Williams Lake, Halifax, Nova Scotia

An Investigation of the Aquatic Ecosystem of an Urbanizing Watershed

by

Richard Scott

Prepared for

Nova Scotia Department of the Environment

January 1992

Table of Contents

List of Figures ii

List of Tables ii

Introduction 1

Historical Review 1

Materials and Methods 2

Results and Discussion 7

Water Quality 8

- pH 8
- Turbidity 9
- Secchi Disk 10
- Specific Conductance 10
- Apparent Color 11
- Total Phosphorus 11
- Total Nitrogen 12
- Chlorophyll a 14
- Chloride 14
- Road Salt 15

Urban Runoff 16

Control of Stormwater 18

Fishing Potential 19

Dam Structure 21

Summary.....22

References.....24

Appendix.....25

List of Figures

1 Bathymetric map and water quality sampling locations..... 3

2 Sub-watershed boundaries..... 5

3 Time plot for pH..... 8

4 Time plot for turbidity..... 9

5 Time plot for specific conductance..... 11

6 Time plot for color..... 12

7 Time plot for total phosphorus..... 13

8 Time plot for total nitrogen..... 13

9 Time plot for chlorophyll a..... 14

10 Time plot for chloride..... 15

11 Relationship between Morphoedaphic Index and angling yield..... 20

List of Tables

1 Surface area, stratum interface areas, stratum volumes and total volume..... 4

2 Physical features of Williams Lake and its drainage basin..... 6

Introduction

In July, 1989, the Centre for Water Resources was approached by the Williams Lake Conservation Company of Halifax, Nova Scotia on behalf of the Nova Scotia Department of the Environment (NSDOE) to outline a field study of Williams Lake to document and evaluate the water quality of the lake. The study, funded by the NSDOE, began in November, 1990 with the collection of the first of five sets of lake and stream water samples for water quality analysis. The citizens group was concerned with road salting activities in the watershed and what impact it may have on the ecosystem. They were also concerned with the excessive aquatic plant growth in the lake. The group wanted information to assist them in their endeavour to maintain the lake as a valuable surface water resource.

This report documents and discusses the water quality characteristics of the surface waters between November, 1990 and September, 1991. The impacts of residential and commercial developments within the Williams Lake watershed are described. In addition, watershed management techniques which could be utilized to minimize the effects of current and future urban developments are presented. The wildlife and fishery of the watershed is also addressed.

Historical Review

The following section was extracted from a document written by Mr. Allan MacKinnon for the Williams Lake Conservation Company Limited.

> Interest in Williams Lake and its potential economic benefits began with the first land grants issued in 1760 to Captain Daniel Hill. Previous to this grant, however, there is considerable evidence that the Mic Mac Indians used the waterway on their summer trek to the salmon river now known as McIntosh Run. Artifacts (arrowheads) have been found along the route and there have been what is suspected to be teepee rings located near Colpitt Lake. Captain Hill's grant contained approximately 500 hectares which included the outfall at the eastern end of the lake. When Hill died in 1772, his wife Elizabeth sold the property to a land speculator, John Murphy, who resold it along with an adjacent grant to James Williams in 1780. A 200 hectare parcel of land in the watershed belonging to William Spry was sold in 1783 to George McIntosh. Mills were erected at the outfall of the lake and the remaining tillable land was farmed for the next 20 years. In 1807, the mill belonging to McIntosh and William Cochran was advertised for sale. In 1811 the mill was purchased by Robert Letson of New York. A print dated 1818 identifies the mill as a three-story building with a gabled roof sitting on a high foundation. Letson's son operated a tannery, also powered by the outfall stream. By this time, Williams Lake, formerly known as Letson's Lake, was a favorite retreat for town's people. Joseph Howe visited the lake so often that a split rock near the outlet dam became known as Howe's rock. Letson's mill and property were sold in 1822. The mill burned two months after this sale. The new owner, Richard Dingle, rebuilt and in 1831 leased the

mill to William Letson for a five year period. during which he added a grist mill. In 1846. William and Elizabeth Yeadon purchased a 1.9 km^2 (1900 hectares) parcel of land on the western and southern sides of the lake for 40 pounds. In 1865. the Halifax Ice Company was formed by G.H. Wolfe of Windsor. He leased the property from Henry Lawson and shipped ice from Lawson's wharf at the mill cove. In 1881. Lawson sold the property to Miles and Chittick who operated the ice business for another 10 years. Chittick later became a Dartmouth ice merchant with a large ice house on Mic Mac Lake. The Chittick mill was sold to the Atlantic Sugar House Company who developed the mill into a sugar refinery. The refinery property along with its water rights were purchased sometime in the early 1900's by A.E. Gilpin.

The first permanent residents of the lake was the Dan Serrich family. who located on the peninsula of the present day Willowdale Subdivision. A carpenter by trade. Mr. Serrich built row boats which he rented to the many fisherman who flocked to the lake each spring. "At that time. 1920. there was a small pond (now Willowdale Terrace) and they had a productive garden on the slope beyond".

Intense urbanizing activity commenced between 1950 and 1953. As a result of concern for the impact of this development. the citizens of Hall's Road in 1955 petitioned the county for restrictions on lot size and septic system design. By 1964. lots were sold on Wyndrock Drive. These lots were serviced by sewer and water. In 1968. the dam structure was rebuilt by Commander Law and Charles Fowler. The Williams Lake Conservation Company was formed at this time.

Stormwater runoff from the area was routed to Williams Lake. particularily in the final design of the Pine Bluff Subdivision. A number of wetland areas were lost to the development. The extension of Wyndrock Drive into Pine Bluff resulted in the isloation of a small portion of Williams Lake into what is now known as Martins Pond.

