SURFACE WATER QUALITY TRENDS IN ONTARIO

1964 - 1979

TECHNICAL REPORT SERIES

Ontario

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Technical Report Series

SURFACE WATER QUALITY TRENDS IN ONTARIO

1964-1979

By

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MINISTRY OF THE ENVIRONMENT
Water Resources Branch
Hydrology and Monitoring Section

Toronto Ontario

1981

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(in pocket)

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ABSTRACT

This report describes a method and its application in analyzing water quality trends at long-term Water Quality Monitoring Network stations in Ontario. The multiplicative form of the (U.S.) National Sanitation Foundation method, with some modifications, is used to aggregate data for seven water quality variables (dissolved oxygen, total coliforms, 5-day biochemical oxygen demand, total phosphorus, nitrate, total soli ds and turbidity) into a single number for each year for the period 1964 to 1979. This number, referred to as an annual water quality rating, is used to facilitate comparisons of water quality with time and among stations.

Of the 169 long-term stations selected for study, 95% (161 stations) show improving or no change in quality. Only 5% (8 stations) show signs of deteriorating quality. Abatement measures relating to these water quality trends are discussed. Two significant measures relate to the reduction of phosphorus in effluents from municipal water pollution control plants through (1) the reduction of phosphorus by the reformulation of laundry detergents after 1970, and (2) the implementation of phosphorus removal at municipal water pollution control plants after 1972.

Relative to 1979 data, broad regional (area-wide) differences are apparent among stations when grouped on the basis of their annual water quality rating numbers. These differences among station groups appear to be related to the population distribution and geologic environments within the Province.

INTRODUCTION

THE PROVINCIAL WATER QUALITY MONITORING NETWORK

The Provincial Water Quality Monitoring Network was established in 1964 by the Ontario Water Resources Commission (OWRC), which is now the Ministry of the Environment (MOE).

The current objectives of this Network are:

a) to ensure that the Provincial Water Quality Objectives are met for various uses (conformance);
b) to determine water quality in Ontario, and through continued surveillance, to detect trends and/or new problems (surveillance);
c) to provide data for specific Ministry needs such as waste assimilation studies, water quality inquiries, requests from Conservation Authorities, etc. (special studies).

The number of water quality stations in the Network increased from less than 200 in 1964 to about 800 in 1975. The number of stations remained relatively constant between 1975 and 1979 due to economic constraints and was reduced to less than 700 in 1980.

Water quality samples are collected routinely about 10 to 12 times per year at the Network stations by the Water Resources Assessment Units of the Ministry's six Regional offices, with the assistance of numerous local Conservation Authorities . A few analyses are performed on site, but the majority of the physical, chemical and bacteriological analyses are performed at the Ministry's laboratories.

Samples were routinely analysed for about 20 water quality variables in the initial years of the Network; the current number of water quality variables is about 60. Analyses for all 60 variables, however, are not commonly available from each station as the selection of water quality variables is tailored to meet site-specific needs.

Water quality data collected under the Network program are published by the Water Resources Branch of this Ministry in an annual series of publications entitled "Water Quality Data for Ontario Lakes and Streams".

PURPOSE AND SCOPE OF REPORT

This report presents an overview of water quality trends at long-term Provincial Water Quality Monitoring Network stations. The report endeavours to display a large quantity of water quality information in a relatively concise manner. Conclusions obtained from this initial analysis will form the bases for more rigorous statistical tests of significance at site-specific locations to be dealt with in future interpretive reports.

Interpretations of trends are based on data for seven water quality variables (dissolved oxygen, total coliforms, 5-day biochemical oxygen demand, total phosphorus, nitrate, total solids and turbidity) that are aggregated into a single number for each year for the period 1964 to 1979. This number, referred to as an annual water quality rating, is used in this report to facilitate comparisons of water quality with time and among stations. As such, it is used in a 'relative' sense, relative to another year and relative to another station.

Although the rating numbers are useful for annual and areal comparisons, these numbers are difficult to interpret when used al one. This difficulty is a consequence of much water quality information being encapsulated into a single number. This difficulty is illustrated in an example of one location showing a high concentration of total phosphorus and a low concentration of nitrate and another location showing the reverse; yet, both locations have equal annual rating numbers. Thus, it can be seen that, in general, stations with equal rating numbers do not necessarily have the same variables in exactly the same concentrations. For this reason, the annual water quality ratings as presented here are not intended for use alone and should be used only in conjunction with the original data relating to each water quality variable to avoid misinterpretations.

Because the rating numbers cannot indicate the suitability of water for particular uses, anyone interested in the quality of water at a specific location should consult the data books (Water Quality Data, Ontario Lakes and Streams) that are published annually. Water quality objectives for surface waters in Ontario are discussed in the publication "Water Management" (MOE, 1978). Future interpretive reports in this series will compare water quality at specific locations with these objectives, using the methodology discussed by O'Neill (1981).

Trends relating to recent environmental issues of stream quality such as trace metals, persistent organics and acidic precipitation are not dealt with in this report because of insufficient historical data. Monitoring programs of this Ministry have been designed and are operating to assess such current environmental issues.

ACKNOWLEDGEMENTS

The study was carried out under the general supervision of Mr. U. Sibul and Mr. R.C. Hore of the Hydrology and Monitoring Section, whose comments and editorial assistance are gratefully acknowledged. Thanks are al so extended to Ms. E. Bye and Ms. D. Oles for their computer assistance and to Mr. P. Frigon who assisted in implementing an earlier version of the present computer program. Mr. R. Spackman, with support from the Cartography and Drafting Section, assisted with the cartographic work.

METHODOLOGY AGGREGATING WATER QUALITY DATA

Aggregations of various kinds of data are quite common, especially when trying to show changes in a group of related variables with respect to time or geographic location. Examples of aggregated data are the Dow Jones Industrial Average, the Toronto Stock Exchange Index, the Cost of Living Index and the Price of a Shopping Basket. One of the more familiar examples is the Price of a Shopping Basket, which reflects the price of a defined number of grocery items and allows price comparisons from time to time and between supermarkets or between areas.

It was realized at the outset of this project that some form of data aggregation would be necessary to facilitate the presentation of a large number of combinations of water quality variables and stations. For example, a simple calculation shows that any attempt to illustrate annual trends for a combination of seven water quality variables at one-hundred and fifty stations would result in (7 x 150) one-thousand and fifty individual graphs.

Because some loss in detail can be expected when water quality data are aggregated, data analyses have been divided into two phases. In the first phase, as represented by this report, selected water quality variables are aggregated and are compared on an annual basis. This first phase represents essentially a screening process whereby impressions and opinions are drawn from the data, thereby providing a rational base for detailed studies in a later phase. Thus, specific water quality variables and specific locations can be pin-pointed for analyses in future reports. Statistical tests of significance for differences in annual means can be performed more economically in the second phase because only a limited number of hypotheses and data would require testing. Reports in the second phase will deal with a smaller data base in greater detail.

SELECTION OF A METHOD FOR AGGREGATING WATER QUALITY DATA

The development and verification of a new method for aggregating water quality data could not be justified solely for this project as sane methods were already available. A suitable, existing method was selected to facilitate the comparisons of water quality with time and among stations.

Two criteria were used in selecting a method:

a) the method should be easy to understand conceptually and also readily implemented on a routine basis;
b) historic data should be available for those water quality variables to be used in the method.

The method developed by the (U.S.) National Sanitation Foundation, and originally proposed in 1970 by Brown *et al.*, best satisfied these criteria and was selected for use in this report. In this method, Brown aggregated nine water quality variables (dissolved oxygen, fecal coliforms, 5-day biochemical oxygen demand, phosphates, nitrates, total solids, turbidity, pH and departure from equilibrium temperature) to yield a single number. The resulting number ranged between 0 and 100; the higher the number the better the quality.

The method is based upon a nation-wide survey of water quality experts in the United States (Brown *et al.*, 1970; Landwehr, 1974). Briefly, the survey was used to determine the water quality variables to be used, the importance to be given to each variable (weighting factor), and the relationship for transforming concentrations of each water quality variable to a non-dimensional scale (subrating).

Two forms of the National Sanitation Foundation (NSF) method have been used by agencies in the United States: the additive form and the multiplicative form. The multiplicative form is used in this report as published literature on the NSF method currently promote the multiplicative form rather than the additive form (Ott, 1978).

PROCEDURE USED IN AGGREGATING WATER QUALITY DATA

Water Quality Rating

Although the basic procedure outlined by Brown *et al.* (1970) has been used in this report, some modifications were necessary because of data considerations. The ensuing discussion describes these modifications and the procedure in general .

The aggregation of the nine water quality variables into a single number, herein referred to as a water quality rating, is computed as follows:

$$\text{Water quality rating (R)} = q_1^{w_1} \times q_2^{w_2} \times \ldots \times q_g^{w_g}$$

where w_1 = the weighting factor for the respective water quality variable; a number between 0 and 1;

qi = the water quality subrating of the respective water quality variable; a number between 0 and 100. Figures 4 through 12 in Appendix A are used for transforming water quality concentrations to water quality subratings.

The water quality rating (R) computed for individual samples from the above equation is a number between 0 and 100. When the individual Rs are averaged for each year, this is referred to as an annual water quality rating and is also a number between 0 and 100.

The nine water quality variables and associated weighting factors (taken from Brown *et al.* 1970) are as follows:

Water Quality Variable	Weighting Factor (w_i)
dissolved oxygen	0.17
total coliforms	0.15
pH	0.12
5-day biochemical oxygen demand	0.10
total phosphorus	0.10
nitrate	0.10
departure from equilibrium temperature	0.10
total solids	0.08
turbidity	0.08

Because of data considerations, the computation of the water quality rating in this report differs from the original method in the following respects:

a) data for departure from equilibrium temperature are not available and this variable was assigned a constant departure from equilibrium temperature of 0°C, which corresponds to a constant subrating of 94 (Figure 12, Appendix A);

b) data for pH are relatively limited in comparison to the other water quality variables and this variable was assigned a constant pH of 7, which corresponds to a constant subrating of 93 (Figure 11, Appendix A);

c) data for fecal conforms are not available prior to 1972, and the original subrating curve for this variable was replaced by a subrating curve for total coliforms (Figure 4, Appendix A);

d) current considerations for total phosphorus are more stringent than past considerations; therefore, the original subrating curve for this variable was replaced by a more stringent subrating curve (Figure 5, Appendix A).

The above assumptions for pH and departure from equilibrium temperature present no problems because of the manner in which water quality ratings are used in the report. Water quality ratings used herein are for comparisons with time and among stations; thus, the consistent use of constants for pH and departure from equilibrium temperature in all the computations will not affect these comparisons. The advantage of keeping these two water quality variables in the computations is that the original weighting factors do not have to be changed, which would have been the case if the two variables had been excluded. The reason for this change is that the method requires the sum of the weighting factors be equal to one.

Thus, although there are nine water quality variables used in computing water quality ratings, two of these (pH and departure from equilibrium temperature) have been considered time-invariant and station-invariant. In actuality, therefore, only seven water quality variables (total coliforms, total phosphorus, nitrate, 5-day biochemical oxygen demand, dissolved oxygen, total solids and turbidity) are compared when annual rating numbers are compared.

Computerized Procedure for Obtaining Annual Water Quality Ratings

Data manipulations and analyses were completely computerized because of the large amount of data and the repetitive nature of the calculations. The steps used in computing annual water quality ratings are as follows:

1) obtain one record* (sample) of water quality data;
2) if all water quality variables are not available for computing a rating (R), disregard the record and return to Step 1. If all variables are available, go to Step 3;
3) convert dissolved oxygen to percent saturation based on tables from Standard Methods (APHA, *et al.*, 1975), which were stored in the computer;
4) convert concentrations to water quality subratings based on curves in Appendix A, which were stored in the computer;
5) compute a water quality rating (R) for each record for the period 1964 to 1979;
6) repeat steps 1 through 5 until all the records for the period 1964 to 1979 at a station are analysed;
7) compute the annual mean water quality rating and annual mean concentrations for each variable for the period 1964 to 1979 at this station, and store on computer files;
8) repeat steps 1 through 7 until all stations are analysed.

The generalized scheme for data handling and for obtaining annual water quality ratings is shown in Figure 1. Having computed and stored the annual mean water quality ratings and concentrations for all stations, these stored data are then retrieved for two main purposes. For the purpose of examining water quality trends during the period 1964 to 1979 at specific stations, the stored data are retrieved in a tabular and graphical format (MOE, 1980a), a sample of which is shown in Figure 2. For the purpose of comparing water quality among stations in 1979, the stored data are retrieved in a tabular format as indicated by the computer output shown in Appendix B.

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* one record refers to a computer (logical) record which is equivalent to a sample taken on a specific date.

