxic effects of lead on fish decreases with increasing hardness and dissolved oxygen.

## Total Cadmium

In the elemental form, cadmium is insoluble in water. It occurs in nature largely as a sulphide salt, greenockite or as a cadmium blend and often as an impurity in zinc-lead ores.

Cadmium salts are cumulative and highly toxic to man having been implicated in some cases of food poisoning. Consumption of cadmium salts causes cramps, nausea, vomiting, and diarrhea. Cadmium affects reproduction in fish and zooplankton; however, the toxic effects vary with species and time of exposure.

## Total Zinc

Generally, zinc occurs only in trace amounts in surface waters. The zinc ion is believed to adsorb strongly and permanently on particulate matter (e.g. silt) which settles out of suspension.

Zinc has no known adverse physiological effects upon man except at very high concentrations. At such concentrations, zinc gives water a milky appearance and causes a greasy film on boiling, thus making it unattractive for domestic water supply. Zinc is toxic to aquatic organisms and its toxicity decreases with increasing hardness.

## Manganese

Manganese is similar to iron in that it is found in many industrial wastes and occurs in soils as manganic and manganous compounds. Under anaerobic conditions the manganic ion is reduced to soluble nitrate, sulfate, and chloride salts of manganese and is leached, along with iron, into ground and surface waters. Its presence like iron, may indicate domestic or industrial pollution.

Water with high manganese content is undesirable for its taste, colour and tendency to form deposits on cooking utensils.

## Total Nickel

Nickel in ores and minerals is insoluble but as a salt (nickel ammonium sulphate, nickel nitrate, nickel chloride) is highly soluble. Electroplating wastes may contain substantial amounts of nickel salts.

Nickel and its salts have generally proven to be non-toxic to man even at very high levels. Contact with nickel salt solutions may result in dermatitis and repeated inhalations of nickel compounds can cause lung cancer. Levels of 0.1 mg/l have been reported to adversely affect plant life.

## Fluoride

Fluorides in high concentrations are not a common constituent of natural surface waters, but may naturally occur in detrimental concentrations in ground waters.

A condition known as "mottled enamel" (dental fluorosis) may occur when the concentration of fluoride ion in drinking water is in excess of 1.0 mg/L; however, small quantities have proven to be beneficial in reducing tooth decay. Excess concentrations affect animal breeding efficiency and may have detrimental effects on some plants.

## Cyanide

Cyanides are likely to occur in effluents from gas works and coke ovens, from the scrubbing of gases produced from blast furnaces, in wastes from the surface cleaning of various metals, and in electroplating processes and other chemical industries.

Cyanide in water is toxic to biological life, the lethal concentration depending on water quality, temperature and type and size of organism.

## Cobalt

Cobalt occurs naturally in the minerals cobaltite, smaltite and erythrite. It is widely used in the manufacture of alloys, the tungsten carbide tool industry and as pigments used in glass staining.