Materials and Methods

Williams Lake was sampled on five occasions between November 1990 and September 1991. Lake water samples were collected from 4 stations positioned throughout the lake. Water column sampling depths for each lake station were identified based on temperature and oxygen profiles of each station. Samples were retrieved using a 2 litre Kemmerer bottle and stored in one litre. wide-mouthed polyethylene bottles which had been previously cleaned with surfactant and thoroughly rinsed with distilled water. Inlet and outlet samples were taken by submerging the polyethylene bottle under the surface while being careful to avoid disturbing or collecting bottom sediment. In addition to the five site visits. two of the inlet streams were sampled during precipitation events. Sampling locations are identified in Figure 1.

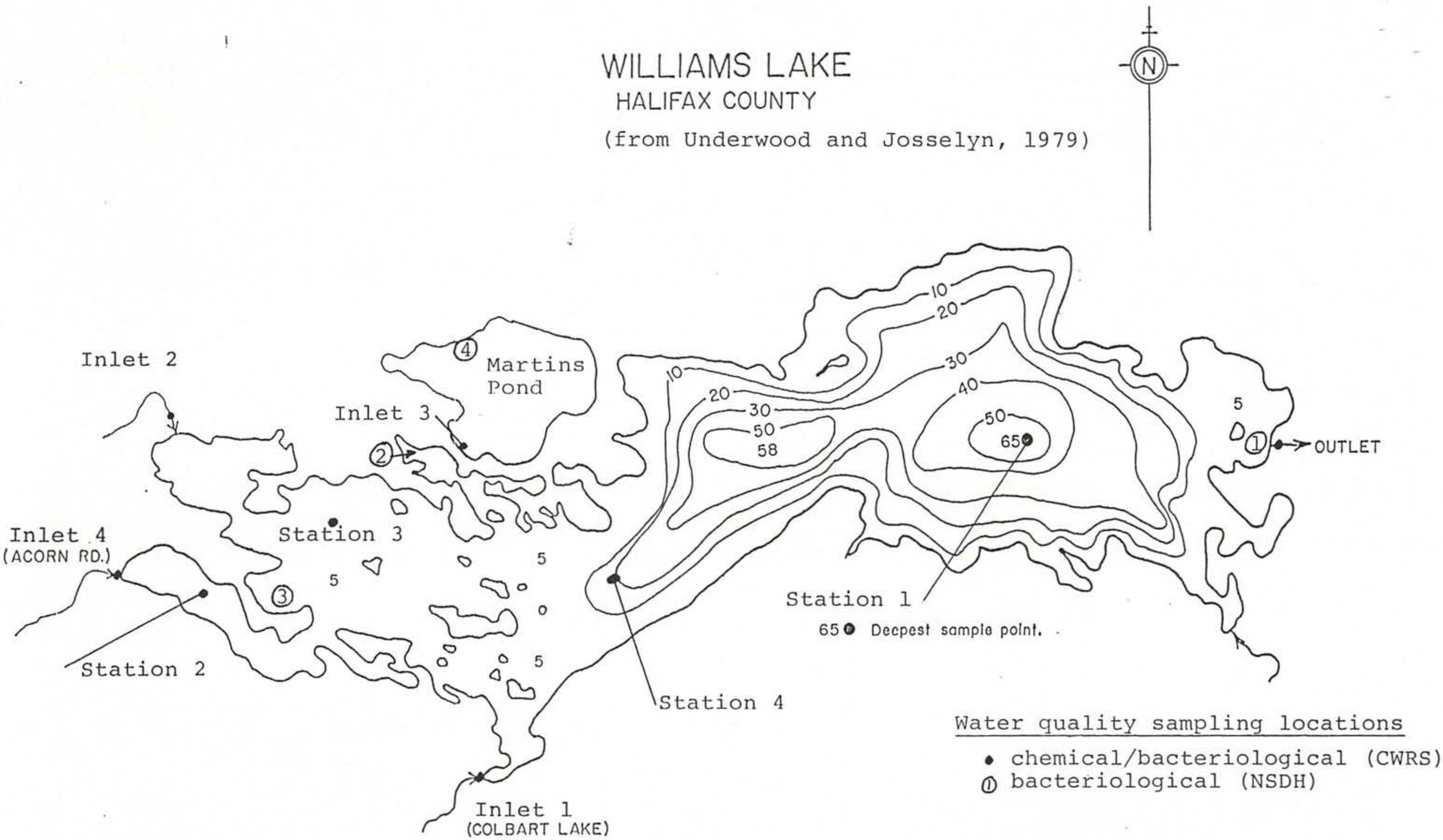


FIGURE 1 - Bathymetric Map Showing Water Quality Sampling Locations

TABLE 1

Table Surface area, stratum interface areas, stratum volumes and total volume of Williams Lake. (based on bathymetric map contained in Dean and Lister (1971) and surface area given in Underwood and Josselyn (1979)