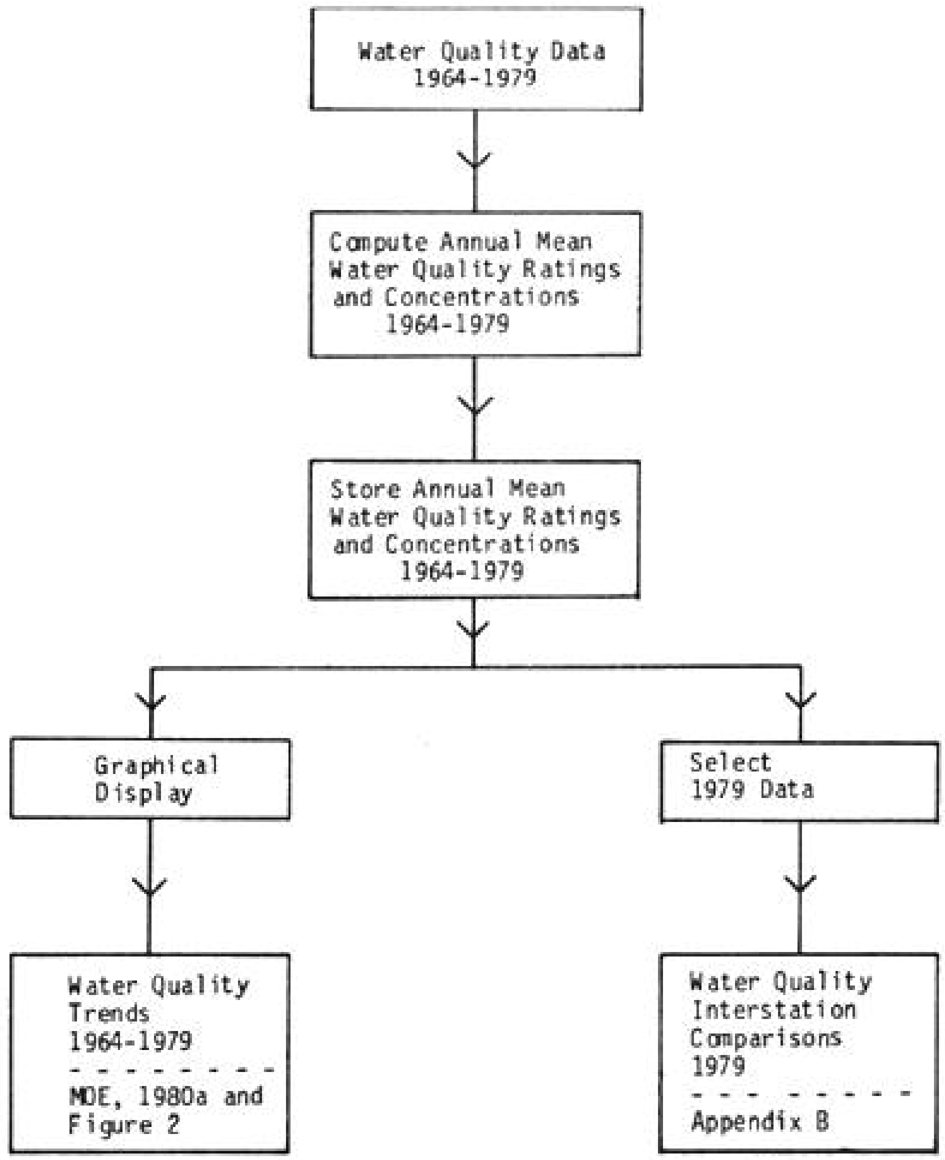


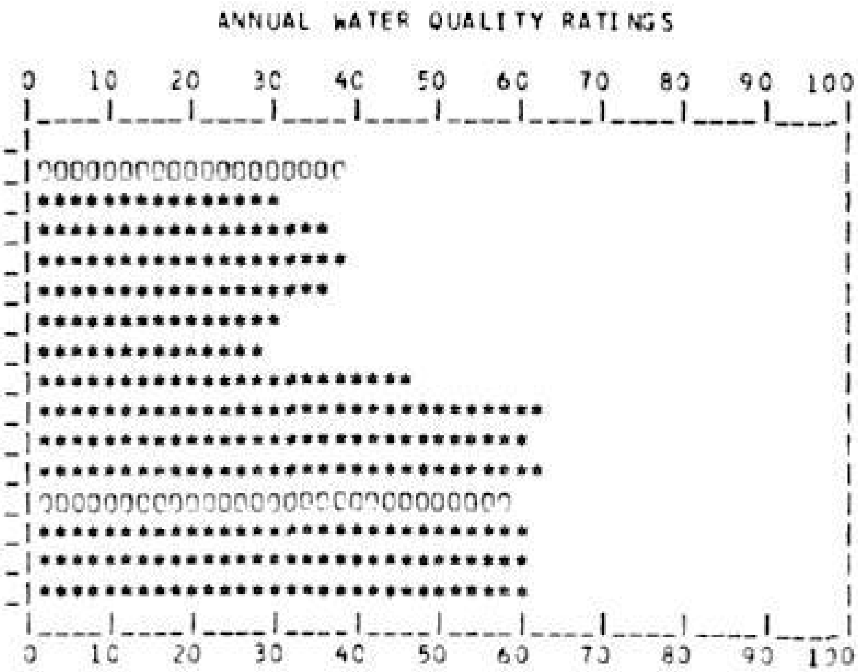
Figure 1: Generalized scheme for obtaining annual water quality ratings.

ONTARIO MINISTRY OF THE ENVIRONMENT WATER RESOURCES BRANCH
HYDROLOGY AND MONITORING SECTION DATE: AUG 12. 1980

WATER QUALITY TRENDS
1964 - 1979

STATION ID:	6-80-2-2	SET-UP DATE:	OCT. 16, 1964
B.O.W/SITE:	ETOBICOKE CREEK WEST	MAJOR BASIN:	GREAT LAKES
SAMPLE POINT:	DERRY ROAD EAST MISSISSAUGA	MINOR BASIN:	LAKE ONTARIO
STATION TYPE:	RIVER	TERM. STREAM:	ETOBICOKE CREEK
MOE REGION:	CENTRAL	U.T.M:	17606925.0 4836550.0 4
		MILEAGE:	I2.70

			ANNUAL MEANS						
YEAR	NO. OF SAMP.	ANNUAL RATING	TOTAL COLI. /100ml.	TOTAL P mg/L	NO_3- N mg/L	BOD_5 mg/L	DO SAT. %	Total Solids mg/L	TURB. FTU
1964	0								
1965	1	38	48000.	3.203	0.360	8.0	102.	768.	6.
1966	7	31	139855.	8.855	0.309	21.5	85.	774.	*27.*
1167	5	36	6779.	5.532	0.856	11.0	62.	692.	63.
1968	12	39	598.	7.921	2.535	9.2	66.	860.	58.
1969	10	37	1634.	3.841	2.058	9.9	53.	542.	23.
1970	10	31	256.	4.110	3.760	9.7	35.	737.	22.
1971	7	29	4563.	3.546	1.076	12.8	33.	608.	30.
1972	5	47	1376.	0.178	0.860	2.8	39.	622.	17.
1973	8	62	561.	0.101	0.907	3.0	97.	598.	11.
1974	11	61	909.	0.056	0.664	3.7	100.	780.	9.
1975	8	62	1221.	0.079	0.650	1.8	102.	621.	21.
1976	3	53	520.	0.120	1.357	1.1	122.	537.	33.
1977	8	61	1107.	0.117	0.573	2.7	118.	565.	21.
1978	8	60	613.	0.147	3.594	1.9	120.	544.	46.
1979	10	61	1787.	0.081	0.686	2.2	108.	830.	14.



0 - Indicates < 5 samples
***** - Indicates 5 samples or more

TOTAL COLIFORM REPORTED AS GEOMETRIC MEANS;

OTHER WATER QUALITY VARIABLES REPORTED AS ARITHMETIC MEANS

Figure 2: Sample of computer output used in examining annual water quality trends.

SURFACE WATER QUALITY TRENDS AT LONG TERM STATIONS, 1964-1979

CRITERIA FOR SELECTING LONG TERM STATIONS

In order to obtain an overview of water quality trends at Provincial Network stations, it was necessary to select stations with a relatively long period of record. In addition, it was necessary that each station have an adequate number of samples f or computing annual water quality ratings. To meet these requirements, the following selection criteria were used:

1) stations must be active in 1979 and have at least 8 years of data, each containing 5 or more samples per year for computing annual water quality ratings;

2) an annual water quality rating based on 5 or more samples per year must be available for at least one of the three years, 1977, 1978 or 1979.

Both criteria had to be met in order for the station to be considered 'long-term'. The first criteria provided a data base over a reasonably long period for examination of water quality trends. The second criteria enabled water quality comparisons among stations for the more recent data in 1979; if water quality ratings were not available for 1979, this criteria provided for the substitution of 1977 or 1978 data to approximate 1979 water quality conditions for purposes of comparison.

AREAL DISTRIBUTION OF LONG TERM STATIONS

Of the over 1520 water quality stations listed in the Provincial Water Quality Network, 793 were still active in 1979 and of these, 169 met the previously defined criteria for long-term stations.

The long-term stations are not uniformly distributed across Ontario. Of the 169 long- term stations, only 4 are located in northern Ontario; the remaining 165 are located in southern Ontario. Table 1 indicates that 82% of all long-term stations are located within four major drainage basins in southern Ontario: Lake Ontario (34%), Lake Erie (18%), Lake Huron (12%) and Georgian Bay (18%) .

TABLE 1: Distribution Of Long Term Stations By Major Drainage Basins

	Major Drainage Basin and Code	No. of Stations	% of All Stations
01	Lake Superior	2	1.2
03	Georgian Bay	31	18.3
04	Lake St. Clair	3	1.8
06	Lake Ontario	57	33.7
08	Lake Huron	20	11.9
09	Hamilton Harbour	3	1.8
11	Niagara River(Lower)	1	0.6
12	St. Lawrence River	9	5.3
14	North Channel	1	0.6
16	Lake Erie	31	18.3
17	Bay of Quinte	9	5.3
18	Ottawa River	1	0.6
19	Hudson Bay	1	0.6
	All Basins	169	

The nonuniform distribution of the long-term and other active stations within the Provincial Network is due to the fact that the Water Quality Network program is, for economic reasons, biased towards sampling at those locations where man' s activities may impact on stream quality. The majority of water quality stations, therefore, are located to measure such effects as discharges from major municipal water pollution control plants and industries , and overland runoff from major urban and agricultural areas. Thus the majority of stations are located in those basins in southern Ontario that contain a large part of the Province's population, industries, cities, and agriculture.

The apparently small number of long-term stations evident in sane major drainage basins (e.g. Lake St. Clair) is due to the relatively stringent nature of the long-term selection criteria, which required that all seven of the selected water quality variables had to be available concurrently, and that each station had to satisfy other criteria relating to number of samples and number of years of record.

WATER QUALITY TRENDS

Water quality trends at long-term stations during the period 1964 to 1979 are based on tabular and graphical data for each station (MOE, 1980a), a sample of which is illustrated in Figure 2. Trend interpretations are based on the overall tendency of the annual water quality rating to increase or decrease with time at each long-term station.

As expected, many stations showed no overall trend due to large fluctuations in the annual water quality rating that tended to mask increases or decreases with time. Stations exhibiting trends were generally characterized by relatively small fluctuations in the annual rating number and by a relatively consistent tendency over a number of years.

TABLE 2: Water Quality Trends By Major Drainage Basins

Major Drainage Basin and Code		Number of Long-Term Stations Trends*			
		3	2	1	Total
01	Lake Superior	1	1	0	2
03	Georgian Bay	6	25	0	31
04	Lake St. Clair	1	2	0	3
06	Lake Ontario	26	27	4	57
08	Lake Huron	6	12	2	20
09	Hamilton Harbour	1	2	0	3
11	Niagara River(Lower)	0	1	0	1
12	St. Lawrence River	0	9	0	9
14	North Channel	0	0	1	1
16	Lake Erie	16	14	1	31
17	Bay pf Quinte	7	2	0	9
18	Ottawa River	1	0	0	1
19	Hudson Bay	0	1	0	1
	All Basins	65	96	8	169
	% of Total	38.5	56.8	4.7	

* 3: Improving
2: No change
1: Deteriorating

Water quality trends at long-term stations (Map 1 and Table 2) indicate that of the 169 stations examined, 95% (161) show improving or no change in water quality based on the combined seven water quality variables (total coliforms, total phosphorus, nitrate, 5-day biochemical oxygen demand, dissolved oxygen, total solids and turbidity). Only 5% (8) of the stations show signs of deteriorating water quality.

Of the 65 stations showing improving quality, 83% (54) of these are located in the four previously mentioned drainage basins: Lake Ontario (40%), Lake Erie (25%), Lake Huron (9%) and Georgian Bay (9%). The majority of these stations are associated with measuring the effects of municipal water pollution control pl ants on stream quality.

Same of the stations showing improving trends are characterized by what will be referred to as a 'concave up' trend, that is, by declining annual water quality ratings during the late 1960s and improving annual water quality ratings during the early 1970s. A number of factors appear to be related to improvements in water quality during the early 1970s and are discussed later in this chapter.

In the Holland River and Black River basins that drain into the southern part of Lake Simcoe in the Georgian Bay drainage basin, this characteristic 'concave up' trend is also apparent at a few locations (#11, #14, #15, #17, #18). A study by Vallery, *et al.* (in preparation) found that there was reasonable evidence to suggest that the dissolved oxygen data between 1972 to 1977 may be erroneous. In that study, no trends were apparent at these locations when dissolved oxygen data were excluded and six of the seven water quality variables aggregated and compared. Therefore, water quality trends at the above locations are interpreted in this report as showing no change, in recognition of the questionable dissolved oxygen data at these locations.

Reductions in biochemical oxygen demand and total phosphorus concentrations, and improvements in dissolved oxygen conditions, are the three most common water quality changes associated with improvements in water quality at the 65 stations during the period 1964 to 1979. Nitrate, on the other hand, shows an apparent increase in concentrations at a large number of stations, including many stations that show an overall improvement. Specific data for individual stations may be obtained from the previously cited files of the Ministry (ICE, 1980a). Factors relating to these water quality trends are discussed later.

Each of the eight stations showing deteriorating quality appear to be quite unique. The deteriorating quality at these stations are associated with various combinations of increasing total coliforms, total phosphorus, nitrate and total solids concentrations and no common combination could be easily identified. Six of these stations (#63, #71, #80, #97, #103 and #127) are associated with municipal water pollution control plants, one (#143) with an industrial discharge, and one (#66) with an urban area.

FACTORS RELATING TO WATER QUALITY TRENDS

Three major factors that are often associated with water quality trends are: the natural variability in the data due to streamflow fluctuations;

1) changes in laboratory procedure and precision; and

2) effects of man-related activities.

Detailed studies of the factors relating to improving water quality trends, as for example in the Humber and Don River basins in the Lake Ontario drainage basin (Chin, *et al.*, in preparation), have indicated that in many instances it is difficult to associate a water quality trend with specific external factors. This is partly due to inadequate or lack of documentation, but mainly to the fact that several external factors may be responsible conjunctively and their individual effects cannot be determined separately.

Streamflow effects on water quality trends are not felt to be as significant as the other two factors and have not been investigated in this report. Ongley (1978) has shown that concentrations and yiel ds are closely related at annual and mean annual levels. This may not be true if a shorter time period is used, as changes in water quality due to dilution and seasonal effects resulting from streamflow fluctuations become more apparent.