Depth Meters	Hectares	% of Total	Stratum	$m^3 \times 10^4$	% of Total
Basin 1					
0	32.73	74.7	0 - 1	23.87	13.5
1	27.78	63.4	1 - 2	19.95	11.3
2	22.83	52.1	2 - 3	17.15	9.7
3	20.62	47.1	3 - 4	15.40	8.7
4	18.41	42.0	4 - 5	13.65	7.7
5	16.19	37.0	5 - 6	12.18	6.9
6	14.68	33.5	6 - 7	10.97	6.2
7	13.11	29.9	7 - 8	9.75	5.5
8	11.59	26.5	8 - 9	8.52	4.8
9	10.02	22.9	9 - 10	7.30	4.1
10	8.50	19.4	10 - 11	6.23	3.5
11	7.28	16.6	11 - 12	5.26	3.0
12	6.06	13.8	12 - 13	4.27	2.4
13	4.78	10.9	13 - 14	3.27	1.8
14	3.55	8.1	14 - 15	2.30	1.3
15	2.33	5.3	15 - 16	1.67	0.9
16	1.92	4.4	16 - 17	1.35	0.8
17	1.51	3.5	17 - 18	1.03	0.6
18	1.11	2.5	18 - 19	0.71	0.4
19	.70	1.6	19 -20	0.38	0.2
20	.29	0.7	20 - 20.3	0.02	0.0
20.3	.00	0.0			

Mean depth - 5.05 m

Depth Meters	Hectares	% of Total	Stratum	$m^3 \times 10^4$	% of Total
Basin 2					
0	11.07	25.3	0 - 1.5	11.77	6.6
1.5	*8.85	*20.2			

Mean depth - 1.06 m

Total lake area - 43.8 hectares
Total lake volume - 177.0 x $10^4 m^3$
Mean depth (whole lake) - 4.0 meters
*estimate

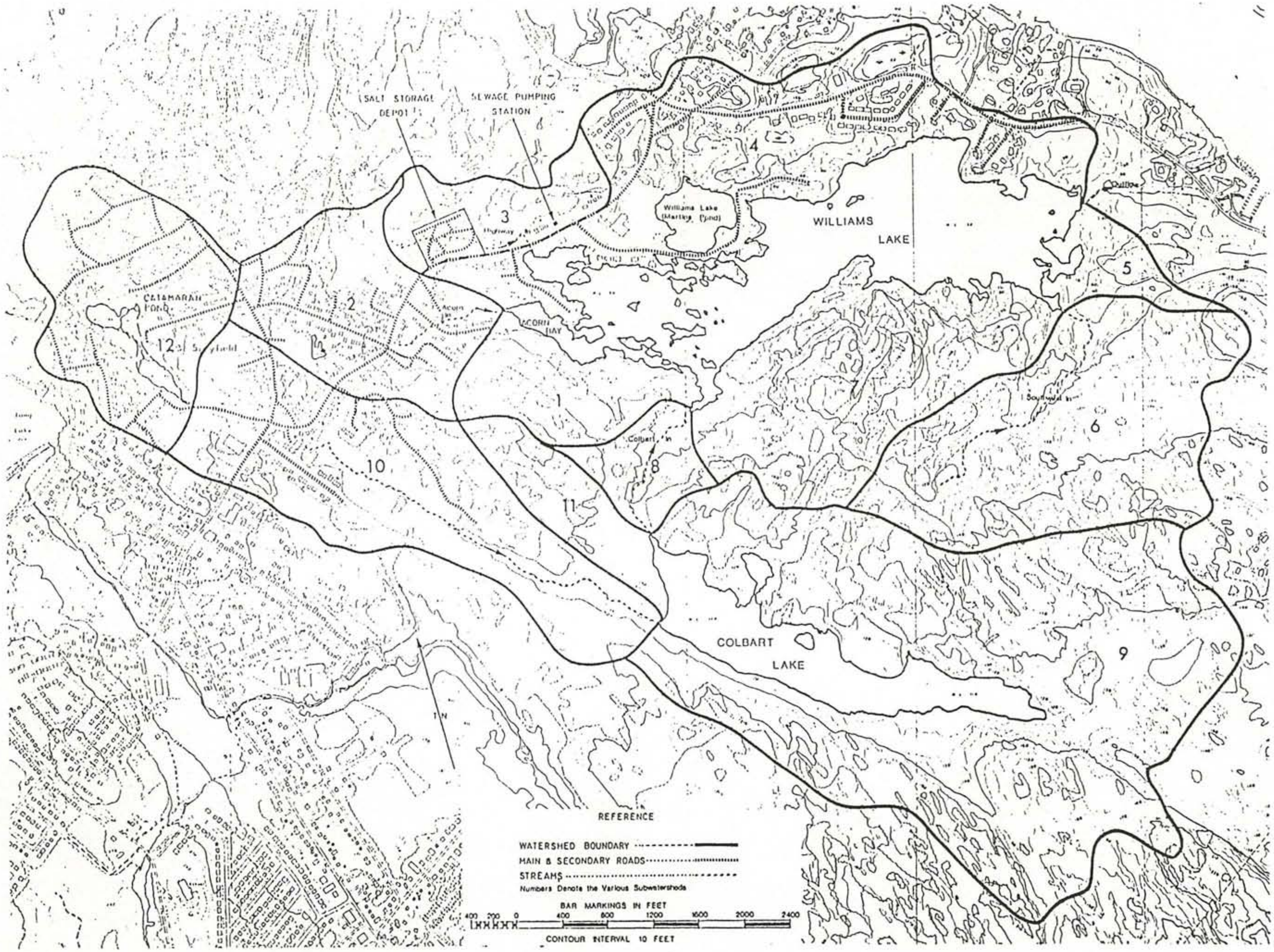


FIGURE 2 - Drainage Basin with Sub-Watershed Boundaries Identified
(from Underwood and Josselyn, 1979)

TABLE 2

TABLE . SOME PHYSICAL FEATURES OF WILLIAMS LAKE AND ITS DRAINAGE BASIN

WATERSHED UNIT	AREA (ha)	RUNOFF* $L \cdot yr^{-1} \times 10^{6}$	Km ROADS
1	13.5	137.2	0
2	27.2	275.9	2.64
3	11.8	120.0	0
4	45.1	457.7	3.26
5	6.3	64.4	0
6	45.7	464.2	0
7	36.8	374.1	0
8	7.6	77.5	0
9	101.5	1030.8	0
10	44.1	448.2	1.44
11	10.6	108.1	0
12	28.9	293.5	2.59
CATAMARAN POND	1.0		
COLBART LAKE	15.3		
SUBTOTAL	395.4	3851.6	9.93
WILLIAMS LAKE	43.8		
TOTALS	439.2	3851.6	9.93

Williams Lake Volume $1.77 \times 10^{6} m^{3}$, Water residence time .39 yrs mean depth 3.9 m

* Using figure of 101.6 cm

Physical features of the Williams Lake watershed were adopted from Underwood and Josselyn (1979) and used to produce stratum areas and stratum volumes presented in Table 1. These values were utilized in the calculations of weighted means. Sub-watershed physical features and boundaries (Underwood and Josselyn, 1979) are presented in Table 2 and Figure 2, respectively.

Samples were kept in insulated containers in the field and were transported to the laboratory as soon as possible after collection where they were stored at 4°C until analysis took place. All samples were analyzed at the CWRS laboratory for pH, turbidity, color, total phosphorus, total nitrogen, chloride, and chlorophyll a. Volume-weighted composite samples for metal analysis prepared at the CWRS laboratory and samples collected for bacteriological analysis were tested by the Victoria General Hospital. Chemical and bacteriological analyses for the five sampling dates, storm event data and lake water metal scan composite data are presented in Tables A-1 to A-3, respectively. Volume-weighted means were calculated and presented in Table A-4 of the Appendix. Volume-weighted means consider the actual weight of each parameter in each layer and therefore provide a more accurate estimate of average lake characteristics.

Additional information included in the Appendix are bacteriological data for locations monitored by the Nova Scotia Department of Health between 1986 and 1991, and a fish stocking record for the period 1976 to 1990, which are given in Tables A-5 and A-6, respectively.

Results and Discussion

Clearly, different water-use interests desire differing water quality characteristics. Management of the Royal Nova Scotia Yacht Squadron and the Saraguay Club, who utilize water draining from Williams Lake as a potable water supply, require a resource that needs minimum pre-distribution treatment, essentially of excellent water quality. The residents of Williams Lake are demanding a resource that is suitable for fishing and swimming and is asethetically pleasing. The provincial Department of Fisheries require a water body to meet certain physical and water quality criteria before it is approved for stocking. Acceptable and objective levels of numerous chemical constituents have been established for specific water uses (Appendix).

The residents of Williams Lake are conscious of the lake water quality because of the recreational and aesthetic benefits to living in the area. Their concern for the receiving waters of urbanizing areas is justified, especially as it pertains to the subject of urban runoff. Degredation of water quality may jeopardize continued presence of numerous species of wildlife which inhabit the lake and its watershed. Mr. Allan McKinnon writes, "The area supports populations of beaver, mink, rabbits, squirrels, raccoons, and muskrat. Frequent visitors to the lake include blue and green heron, red-tailed hawk, osprey and owl. Other less frequently observed species include deer, bobcat, coyote, weasel, black bear, porcupine and sea otter." Ducks and seagulls also use the lake.

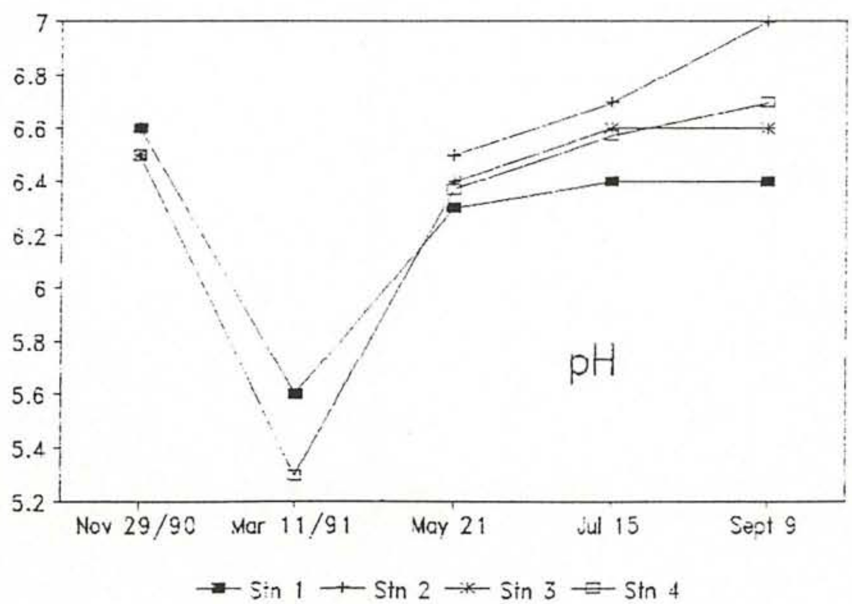
Water Quality

An irregular shoreline, numerous islands and depth separate Williams Lake into one large, deep basin and a second shallower basin. The shallow basin is sectioned into three main parts, two of which receive direct urban runoff. Martins Pond, created as the result of the extension of Wyndrock Drive, was not a major part of this study in that only water leaving the pond was analysed. The water quality associated with each basin monitored (Stations 1, 2, 3 and 4) varies. Major inflows to Williams Lake are located in the shallower western end (Basin 2) of the lake. Two of these inflows, Inlets 2 and 4, for the most part, are governed by urban runoff. Inlet 1 drains Colbart Lake, while Inlet 3 drains Martins Pond. The current surface water drainage patterns of Williams Lake are such that Basin 2 and Martins Pond act as stormwater filters for Basin 1. Aquatic plant growth in the western end of the lake enhances nutrient removal during the growing season as water moves toward the outlet. The increased plant production, however, results in an increased rate of sediment buildup. Residents have complained of excessive weed growth and smells produced from stagnant water and from sediments exposed as a result of receding lake levels during the summer months. These seasonal lake characteristics are especially persistent in the cove at the foot of Acorn Drive.