Two changes in laboratory procedure that have affected the data base used in this report rel ate to turbidity and nitrate. Changes in laboratory procedure for turbidity after 1972 resulted in the reporting of this variable in different units. Between 1964 and 1972, turbidity is reported in Jackson Turbidity Units; between 1973 and 1979, it is reported in Formazin Turbidity Units. The turbidity values for these two time periods should not differ significantly if greater than 10 units, but they are not comparable at lower levels.

Three laboratory methods have been used for the determination of nitrate during the period 1964 to 1979. A phenoldisulfonic acid method was used between 1964 and 1967; a cadmium column method between 1968 and 1975, and a hydrazine method between 1976 and 1979. Nitrate values for the period 1976 to 1979 are believed to be about 25 to 30 percent greater than values in the previous periods due to these analytical changes (King, D.M., pers. comm.).

These laboratory changes are believed to be only partly related to the increase in mean nitrate concentrations apparent at many stations. In addition, it is speculated that increased nitrate concentrations may also be partly due to increased nitrification of effluents from water pollution control plants, or increased nitrate loads from agricultural runoff in some areas. Further investigations will be required to verify these reasons.

Effects of man-related activities are believed to be the most significant of the three major factors relating to water quality trends in this report. Although the discussion that follows focuses on the abatement measures associated with the improving trends apparent at many stations, it should be recognized that land-use and other related changes during the 1964 to 1979 period, in all likelihood, partly counteracted these abatement measures.

Two abatement measures of Province-wide significance contributing to improving water quality trends apparent at many stations are the efforts of the Government of Canada and the Province of Ontario to reduce phosphorus discharges from all sources. In 1970, the Government of Canada enacted a policy which resulted in the subsequent reduction of phosphorus content and reformulation of laundry detergents between 1970 and 1973. Concurrently with this, the Province of Ontario implemented a program for phosphorus removal at municipal water pollution control plants.

A target date of December 31, 1973 was set for most municipalities discharging to Lake Erie and Lake Huron basins, and a target of December 31, 1975 was set for most municipalities discharging into Lake Ontario and Ottawa River basins (Archer, 1976). Both programs have been successful in reducing the phosphorus concentrations of effluents from municipal water pollution control plants (Appleby, 1977). The improved stream quality apparent at many locations is undoubtedly due to the reduction of phosphorus concentrations in effluents from municipal water pollution control plants.

Other abatement measures relate to the increased number of new water pollution control plants built in the Province during the period 1970 to 1976 (Hogarth, pers. comm.). In addition, many of the older water pollution control plants had become hydraulically overloaded and many were upgraded during this same period to increase their hydraulic capacities.

These water pollution control plant improvements are substantiated by a report of the Great Lakes Water Quality Board (1980), which shows an increase in capital commitments for municipal sewerage construction in the Great Lakes basin of Ontario from $57 million in 1971 to $200 million in 1979 (Table 3).

In some places, effluent discharges from municipal water pollution control plants were diverted away from streams. This occurred mainly in areas centred around Toronto in the Lake Ontario basin. The diversion of effluent discharges from some streams in the Credit River, Etobicoke Creek, Mimico Creek and Don River basins during the period 1970 to 1973 is undoubtedly another measure that contributed to the improved stream quality at these locations.

In addition, corrective measures taken by the MOE in the 1970s resulted in the abatement of various point sources of pollution that had been identified in OWRC reports of the 1960s. Discharges from industrial outfalls and septic tanks, piggery wastes and dairy products wastes, are but a few examples of the numerous small, but cumulatively significant, point sources of pollution that have been curtailed and documented within MOE internal files.

TABLE 3: Funds Committed For Municipal Sewerage Construction In The Great Lakes Basin, Ontario, 1971-1979.

Year	Funds Committed* (in millions of dollars)
1971	57
1972	66
1973	138
1974	103
1975	112
1976	174
1977	150
1978	191
1979	200
TOTAL	1,191

* Figures represent total capital commitments for water pollution control plants and interceptor sewers by all levels of government.

Source: Great Lakes Water Quality Board, 1980.

Previous reference was made to some stations showing trends that are characterized by declining annual water quality ratings during the late 1960s and increasing annual water quality ratings during the early 1970s. The resulting reversals of water quality trends from deteriorating to improving at these stations are undoubtedly linked to the abatement measures discussed above and do not appear to be linked to erroneous oxygen data, as was the case for stations in the Holland River and Black River basins.

SURFACE WATER QUALITY INTERSTATION COMPARISONS, 1979

GROUPING OF LONG TERM STATIONS

Long-term stations have been placed into 5 groups for ease of comparing differences in water quality among stations and to facilitate illustrating differences in the areal distribution of these station groups.

Of the total (793) active stations within the Provincial Water Quality Monitoring Network in 1979, 402 had adequate data for computing annual rating numbers in that year. This data base of 402 stations (MOE, 1980b), which represents short-term stations and the majority of the 169 long-term stations, was used initially to define the station groups. First, the 402 stations were ranked on the basis of their annual rating numbers in 1979. Five station groups were then selected on the basis of the frequency distribution of the 1979 rating (Figure 3) such that each group contained one-fifth the total number (402) of stations. The number of stations in each group are only approximately equal because the annual water quality rating bounds are not coincident with the respective percentile (cumulative percentage) bounds.

An important point should be noted about the data base for the long-term stations. Although all 169 long-term stations have at least 8 years of data and were active in 1979, about 14% of the stations did not have adequate data for computing annual water quality ratings in 1979. At the stations where this occurred, (the most recent) rating numbers and data for 1978 or 1977 had to be used for purposes of comparison, the underlying assumption being that data for years closest to 1979 best approximate 1979 water quality conditions. This is a reasonable assumption, judging from the small temporal fluctuations at other stations during these years.

Although the proportions of the 169 long-term stations within the 5 station groups are not identical to the proportions determined from the 402 Provincial Network stations (Table 4), the long-term stations are apportioned among each of the 5 groups and, therefore, are representative of a wide range of water quality conditions in the Province. Differences between these two distributions are most evident for groups 3 and 5. There are about 5% more long-term stations in Group 3 and about 7% less long-term stations in Group 5 than for the Provincial Network stations in the same

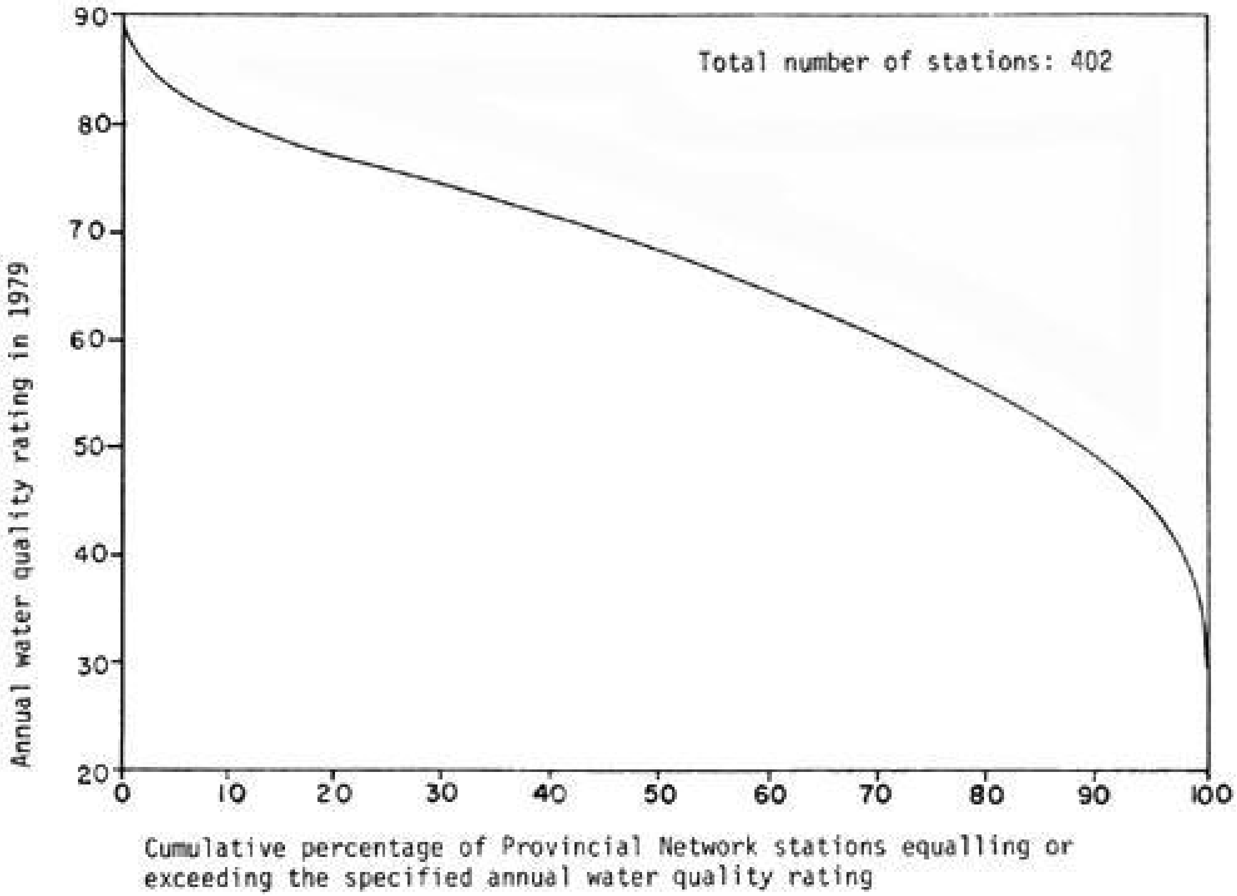


Figure 3: Cumulative frequency distribution of Provincial Network stations for specified annual water quality ratings in 1979.

categories. Thus, while long-term stations with the lower water quality ratings (Group 1) are adequately represented, stations with the higher water quality ratings (Group 5) are slightly under-represented in comparison to the larger data-base of 402 stations.

TABLE 4: Comparison Of The Distribution Of Long Term Stations By Station Groups As Determined From The Provincial Network Stations.

Station Groups	Range of Annual Rating*	Provincial Network 1979		Long-Term Stations 1979	
		No.	%	No.	%
5	77-89	74	18.4	20	11.8
4	71-76	93	23.1	39	23.1
3	64-70	70	17.4	38	22.5
2	56-63	85	21.1	36	21.3
1	28-55	80	19.9	36	21.3
All Groups		402		169	

* Highest rating for Group 5 long-term stations is 88.

INTERSTATION COMPARISONS

The comparisons of water quality among long-term stations in 1979 (Map 2) are based on the previously discussed classification scheme. Only the long-term stations are shown on Map 2 because only these stations have been classified into the 5 groups for analysis, as shown in Table 4. Group 5 stations (with higher water quality ratings) may be considered having relatively better quality than Group 1 stations (with lower water quality ratings).

An indication of the relative magnitude of the seven water quality variables that make up the annual water quality ratings may be obtained from the 5 group means and ranges shown in Table 5. Dissolved oxygen shows decreasing mean concentrations (in percent saturation) progressing from Group 5 to Group 1 and the other six

TABLE 5: Summary Of Annual Water Quality Ratings And Data For Long Term Station Groups, 1979*

Station Groups (No. Samples)	Group Statistic	Annual Rating	Total Coliforms /100 mL	Total Phosphorus mg/L	Filtered Nitrate mg/L	5-day BOD mg/L	Diss. O_2 Satur. %	Total Solids mg/L	Turbidity FTU
5	Mean	82	71	0.024	0.132	0.9	93	147	2
(20)	Range	77-88	7-274	0.006-0.048	0.042-0.417	0.3-2.0	77-117	32-265	1-7
4	Mean	74	482	0.037	0.656	0.7	92	281	6
(39)	Range	71-76	97-1640	0.020-0.056	0.029-1.58	0.3-1.7	74-106	151-371	2-16
3	Mean	67	1250	0.082	1.37	1.1	91	339	10
(38)	Range	64-70	79-5080	0.020-0.336	0.107-3.55	0.4-1.9	21-103	140-491	3-30
2	Mean	60	1900	0.121	2.28	1.3	89	451	13
(36)	Range	56-63	343-15300	0.058-0.289	0.116-6.72	0.5-3.0	52-119	234-830	2-51
1	Mean	47	18800	0.368	3.56	6.0	82	584	25
(36)	Range	28-55	162-99900	0.106-1.83	0.160-14.5	1.4-83	40-121	357-1143	3-115
All Groups	Mean	65	4810	0.134	1.72	2.1	89	379	12
(169)	Range	28-88	7-99900	0.006-1.83	0.029-14.5	0.3-83	21-121	32-1143	1-115

* Approximately 14% of the stations did not have adequate data for computing annual water quality ratings in 1979 and (the most recent) data for 1978 or 1977 were substituted.

variables generally show increasing mean concentrations progressing from Group 5 to Group 1. The differences between the mean concentrations of the two extreme groups (5 and 1) are largest for total coliforms (3 orders of magnitude) and for total phosphorus, filtered nitrate, 5-day biochemical oxygen demand and turbidity (one order of magnitude).

A fair amount of overlap is evident in the range of concentrations for each of the five station groups (Table 5). This is not surprising since, as explained earlier, equal rating numbers may be obtained from different combinations of the seven water quality variables. Because of this, the data for each long-term station have been provided in Appendix B.

The areal distribution of the five station groups, which are shown on Map 2 and summarized by major drainage basins in Table 6, indicates that these groups are not uniformly distributed. This nonuniform areal distribution is most evident when groups 5 and 1 are compared. Group 5 stations are located predominantly in the Georgian Bay and the Bay of Quinte basins, whereas Group 1 stations are located predominantly in the Lake Ontario, Lake Erie and southern part of Lake Huron basins. A few Group 1 stations are located in the Georgian Bay basin mainly in the Holland River basin south of Lake Simcoe.

TABLE 6: Distribution Of Long Term Station Groups By Major Drainage Basins.