pH

Seasonality of Williams Lake pH is typical of most lakes with similar watershed characteristics (Figure 3). The depression of pH in the lake observed during the late winter sampling period is caused by the injection of acidic snowmelt and rainwater into the system and by the winter-long build up of carbon dioxide under the ice cover (the presence of an ice cover during

Figure 3.

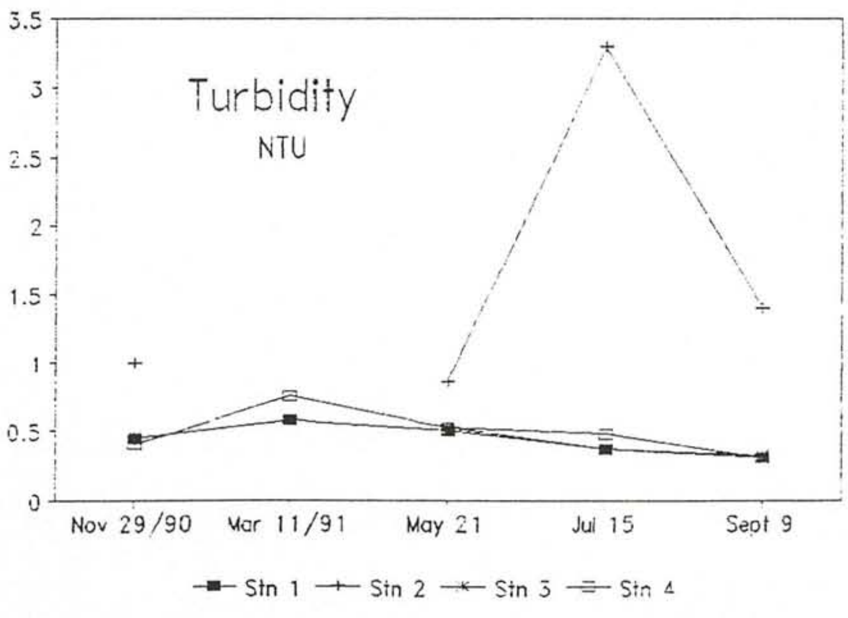


the winter months reduces the depth to which photosynthesis takes place (the trophogenic zone), in effect reducing the rate at which carbon dioxide (produced by bacteria consuming organic matter) is utilized by photosynthetic plants and algae. Hence, the resulting increase in carbon dioxide, a component governing pH, leads to a decrease in pH). The degree to which a lake reacts to the melt-water varies with each lake. The spring depression of pH is typical for Nova Scotian lakes due to the acidic nature of our precipitation. pH also decreased with depth in the stratified Basin 1. Stratification refers to a definite temperature gradient with depth in which three distinctive layers of similar temperature are present. The upper, circulating warm layer is referred to as the epilimnion; the middle layer of rapidly decreasing temperature is the metalimnion; and the bottom layer of cool water of uniform temperature is the hypolimnion. This pH decrease is the result of a net increase of carbon dioxide content (the process by which a net increase in carbon dioxide is observed is identical to that described above for the winter situation).

Turbidity

Turbidity is caused by suspended matter, such as clay particles, finely divided organic and inorganic matter, and plankton and other microscopic organisms. In clear (colorless) lakes like Williams Lake, the level of turbidity is reflected in the ability of an individual to see the lake bottom, for instance. The turbidity of the two main basins of Williams Lake is low. The

Figure 4.



exception to this generalization is the small cove at the foot of Acorn Drive (Figure 4). This cove, receiving drainage from Inlet 4, experiences occassional turbid conditions, usually associated with rainfall events. Other areas include Martins Pond and the western end of

Williams Lake at Inlet 2. These locations are severely impacted upon by discharging stormwater. Low values of turbidity observed in the main basin of Williams Lake (Stations 1 and 4) indicate that this phenomenom is restricted to these areas.

Secchi Disk

The measurement for water transparency is obtained using a Secchi disk, which is a 20cm diameter disk broken up into quadrants of alternating black and white sections. The Secchi depth is the depth at which the disk, when lowered into a water body, can no longer be seen. Transparency decreases as turbidity increases. The only location offering sufficient depth for a reading was Station 1. The Secchi disk was still visible at the bottom at the shallowerer stations. The readings at Station 1 ranged between 4.5 and 7.5 metres. The influence of an ice cover is reflected in the fact that the minimum value of 4.5 metres was recorded during the winter period. The lack of particulate and organic matter in Williams Lake during the ice-free season led to little variability in Secchi disk readings.

Specific Conductance

Specific conductance is the numerical expression of the ability of an aqueous solution to carry an electrical current. The measurement depends on the presence of total dissolved solids, their concentration and the solution's temperature.