Major Drainage Basin and Code		Number of Stations Groups 5	4	3	2	1	Total
01	Lake Superior	0	2	0	0	0	2
03	Georgian Bay	7	10	4	5	5	31
04	Lake St. Clair	0	0	0	1	2	3
06	Lake Ontario	1	16	12	12	16	57
08	Lake Huron	1	4	6	4	5	20
09	Hamilton Harbour	0	0	2	0	1	3
11	Niagara River (Lower)	0	0	0	1	0	1
12	St. Lawrence River	3	1	2	2	1	9
14	North Channel	0	0	0	0	1	1
16	Lake Erie	0	6	10	11	4	31
17	Bay of Quinte	8	0	1	0	0	9
18	Ottawa River	0	0	0	0	1	1
19	Hudson Bay	0	0	1	0	0	1
	All Basins	20	39	38	36	36	169

An example of the extreme remedial measures required to improve in-stream quality at some locations is illustrated for the Don River basin in the Lake Ontario drainage basin and for the Holland River basin in the Georgian Bay drainage basin, both of which contain a number of Group 1 stations. In the Don River basin, the diversions (from streams) of effluent discharges from municipal water pollution control plants is to be implemented in 1981 by the York-Durham Sewage System.

Diversions from this system, plus some of the earlier ones that have occurred in the basin, have been designed for routing wastewater flows to treatment plants that discharge into Lake Ontario. Other diversions are planned for the Holland River basin for 1986. Improvements in stream water quality should be apparent at stations #61 through #65 in the Don River basin and stations #13, #16 and #17 in the Holland River basin after implementation of these plans.

This nonuniform distribution of the station groups partly relates to the nonuniform distribution of man and his activities within the Province. Group 5 stations are associated with the less populous areas, whereas Group 1 stations are associated with measuring the effects of municipal water pollution control plants, industrial discharges, and runoff from major urban and agricultural areas in the more populous southern parts of the Province.

Another factor contributing to the nonuniform distribution of the station groups relates to the influence of geologic environments on stream quality. Within southern Ontario there are two major geologic environments: areas to the north consisting mainly of Precambrian crystalline bedrock usually exposed or near the surface, and areas to the south consisting mainly of Paleozoic carbonate bedrock overlain by Pleistocene glacial deposits (for boundary, see Map 2). Under natural conditions, Precambrian areas can be expected to show generally markedly lower concentrations for water quality variables such as total phosphorus, total solids and turbidity than Paleozoic areas. Because of the inverse relationships of concentrations of these variables to water quality ratings, lower concentrations would be reflected by higher water quality ratings.

The influence of geologic environments on stream quality is not readily apparent from the areal distribution of the long-term stations alone: firstly, because few Group 5 stations are shown within the Precambrian areas on Map 2; and secondly, because the percentage of long-term stations in Group 5 is slightly under represented in comparison to the percentages obtained from the larger data base of 402 stations (Table 4). This larger data base, while not presented in this report, is contained in MOE internal files

(MOE, 1980b) and better depicts the preponderance of Group 5 stations within the Precambrian areas.

SUMMARY AND RECOMMENDATIONS

SUMMARY

Surface water quality trends in this report are based on data for seven water quality variables (dissolved oxygen, total coliforms, 5-day biochemical oxygen demand, total phosphorus, nitrate, total solids and turbidity) that are aggregated into a single annual number for the period 1964 to 1979. This number, referred to as an annual water quality rating, ranges between 0 and 100; the higher the number, the better the quality. Interpretations of trends are based on the consistency of the tendency of these annual water quality ratings to increase or decrease with time.

The procedure for computing annual water quality ratings is based on a modified version of the multiplicative form of the (U.S.) National Sanitation Foundation method.

Of the 169 long-term stations selected for study, 165 are located in southern Ontario and 4 in northern Ontario. About 82% of all long- term stations are located within four (Lake Ontario, Lake Erie, Lake Huron and Georgian Bay) major drainage basins in southern Ontario.

The nonuniform areal distribution of long-term stations indicated by these data reflects the overall Provincial Water Quality Network program, which for economic reasons, is biased towards sampling in those areas of the Province where man and his activities have the greatest potential for impacts on stream quality.

Surface water quality trends at the 169 long- term stations during the period 1964 to 1979 (Map 1) indicate that 95% (161 stations) show improving or no change in water quality. Only 5% (8 stations) show signs of deteriorating quality.

Of the 65 stations showing improving quality, 83% (54) are located in the four previously mentioned major drainage basins. The majority of these stations are associated with measuring the effects of discharges from municipal water pollution control plants on stream quality in these basins.

Reductions in biochemical oxygen demand and total phosphorus concentrations, and improvements in dissolved oxygen conditions are the three most common water quality changes associated with the improvements in water quality. Nitrate, on the other hand, shows increasing concentrations at a large number of stations.

The increase in nitrate concentrations is partly attributed to a change in the laboratory analytical method that now yields increased concentrations over the earlier methodology. Other reasons for this increase may relate to increased nitrification at municipal water pollution control plants, or to increased nitrate concentrations in runoff from agricultural land; however, these reasons have not been investigated or confirmed at the present time.

Although factors relating to improving water quality trends have not been studied in detail for each long-term station, past studies in several river basins have identified at least two factors of Province-wide significance that may be confidently associated with these improving trends. These two factors relate to measures for the reduction of phosphorus concentrations in effluents from municipal water pollution control pl ants through the reduction of phosphorus by reformulation of laundry detergents after 1970, and through the implementation of phosphorus removal at a large number of municipal water pollution control pl ants after 1972.

Other abatement measures are associated with the construction of new water pollution control plants, upgrading of old plants, and the diversion of their effluent discharges away from streams in some areas. The curtailment of numerous point sources during the early 1970s was another measure related to the improving trends. These abatement measures, however, tend to have a more site-specific effect on water quality.

Although various combinations of total coliforms, total phosphorus, nitrate and total soli ds appear to be related to the deteriorating trends shown at 8 stations, each station appears unique as there is no common combination of water quality variables that could be easily identified. Six of these stations are associated with measuring the effects from municipal water pollution control plants, one from an industrial discharge and one from an urban area.

In order to compare water quality among the 169 long-term stations (Map 2), stations were placed into 5 groups on the basis of their annual water quality ratings in 1979. Group 5 stations (with higher water quality ratings) may be considered having relatively better quality than Group 1 stations (with lower water quality ratings).

The largest differences between the mean concentrations of the two extreme station groups (5 and 1) are for total coliforms (3 orders of magnitude) and for total phosphorus, nitrate, 5-day biochemical oxygen demand and turbidity (one order of magnitude).

The nonuniform areal distribution of the station groups is most evident when the two extreme station groups are compared. Group 5 stations are associated with the less populous areas such as the Georgian Bay and the Bay of Quinte basins, whereas Group 1 stations are associated with the more populous basins such as Lake Ontario, Lake Erie and the southern part of Lake Huron basins. A few Group 1 stations are located in the Georgian Bay basin, mainly in the Holland River basin south of Lake Simcoe.

Another factor contributing to this apparent nonuniform areal distribution of station groups is the influence of geologic environments on stream quality. Within Ontario, Group 5 stations are influenced by areas consisting mainly of Precambrian crystalline bedrock, which is usually exposed or near the surface, whereas Group 1 stations are influenced by areas consisting mainly of Paleozoic carbonate bedrock overlain by Pleistocene glacial deposits. Under natural conditions, Precambrian areas can be expected to show generally markedly lower concentrations for water quality variables such as total phosphorus, total solids and turbidity than Paleozoic areas.

RECOMMENDATIONS

As a result of this initial analysis, it is recommended that site-specific investigations be carried out at the following sites:

- at the 8 water quality stations showing deteriorating trends;

- at Group 1 stations, with priority being given to stations in the Lake Ontario and Lake Erie drainage basins; and

- at stations in drainage basins not adequately represented in this report.

Locations for site-specific studies should be selected in conjunction with MOE Regional staff to further pin-point areas of priority.

Since timely reports on the status of and trends in water quality are pre-requisites for the efficient implementation of water resources programs, it is further recommended that exploration and implementation of effective ways for data analyses and data presentations to assist resources managers in water quality interpretations be continued. To this end, efforts should be directed in the following specific areas:

- continue to explore computer methods for effectively presenting information, e.g., computerized graphs, maps, and statistical analyses;

- investigate ways of including additional variables such as heavy metals, pesticides and herbicides into aggregated data; and

- investigate methods for determining water quality trends and changes based on relatively short periods of data.

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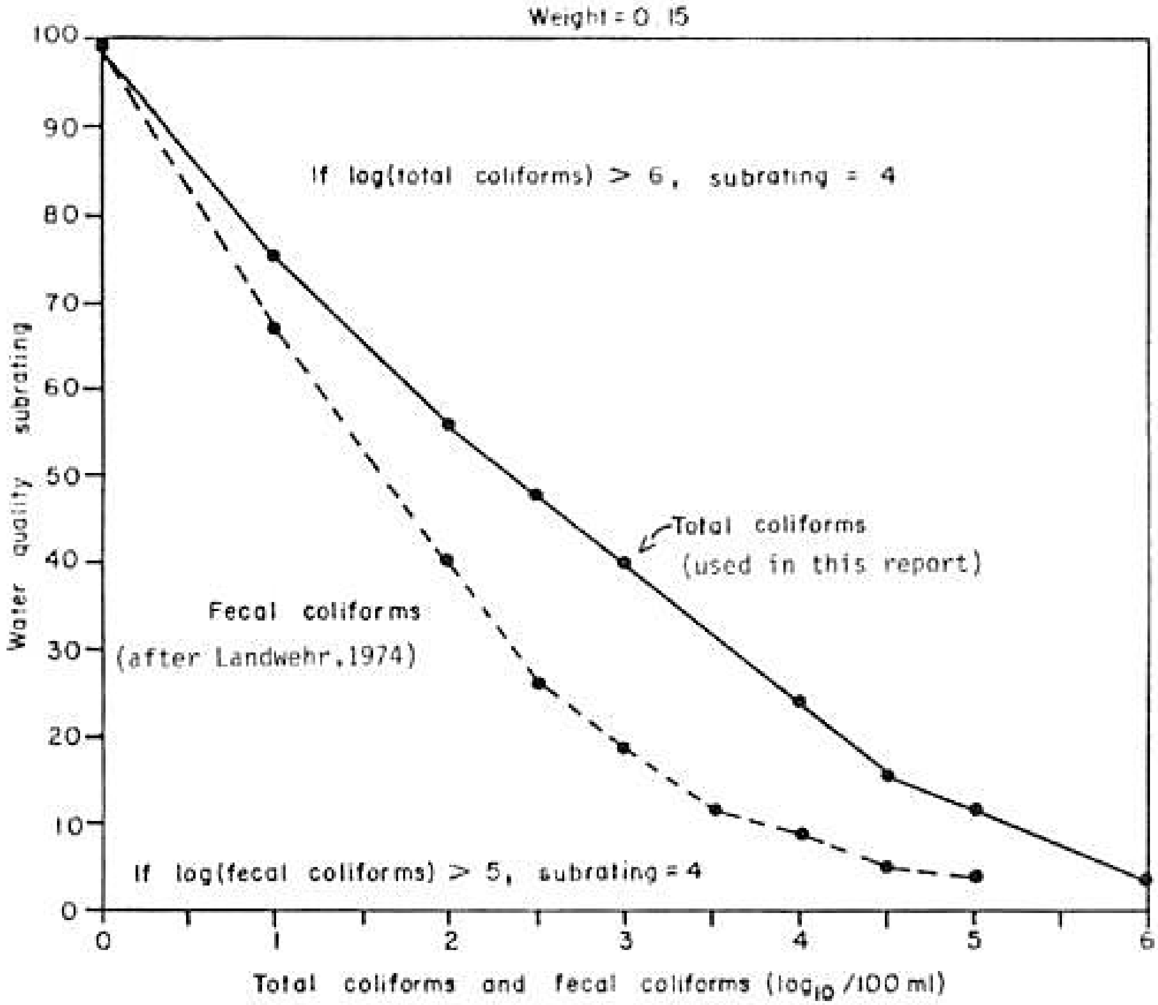
APPENDIX A