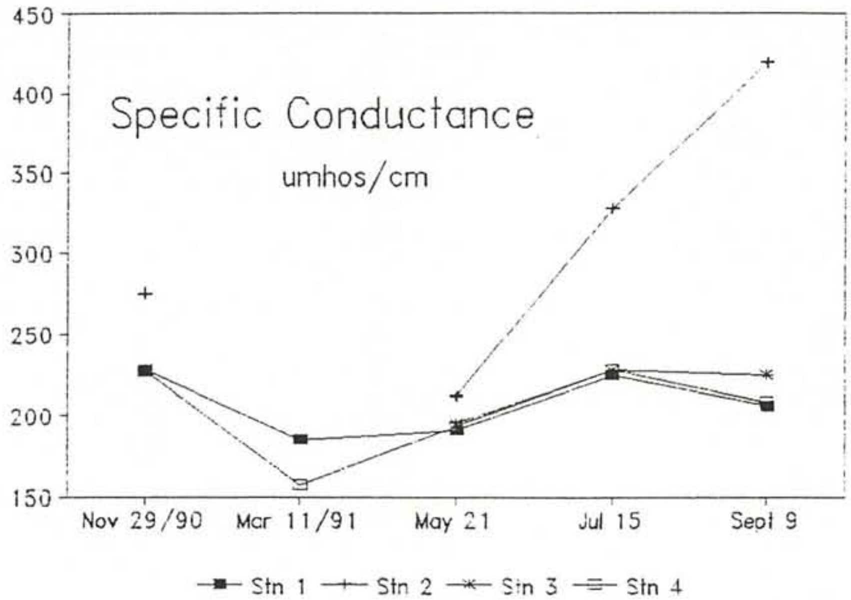
To give the reader a means of comparison, a few examples of specific conductance relative to other water sources are: distilled water is less than 5 umhos/cm, City of Halifax tapwater is 70 to 90 umhos/cm, and seawater is greater than 30,000 umhos/cm.

Specific conductance at all inlake locations sampled during the study varied with the season (Figure 5). Maximum values were recorded in July at which time chloride levels also peaked. This particular lake response gives us a glimpse of the lag between the cessation of road salt application in the watershed and length of time before the maximum impact on receiving surface waters is observed. Data collected during the study indicate a 3 month lag. The relationship between specific conductance and the concentration of chloride (see Section on Chloride) in Williams Lake allows for the estimation of chloride from a specific conductance reading using the following equation:

$$\text{Chloride (mg/L)} = .202\ (\text{specific conductance, umhos/cm}) + 2.48 \qquad (r^2 = .971,\ n = 68)$$

With proper equipment and the formula above, the lay-person could easily obtain and convert a reading of specific conductance into a scientifically acceptable estimation of chloride. This technique of data aquisition could be used to answer future inquiries regarding salt in Williams Lake.

Figure 5.



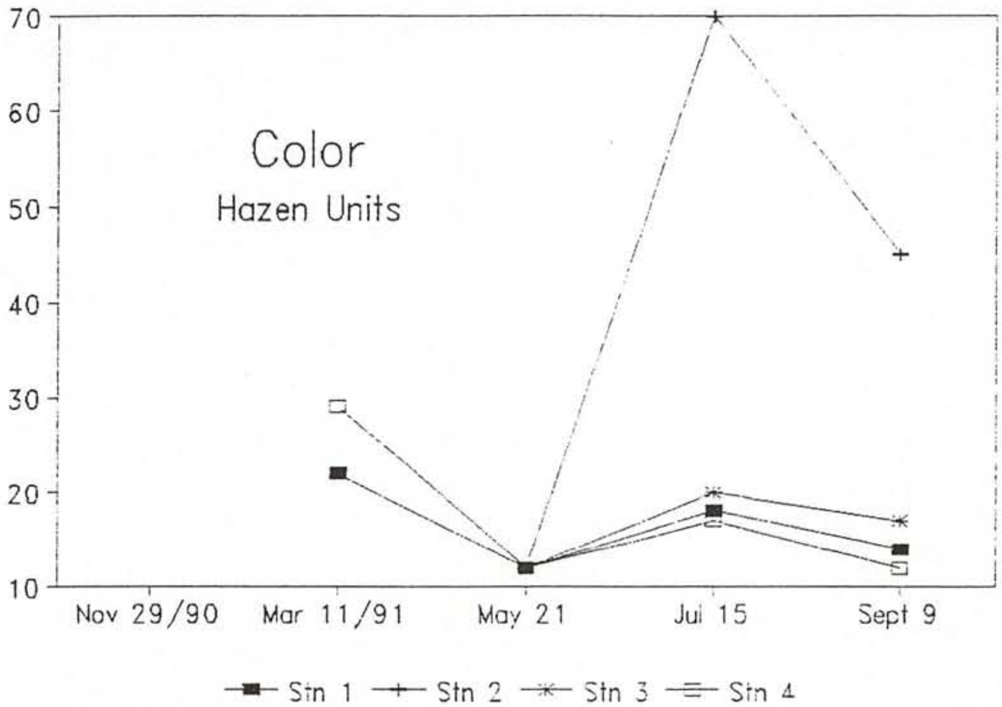
Apparent Color

The absence of coloring agents in the Williams Lake watershed, chiefly dissloved organic compounds derived from peat and marsh detritus, yields a near colorless surface water. The mean apparent color value observed for Williams Lake was 17 Hazen Units. Higher readings at Station 2 (Acorn Drive cove) are not a reflection of the organic content of this sub-watershed but of the nature of the test, in that the measurement is influenced by turbidity. The increase in color from 35 to 80 Hazen Units observed in Inlet 1 are not accompanied by similar increases in turbidity (Figure 6). The increase is likely due to the reduced movement of water through the system resulting in longer contact time with color producing material present in the sub-watershed .