GRAPHS USED IN TRANSFORMING WATER QUALITY CONCENTRATIONS INTO WATER QUALITY SUBRATINGS

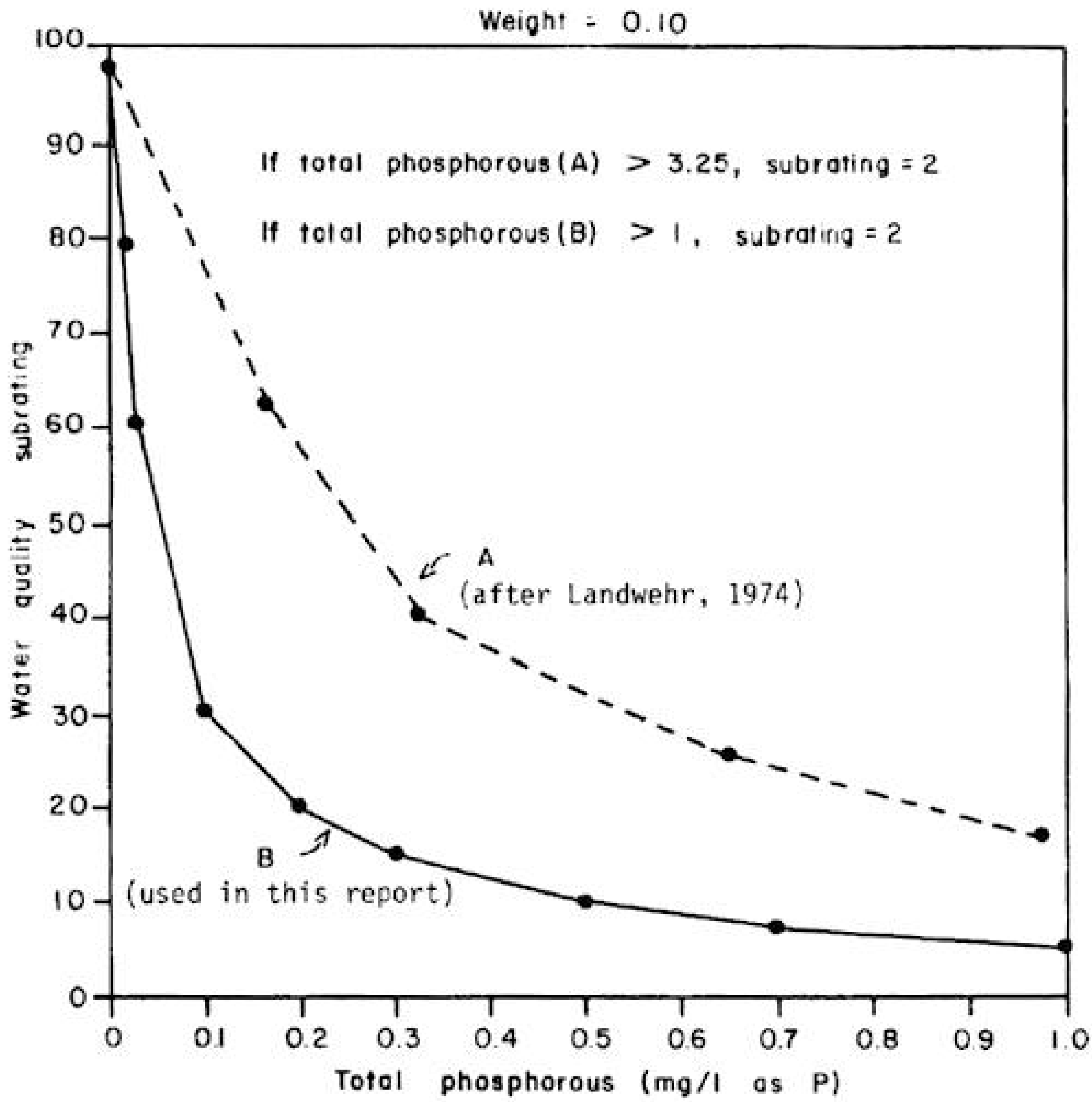
Graphs shown in solid lines are used in computing water quality ratings and are based on transformation curves of the National Sanitation Foundation (NSF) method (Landwehr, 1974). In the two instances where the NSF curves are replaced, the NSF curves are shown as broken lines for comparison. Dots on each curve represent the digital representation of that curve as used in the computer program.

Four of the transformation curves are of a dual nature, that is, the same subrating number is associated with two different concentrations. Although the rationale for these curves are not discussed in the original reference by Brown *et al.* (1970), some opinions are provided here with each dual curve.



Note: The curve for total coliforms that is used in this report has been constructed to reflect that these indicator organisms are found in greater numbers in surface water than fecal coliforms. Recreational considerations for water, for example, suggest that total and fecal coliforms should not exceed 1000 and 100 per 100 mL, respectively, based on specific sampling requirements.

Figure 4: Subrating transformation curves for total coliforms and fecal coliforms.



Note: The curve used in this report has been constructed to reflect current stringent considerations for total phosphorus by providing greater sensitivity at low concentrations (less than 0.1 mg/L), which the NSF curve does not provide. Current evidence suggests that total phosphorus concentrations as low as 0.03 mg/L may be required to eliminate excessive plant growth in rivers.

Figure 5: Subrating transformation curves for total phosphorus.

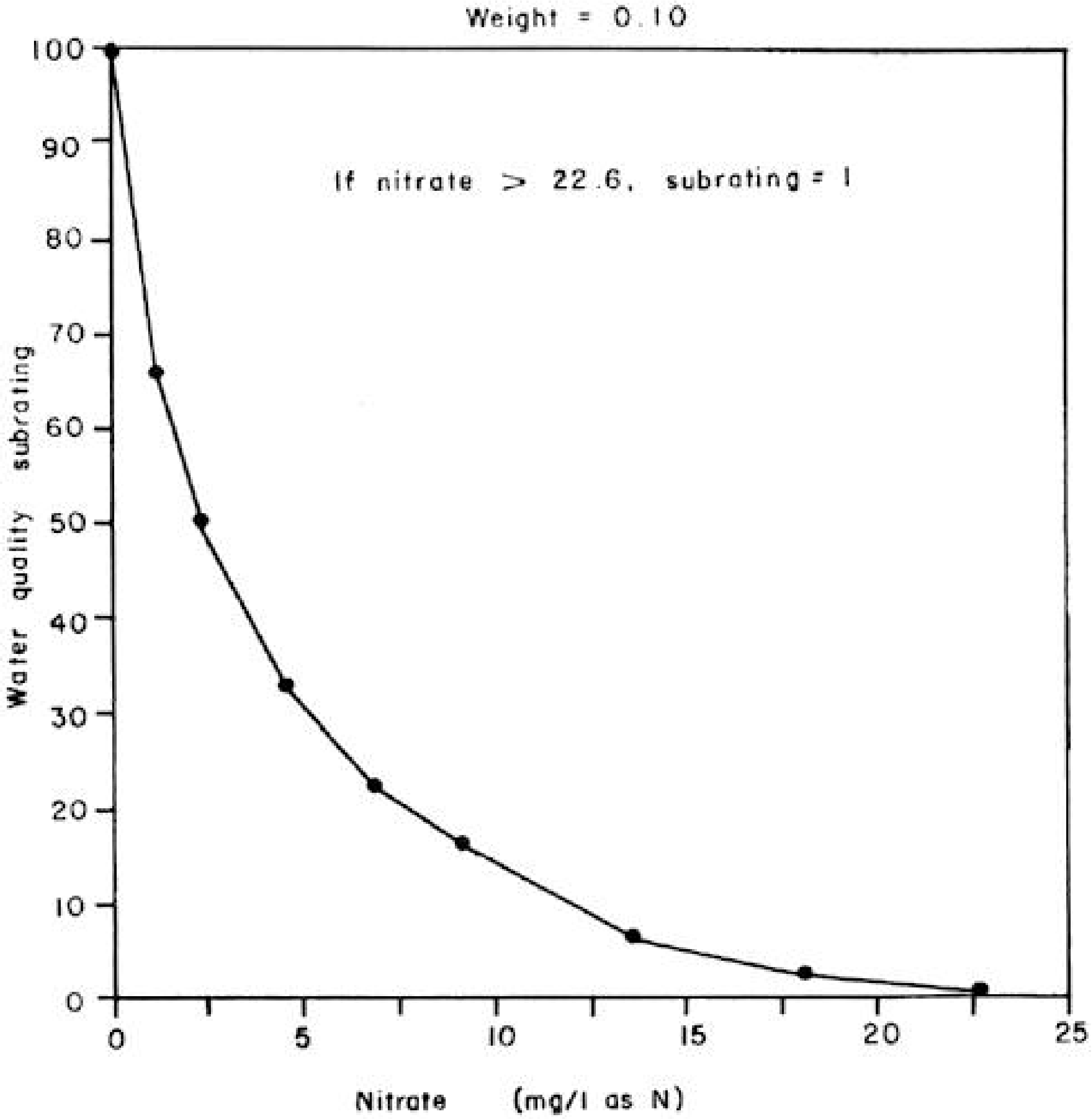


Figure 6: Subrating transformation curve for nitrate.

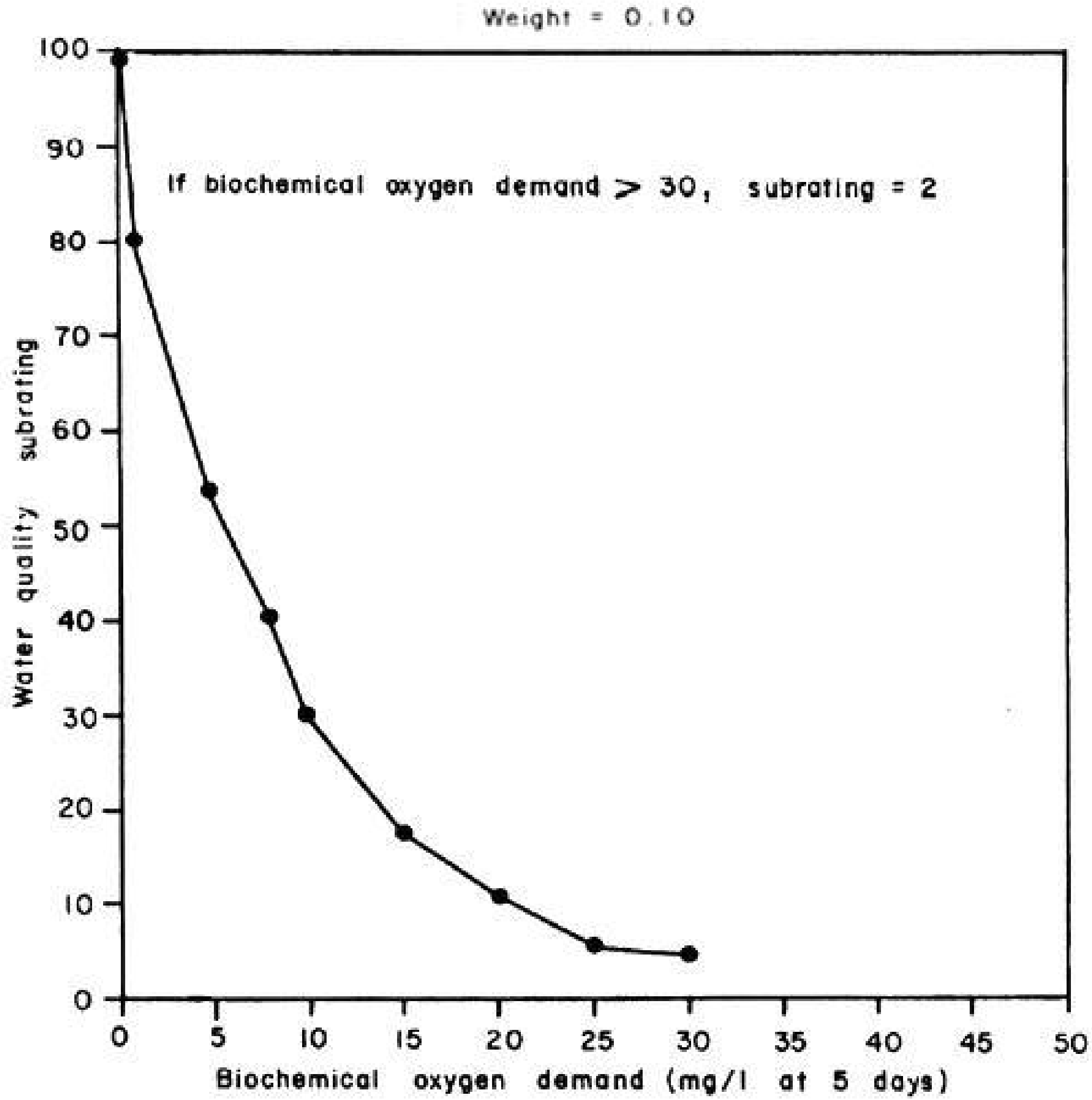
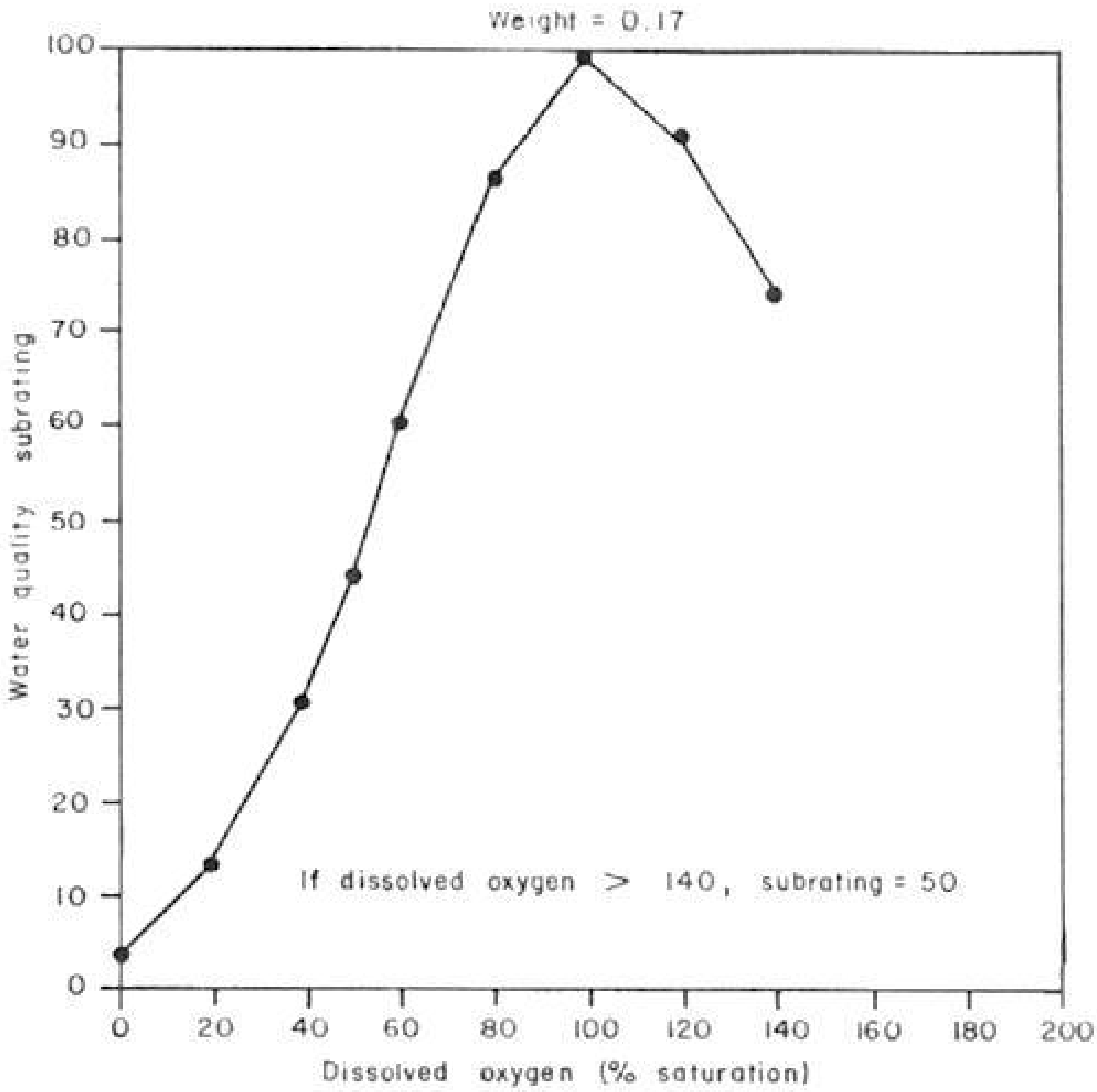
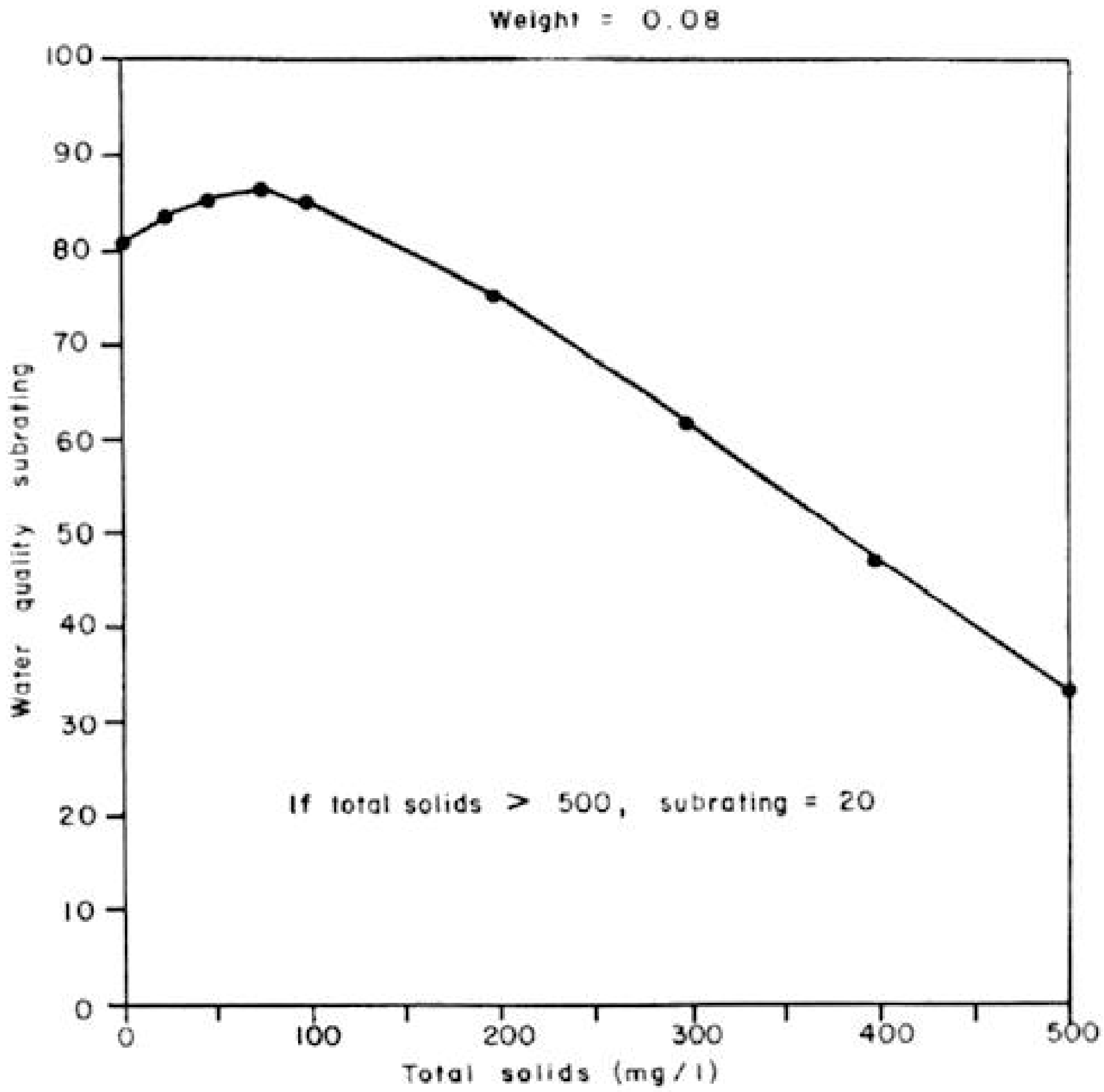


Figure 7: Subrating transformation curve for 5-day biochemical oxygen demand.



Note: The highest water quality subrating is at 100% saturation, with a decreased subrating on either side of this optimum. On the low side, inadequate dissolved oxygen provides an unfavourable environment for aquatic life. Considerations for cold water biota, for example, indicate that dissolved oxygen should not be below 57% of saturation at 20°C. The absence of dissolved oxygen may produce odours and aesthetic problems in surface waters. On the high side, supersaturated conditions (above 100%) may be indicative of algal problems and may contribute to gas bubble disease (emboli formation) in fish.

Figure 8: Subrating transformation curve for dissolved oxygen.



Note: The water quality subrating curve decreases for both very low and very high total solids content in water. Total solids are composed of dissolved solids and suspended solids. Surface waters devoid of dissolved solids will not support aquatic life. In addition, toxicity of some heavy metals and organic compounds may increase with a reduction in dissolved solids concentrations. High concentrations of suspended solids may kill fish and destroy spawning grounds by blanketing stream beds.

Figure 9: Subrating transformation curve for total solids.

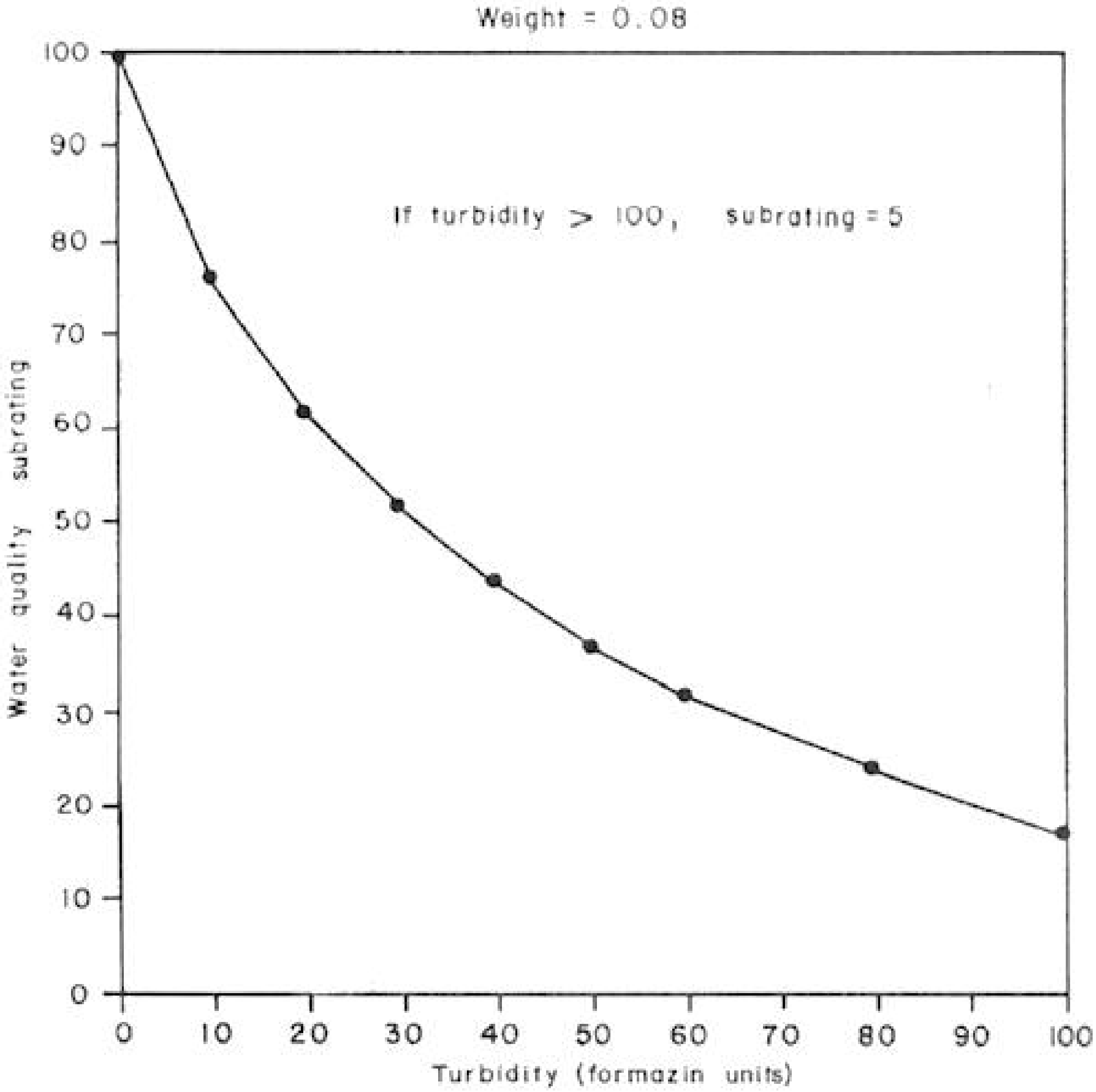
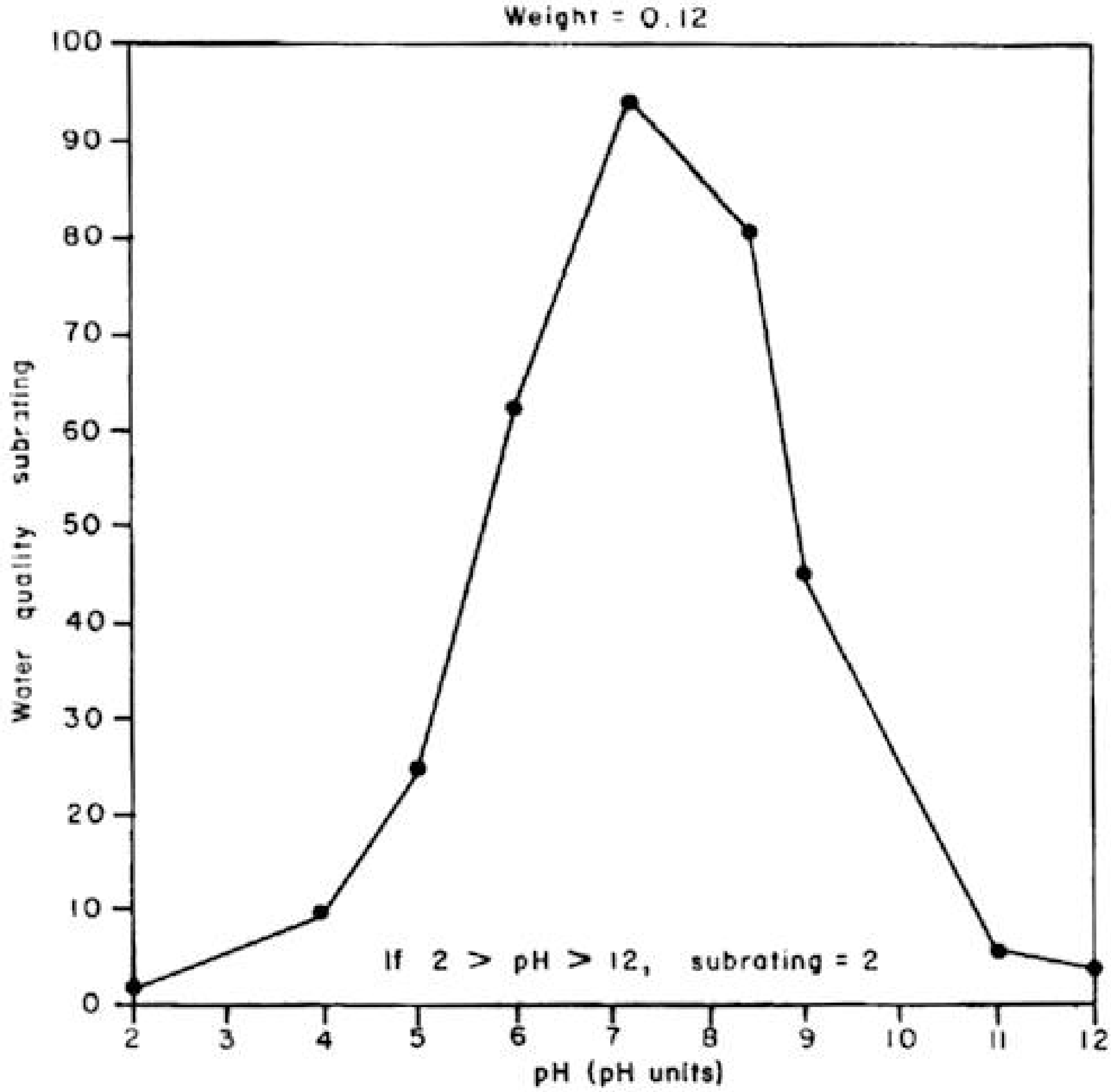
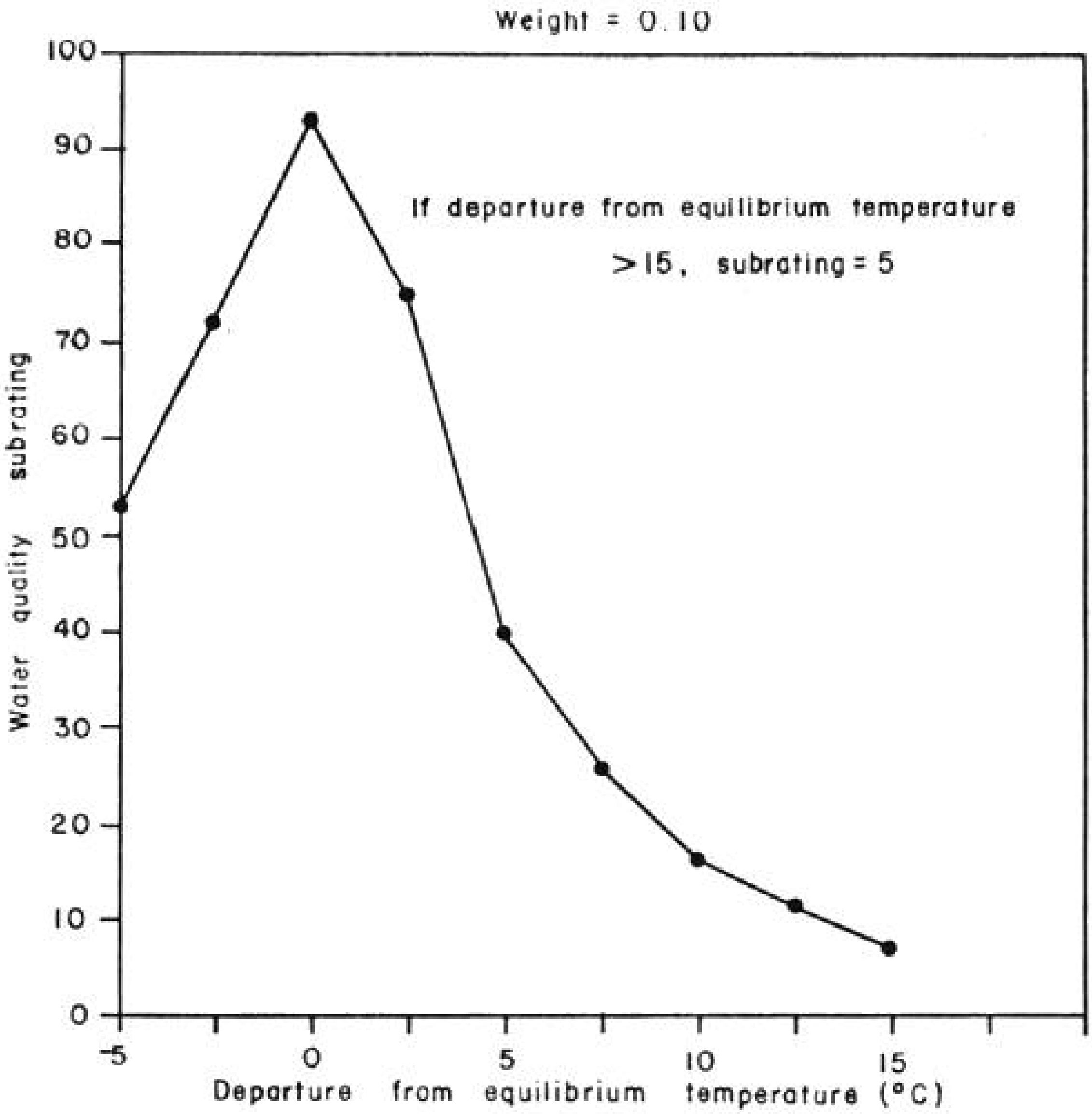