Total Phosphorus

The role of phosphorus in lake eutrophication has been investigated for decades. Researchers have identified phosphorus as the element most likely to determine the amount of algal growth in surface waters. Lakes can be classified based on the amount of this nutrient present as oligotrophic (low), mesotrophic (moderate) and eutrophic (high). Physical features associated with each category are: oligotrophic - clear water with high visibility, and low algal growth (not to be confused with plant growth); mesotrophic - higher production of algae reducing the lake transparency, loss of sensitive fish species (trout) to more tolerant species (bass, sucker etc.); and eutrophic - low transparency, unsuitable for recreational use.

Figure 6.



Based on a mean annual phosphorus concentration of 8.1 ug/L, Williams Lake is oligotrophic. There are areas in the lake, which because of their shallowness. have significant amounts of aquatic plant growth. This is not a reflection of the trophic level of the lake but an example of how morphology (lake basin shape) effects the appearance of a lake. The nutrients necessary for these plants are derived mainly from the sediments. A portion is also obtained from surface waters entering the lake via streams and stormsewers. Sufficient growth of plants in the western end of the lake is a benefit to the trophic status and aesethic properties of the larger, deeper basin. The plants filter out much of the nutrient load entering the lake from both the urban drainage system and properties bordering the lake through processes of sedimentation and chemical and biological uptake. In lake total phosphorus measurements for the study period are plotted in Figure 7.

Total Nitrogen

Nitrogen is the second most important nutrient in the eutrophication process. Unlike phosphorus, nitrogen has a gaseous phase which facilitates movement through the aquatic environment. It it for this reason that nitrogen is seldomly considered to be a limiting or controlling factor in the eutrophication process. Total nitrogen levels in Williams Lake are indicative of oligotrophic waters (Figure 8). A value of 0.3 mg/L is suggested as an average upper limit for nitrogen in oligotrophic systems. Elevated levels observed for Inlet 4 (Acorn Drive) are typical of urban runoff.

Figure 7.

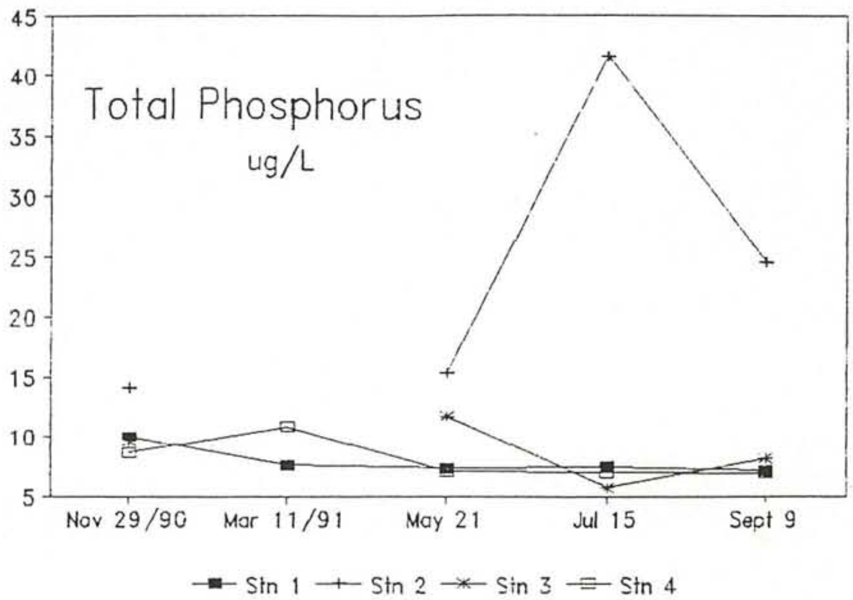
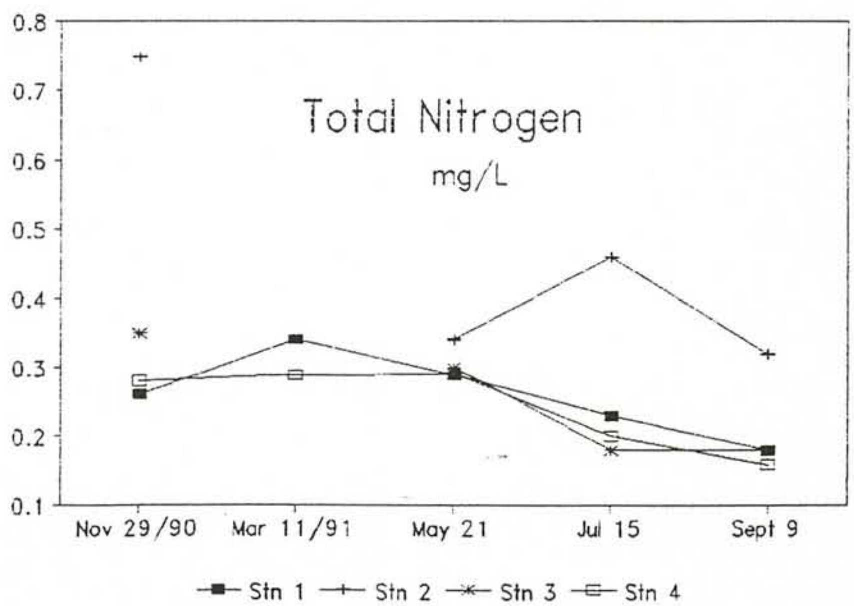