Figure 10: Subrating transformation curve for turbidity.



Note: The optimum pH is 7, with lower subratings for pH values on either side of this optimum. Acidic (low pH) water is as undesirable as alkaline (high pH) water for many uses. A pH range of 6.5 to 8.5, for example is desirable for recreational use of water and protection of aquatic life. Because of limited data, a constant pH of 7, which corresponds to the maximum subrating of 93, has been used in this report.

Figure 11: Subrating transformation curve for pH.



Note: Departures from equilibrium temperature (0°C departure) are undesirable and consequently have a lower subrating. Temperatures above or below the natural temperature of any body of water may significantly affect the diversity, distribution and abundance of aquatic life. Because of unavailable data, a constant departure of 0°C from equilibrium temperature, which corresponds to the maximum subrating of 94, has been used in this report.

Figure 12: Subrating transformation curve for departure from equilibrium temperature.

APPENDIX B

ANNUAL WATER QUALITY RATINGS AND DATA FOR LONG TERM STATIONS, 1979*

Station groupings shown on Map 2 are based on the annual water quality ratings in this Appendix and are as follows:

Symbol on Map 2	Group	Range of Annual Ratings
●	5	77 - 88
◕	4	71 - 76
◑	3	64 - 70
◔	2	56 - 63
○	1	28 -55

* Ratings and data for 1978 or 1977 are substituted where 1979 data are inadequate.

ONTARIO MINISTRY OF THE ENVIRONMENT WATER RESOURCES BRANCH
HYDROLOGY AND MONITORING SECTION PREPARED ON: 10/17/80

ANNUAL WATER QUALITY RATINGS AND
DATA FOR LONG-TERM STATIONS1979*
****** **********************************

Study Map No.	Station ID	Region	Year	Rating	Rec. Used	Rec. Read	Total Coliforms /100 ml	Total Phos. mg/L-P	Filtered NO_3 mg/L-N	5 DAY B.O.D mg/L	Diss. Oxygen % SAT	Total Solids mg/L	TURB. FTU
1	01-0106-001-02	06	1979	73	9	13	1225	.036	.167	1.5	81	169	7
2	01-0107-001-02	06	1979	74	9	12	521	.032	.226	1.5	82	223	11
3	03-0017-002-02	01	1979	74	12	12	604	.031	.800	.6	106	304	5
4	03-0036-002-02	01	1979	74	10	11	442	.039	.533	.9	106	286	10
5	03-0047-001-02	03	1979	76	12	12	305	.020	.603	.4	90	266	5
6	03-0057-003-02	03	1979	74	11	12	218	.041	.690	.9	93	303	6
7	03-0057-005-02	03	1979	75	11	12	175	.026	1.328	.3	91	287	8
8	03-0057-007-02	03	1979	60	11	12	8886	.150	1.218	.9	87	328	6
9	03-0057-009-02	03	1977	60	12	12	728	.108	.842	3.0	98	549	8
10	03-0057-010-02	03	1979	69	12	12	440	.063	1.490	.6	87	291	9
11	03-0077-001-02	03	1979	48	11	12	1318	.366	2.895	3.7	78	535	17
12	03-0077-002-02	03	1779	58	11	12	343	.287	1.125	2.4	78	451	8
13	03-0077-003-02	03	1979	42	11	12	15760	.537	3.265	4.7	72	558	28
14	03-0077-004-02	03	1979	67	10	12	237	.046	.502	1.4	62	362	6
15	03-0077-005-02	03	1979	67	10	12	221	.103	.470	1.6	66	472	9
16	03-0077-006-02	03	1779	46	10	12	7809	.519	1.663	4.0	66	498	17
17	03-0077-007-02	03	i979	50	10	12	12369	.155	1.118	5.5	71	627	12
19	03-0077-008-02	03	i909	72	11	12	246	.045	.365	1.4	74	297	2
19	03-0077-011-02	03	1979	72	9	12	625	.042	.254	.9	75	295	2
20	03-0077-012-02	03	1777	85	11	12	14	.020	.062	.7	89	184	2
21	03-0077-013-02	03	1978	86	8	10	21	.012	.046	.5	102	128	2
22	03-0077-014-02	03	1779	71	11	12	1641	.040	.644	1.2	90	279	3
23	03-0077-017-02	03	1979	59	10	12	1331	.259	1.136	2.0	68	442	7
24	03-0077-018-02	03	19/9	62	11	12	1410	.090	.468	1.6	68	367	3
25	03-0077-019-02	03	1979	72	11	12	296	.043	.229	.9	76	291	7
26	01-0077-021-02	03	1979	69	11	12	1414	.062	.629	.9	86	289	1
27	03-0077-022-02	03	1979	96	11	12	9	.018	.042	.4	97	209	2
28	03-0077-023-02	03	1979	87	11	12	69	.022	.074	.4	91	141	2
29	03-0077-025-02	03	1979	74	11	12	381	.030	.390	.6	86	320	5
30	03-0085-001-02	03	1979	84	8	10	52	.006	.201	. 3	81	32	1
31	03-0085-003-02	03	1979	88	10	11	8	.006	.253	.4	83	32	1
32	03-0092-001-02	03	1979	82	9	10	112	.009	.190	.4	77	32	1

TOTAL COLIFORMS REPORTED AS GEOMETRIC MEANS
OTHER WATER QUALITY VARIABLES REPORTED AS ARITHMETIC MEANS

* RATINGS AND DATA FOR 1978 OR 1977 ARE SUBSTITUTED WHERE 1979 DATA ARE INADEQUATE

ONTARIO MINISTRY OF THE ENVIRONMENT
WATER RESOURCES BRANCH
HYDROLOGY AND MONITORING SECTION   PREPARED ON: 10/17/80

ANNUAL WATER QUALITY RATINGS AND
DATA FOR LONG-TERM STATIONS. 1979*

Study	Map No.	Station ID	Region	Year	Rating	Rec. Used	Rec. Read	Total Coliforms /100 ml	Total Phos. mg/L-P	Filtered NO_3 mg/L-N	5 DAY B.O.D mg/L	Diss. Oxygen % SAT	Total Solids mg/L	TURB. FTU
	33	03-0097-001-02	03	1977	46	6	13	1102	.462	.853	7.7	43	383	9
	34	04-0001-001-02	01	1979	44	12	12	4046	.414	4.697	3.7	58	460	30
	35	04-0013-015-02	01	1979	63	11	12	1270	.058	4.262	1.3	82	345	5
	36	04-0013-016-02	01	1979	43	11	12	99887	.277	2.630	4.7	79	510	16
	37	06-0014-001-02	02	1978	76	11	12	148	.040	.228	.9	104	222	16
	38	06-0014-002-02	02	1979	86	11	11	14	.017	.202	.4	95	201	3
	39	06-0017-001-02	02	1978	70	15	27	3594	.037	.172	1.7	95	221	11
	40	06-0017-002-02	02	1979	67	12	12	5081	.062	.357	1.6	98	751	14
	41	06-0017-003-02	02	1979	28	11	12	96613	.291	.160	82.7	76	605	102
	42	06-0017-004-02	02	1979	76	12	12	260	.037	.253	.7	98	224	13
	43	06-0024-001-02	02	1978	58	10	12	670	.172	1.671	2.0	94	528	45
	44	06-0024-002-02	02	1979	56	10	12	1267	.214	2.538	1.7	93	817	17
	45	06-0060-001-02	03	1979	71	10	11	273	.043	1.054	.6	90	371	11
	46	06-0060-002-02	03	1979	74	10	11	210	.028	1.340	.4	103	368	5
	47	06-0063-001-02	03	1979	73	10	12	356	.039	.802	.8	96	344	6
	42	06-0063-002-02	03	1979	60	10	11	844	.078	2.839	.5	119	449	4
	49	06-0076-003-02	03	1979	72	12	12	306	.039	1.298	.6	98	352	5
	50	06-0076-004-02	03	1979	61	12	i2	347	.103	3.654	1.0	95	546	5
	51	06-0076-006-02	03	1779	57	22	24	650	.176	1.392	.6	55	394	2
	52	06-0076-000-02	03	1979	51	12	12	326	.241	4.844	5.5	75	962	8
	53	06-0080-001-02	03	1978	55	19	20	10172	.119	.776	2.8	105	683	32
	51	06-0080-002-02	03	1979	61	10	10	1707	.081	.666	2.2	108	830	14
	55	06-0082 001-02	03	1979	54	9	9	17636	.459	.835	2.8	87	498	22
	56	06-0083-001-02	03	1979	52	20	28	13514	.129	.708	2.7	86	558	45
	57	06-0083-002-02	03	1979	64	10	10	668	.096	.622	1.3	98	419	30
	58	06-0083-003-02	03	1979	61	10	10	1621	.189	.572	1.3	96	485	49
	59	06-0083-004-02	03	1979	70	10	10	526	.097	.449	.8	92	465	25
	60	06-0083-005-02	03	1979	67	9	9	1243	.091	.654	.9	63	325	13
	61	06-0085-001-02	03	1978	42	15	22	27281	.360	1.625	6.1	74	767	27
	62	06-0085-002-02	03	1979	55	10	10	9273	.126	1.085	2.2	91	740	15
	63	06-0085-003-02	03	1979	42	10	10	60193	.326	2.434	4.9	82	645	36
	64	06-0085-004-02	03	I979	46	10	10	30659	.266	2.149	9.2	107	626	25
	65	06-0085-005-02	03	1979	36	9	10	39515	.749	6.643	7.1	72	756	24
	66	06-0094-002-02	03	1979	19	14	12	19203	.308	3.158	2.7	98	1144	?

TOTAL COLIFORMS REPORTED AS GEOMETRIC MEANS
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Study Map No.	Station ID	Region	Year	Rating	Rec. Used	Rec. Read	Total Coliforms /100 ml	Total Phos. mg/L-P	Filtered NO_3 mg/L-N	5 DAY B.O.D mg/L	Diss. Oxygen % SAT	Total Solids mg/L	TURB. FTU
67	06-0097-002-02	03	1979	62	12	12	1203	.100	1.966	.9	88	454	18
68	06-0097-003-02	03	1979	54	12	12	2389	.170	2.809	1.7	96	491	22
69	06-0097-005-02	03	1979	59	12	12	1452	.115	2.027	1.1	88	499	26
70	06-0104-001-02	03	1979	63	12	12	3167	.103	.833	1.0	89	363	17
71	06-0104-003-02	03	1979	42	12	12	20835	.257	13.852	3.0	83	447	16
72	06-0104-005-02	03	1979	71	12	12	754	.047	.769	.4	90	343	15
73	06-0107-001-02	03	1979	68	11	12	359	.052	.750	.8	99	433	11
74	06-0108-001-02	03	1979	65	11	12	902	.086	.791	1.2	96	383	14
75	06-0109-003-02	03	1979	41	11	12	7674	.775	7.956	4.1	91	649	18
76	06-0111-001-02	03	1979	69	10	11	1048	.053	.613	.7	98	359	10
77	06-0114-002-02	03	1979	50	11	12	10429	.295	.913	10.4	76	671	11
78	06-0112-001-02	03	1979	62	11	12	1630	.069	.969	1.1	95	719	17
79	06-0116-001-02	03	1979	73	11	12	907	.037	.604	.4	102	279	9
80	06-0116-002-02	03	1979	55	10	12	7425	.205	1.947	2.5	96	357	8
81	06-0116-003-02	03	1979	69	12	12	1040	.041	1.687	.6	97	308	8
82	06-0117-002-02	03	1979	70	12	12	526	.020	2.366	.4	91	380	3
83	06-0118-001-02	03	1979	76	12	12	235	.031	.455	.4	99	277	6
84	06-0129-001-02	03	1979	72	12	12	738	.053	.527	.5	101	287	11
85	06-0130-001-02	03	1979	73	12	12	491	.043	.723	.7	102	300	8
86	06-0133-001-02	03	1979	66	11	11	79	.336	.664	1.3	101	335	2
87	06-0142-001-02	03	1979	76	11	12	375	.034	.497	.7	95	268	4
88	06-0146-001-02	03	1979	66	11	12	3204	.102	.647	.5	96	311	6
89	06-0148-001-02	03	1979	74	11	12	302	.037	1.024	.5	92	283	3
90	06-0151-001-02	03	1979	71	10	12	721	.037	.985	.4	92	336	5
91	06-0152-001-02	03	1979	71	11	12	642	.056	.670	.5	91	320	6
92	06-0180-002-02	03	1977	74	8	12	97	.023	.097	.7	91	206	3
93	06-0183-002-02	03	1978	63	7	12	496	.072	.116	.8	52	413	4
94	08-0010-001-02	01	1979	48	10	10	6435	.106	10.214	1.5	98	496	32
95	08-0022-002-02	01	1979	46	8	12	11739	.290	4.631	4.6	110	464	17
96	08-0012-007-02	01	1979	57	7	12	2413	.066	6.663	1.3	90	366	2
97	08-0022-010-02	01	1979	59	8	12	646	.060	6.722	1.6	90	347	4
98	08-0022-011-02	01	1979	58	6	12	724	.107	5.153	1.8	71	376	9
99	08-0056-002-02	01	1979	61	7	12	1790	.067	4.939	1.0	88	319	9
100	08-0056-003-02	01	1979	64	6	12	432	.243	3.552	1.1	96	376	5

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ANNUAL WATER QUALITY RATINGS AND
DATA FOR LONG-TERM STATIONS1979*

Study	Map No.	Station ID	Region	Year	Rating	Rec. Used	Rec. Read	Total Coliforms /100 ml	Total Phos. mg/L-P	Filtered NO_3 mg/L-N	5 DAY B.O.D mg/L	Diss. Oxygen % SAT	Total Solids mg/L	TURB. FTU
	101	08-0056-004-02	01	1979	67	6	12	784	.057	3.183	1.0	93	347	4
	102	09-0056-006-02	01	1979	40	6	12	39471	.713	3.350	4.2	54	461	5
	103	08-0056-007-02	02	1979	52	6	12	3133	.131	3.007	2.2	62	374	4
	104	08-0056-009-02	01	1979	55	6	12	2230	.211	3.335	2.1	83	411	5
	105	00-0076-001-02	01	1979	68	7	12	272	.058	1.961	1.0	103	329	26
	106	08-0076-002-02	01	1979	65	7	12	4711	.059	1.463	1.0	94	334	7
	107	00-0123-002-02	01	1979	74	10	12	586	.023	.888	.5	93	340	4
	108	08-0123-003-02	01	1979	76	9	10	778	.022	.597	.6	89	258	8
	109	08-0123-004-02	01	1979	67	10	12	906	.065	2.611	.6	85	320	3
	110	08-0123-005-02	01	1979	75	10	12	1370	.022	.356	.6	89	245	?
	111	08-0123-006-02	01	1979	75	10	12	178	.032	1.372	.5	85	292	2
	112	08-0135-002-02	01	1979	70	9	9	654	.052	1.023	.7	90	316	3
	113	08-0135-003-02	01	1979	78	11	11	139	.026	.417	.7	91	265	4
	114	09-0008-001-02	02	1979	64	12	12	3202	.103	.819	1.2	98	461	6
	115	09-0009-001-02	02	1979	54	10	11	2385	.169	1.633	3.1	121	518	20
	116	09-0009-002-02	02	1979	64	10	11	3615	.034	2.539	.8	102	451	3
	117	11-0001-005-02	02	1979	56	12	12	15278	.151	.926	1.6	82	234	51
	118	12-0002-005-02	04	1978	62	9	11	826	.128	.409	1.9	65	358	9
	119	12-0002-007-02	04	1978	58	9	12	2881	.112	.548	1.3	95	555	26
	120	12-0004-001-07	04	1977	74	6	11	287	.044	.176	1.7	95	151	4
	124	12-0004-002-02	04	1977	79	5	11	28	.034	.130	2.0	96	132	3
	122	12-0004-004-02	04	1977	87	8	12	7	.026	.042	1.6	107	108	1
	123	12-0004-007-02	04	1977	67	8	12	570	.094	.135	1.8	81	205	10
	124	12-0017-001-02	04	1977	70	8	16	1216	.071	.107	1.7	84	140	4
	125	12-0017-004-02	04	1977	80	8	12	52	.036	.157	1.7	95	154	2
	126	12-0034-001-02	04	1977	52	7	11	33849	.209	.368	3.1	73	391	10
	127	14-0028-017-02	05	1978	46	7	10	162	1.286	1.964	1.9	40	688	3
	128	16-0027-001-02	01	1979	43	9	9	30258	.204	9.440	1.8	96	624	19
	129	16-0072-004-02	01	1979	17	7	8	8661	.166	4.814	2.2	72	524	55
	130	16-0124-003 02	02	1979	71	12	12	204	.053	1.580	0.5	92	350	15
	131	16-0126-001-02	02	1979	72	12	12	612	.034	1.115	0.4	91	287	8
	132	16-0159-001-02	02	1979	66	12	12	326	.078	1.956	0.9	100	381	10
	133	16-0159-002-02	02	1979	63	12	12	1066	.130	2.461	0.6	100	380	4
	134	16-0164-001-02	02	1979	63	12	12	581	.108	1.286	1.4	106	407	20

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Study	Map No.	Station ID	Region	Year	Rating	Rec. Used	Rec. Read	Total Coliforms /100 ml	Total Phos. mg/L-P	Filtered NO_3 mg/L-N	5 DAY B.O.D mg/L	Diss. Oxygen % SAT	Total Solids mg/L	TURB. FTU
	135	16-0164-009-02	02	1979	65	12	12	327	.050	3.046	.5	95	491	10
	136	16-0184-010-02	02	1979	63	12	13	1030	.092	2.371	1.0	100	402	5
	137	16-0184-012-02	02	1979	62	12	13	790	.155	2.388	1.1	99	388	10
	138	16-0584-015-02	02	1979	69	12	13	619	.057	1.773	.9	93	314	9
	139	16-0184-016-02	02	1979	45	12	12	40049	.251	3.703	3.2	82	660	11
	140	16-0184-017-02	02	1979	68	46	48	418	.082	1.762	1.0	96	282	18
	141	16-0164-019-02	02	1979	76	12	12	202	.046	.029	1.2	88	154	7
	142	16-0184-024-02	02	1979	63	17	13	925	.082	2.342	1.3	95	450	12
	143	16-0184-026-0?	02	1779	36	12	12	930	1.827	14.528	1.5	106	541	4
	144	16-0184-027-02	02	1979	62	12	12	1254	.130	2.423	1.3	101	482	13
	145	16-0184-028-02	02	1979	67	12	12	937	.070	1.687	1.0	90	331	10
	146	16-0184-029-02	02	1979	64	12	12	1076	.110	2.830	.9	96	320	20
	147	16-0184-031-02	02	1979	64	12	12	946	.077	3.177	.9	95	399	9
	148	16-0184-032-02	02	1979	62	12	12	1165	.114	3.064	.8	90	366	13
	149	16-0184-033-02	02	1979	62	12	12	1432	.070	3.529	.7	99	440	7
	150	16-0184-034-02	02	1979	67	12	12	2901	.047	1.182	1.5	100	379	5
	151	16-0184-036-02	02	1979	57	12	12	3020	.102	2.115	2.3	72	395	4
	152	16-0184-037-02	02	1979	76	46	48	206	.039	.553	.7	99	253	6
	153	16-0184-038-02	02	1979	56	12	12	1127	.136	4.536	1.0	107	554	4
	154	16-0184-039-02	02	1974	74	12	12	649	.039	.447	.8	97	236	4
	155	16-0184-041-02	02	1979	67	12	12	542	.066	1.979	.9	93	339	8
	156	16-0184-042-02	02	1979	68	12	12	920	.085	1.432	1.4	101	305	10
	157	16-0184-043-02	02	1979	75	46	48	233	.026	.918	.8	87	286	3
	159	16-0184-044-02	02	1979	61	12	12	2746	.103	1.727	.9	88	444	6
	159	17-0021-002-02	03	1979	78	10	12	62	.037	.080	1.9	86	148	7
	160	17-0021-004-02	03	1979	77	10	11	121	.048	.089	1.6	94	153	5
	164	17-0021-005-02	03	1979	80	10	12	61	.028	.082	1.8	93	147	5
	162	17-0021-006-02	03	1979	79	11	11	119	.020	.087	3	86	182	2
	163	17-0021-007-02	03	1979	79	12	12	101	.024	.180	.4	84	263	1
	164	17-0021-008-02	03	1979	70	9	9	274	.032	.118	.6	92	144	2
	165	17-0021-013-02	03	1979	83	11	12	50	.017	.081	.5	94	128	2
	166	17-0026-001-02	04	1978	77	6	13	115	.033	.104	.8	117	149	2
	167	17-0037-001-02	04	1977	64	7	15	814	.106	.545	1.9	88	284	16
	168	18-2590-020-02	04	1978	54	12	12	3058	.155	.385	1.4	83	688	58

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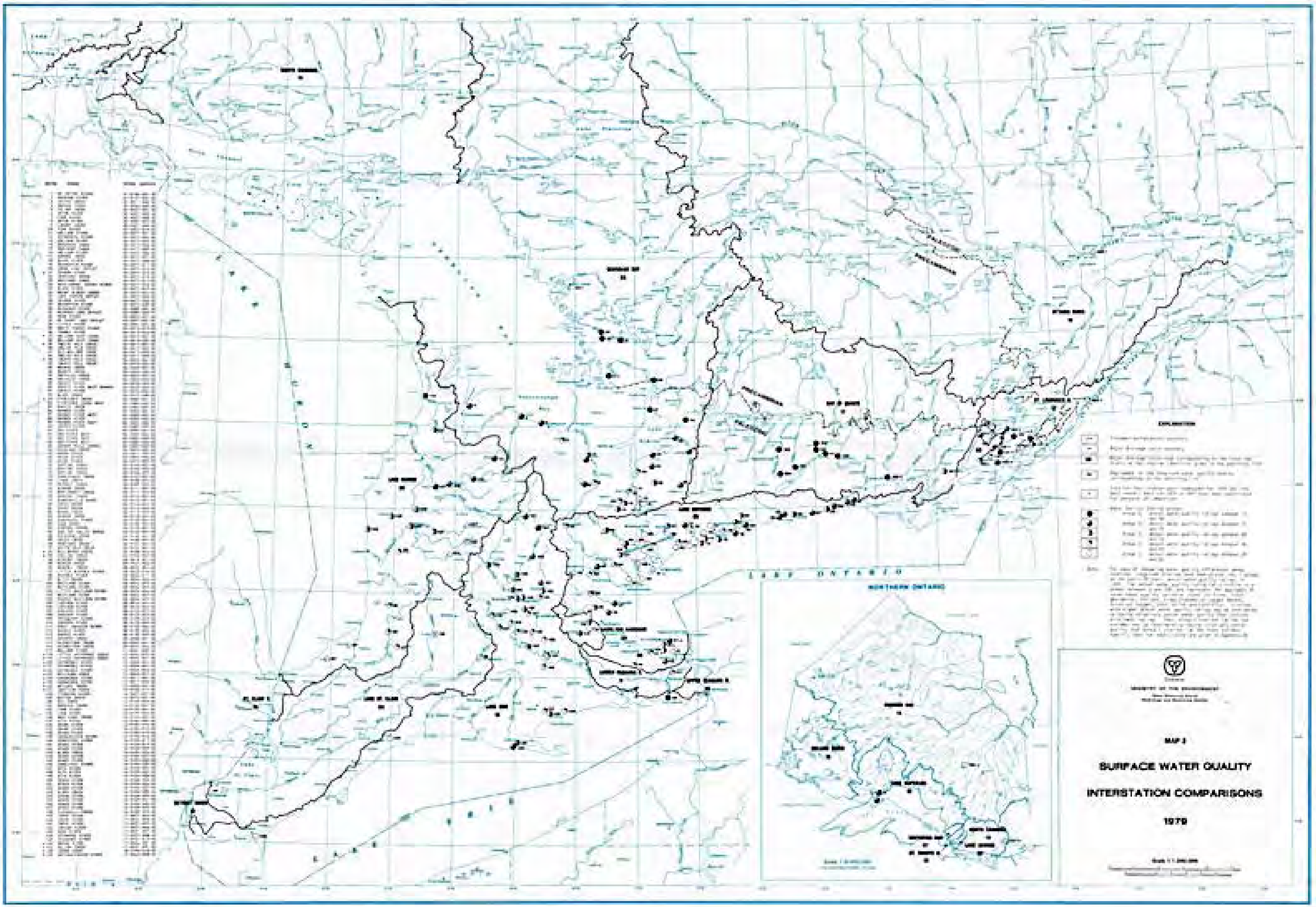
	169	19-0064-008-02	05	1978	66	10	11	711	.116	.382	1.9	21	223	4
MEAN					65	11	13	4815	.134	1.717	2.1	89	379	12
MIN					28	5	8	7	.006	.029	.3	21	32	1
MAY					88	46	48	99887	1.827	14.528	82.7	121	1143	115



SURFACE WATER QUALITY
INTERSTATION COMPARISONS
1979