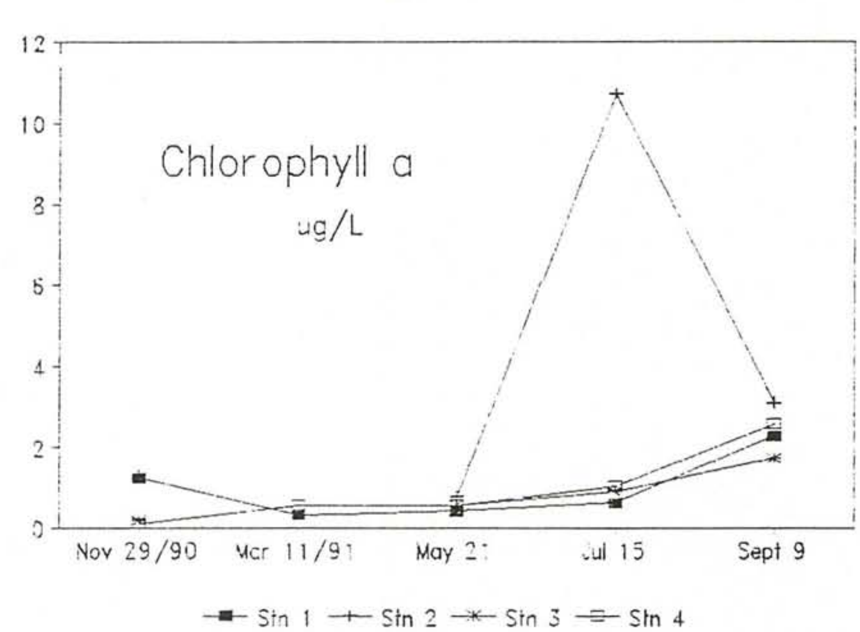
Figure 8.



Chlorophyll a

Chlorophyll is the primary photosynthetic pigment of phosynthetic organisms and is an indicator of algal biomass and lake productivity. Levels of production are linked with nutrient (phosphorus and nitrogen) concentration, light intensity and temperature. A maximum usually occurs in the spring and autumn. Chlorophyll a production in Williams Lake, with the exception of the small cove at the foot of Acorn Drive, were low and indicative of oligotrophic conditions (Figure 9). High nutrient loading to this area by stormwater and feeding water fowl, coupled with the extended residence times in low flow periods (as experienced during the study period) resulted in increased localized chlorophyll a concentrations.

Figure 9.

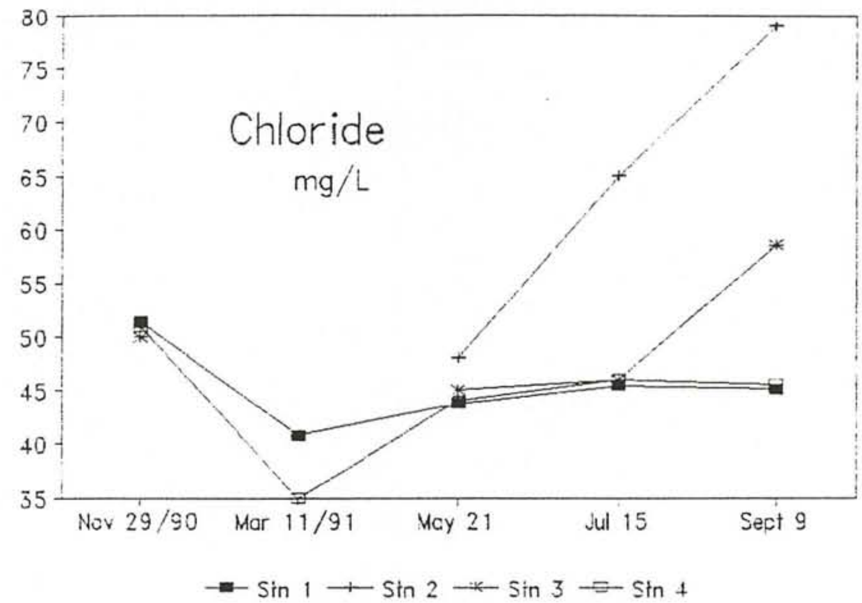


Chloride

The implications of chloride in surface water are discussed in the section on "Road Salt".

The main source of chloride in the Williams Lake watershed is road salt. A report by Underwood and Josselyn (1979) gives a detailed description of potential sources of salt for Williams Lake. For the study period, November 1990 to September 1991, the mean whole-lake chloride concentration was 45.1 mg/L. There was a slight chemical gradient moving west to east in the lake, which could probably be attributed to dilution effects (Figure 10). The highest chloride concentrations were observed in Inlet 4 (Acorn Drive). A comparison of mean-annual chloride values for the four inlets shows that the sub-watershed treated with sand

Figure 10.



(Inlet 2) during the winter months is the lowest. Current rates of de-icing salt application in the Williams Lake watershed, if continued, should not result in objectionable chloride levels in the lake.

Road Salt

Lobbying efforts of the Williams Lake Conservation Company have resulted in the application of sand instead of salt on roads in the vicinity of the lake during the winter months. As a result, the concentration of sodium chloride in Williams Lake has decreased from 58.9 mg/L, measured in 1976-77 (Underwood) to 45.0 mg/L, recorded in 1990-91 (this study). The decrease in levels observed for the two study periods may be a reflection of any or all of the following: the amount of salt applied to the entire watershed varied; the removal of the Department of Transportation salt storage facility on Williams Lake Road; and/or the replacement of salt with sand in portions of the watershed.

The sodium chloride data reported in 1977, was converted to sodium and chloride ions using equivalents. By this method, the 97.1 mg/L NaCl was broken down to 38.2 mg/L Na and 58.9 mg/L Cl.

Elevated sodium chloride levels in lakes can have a number of impacts on the aquatic ecosystem. In extreme cases, formation of a dense saline layer in the bottom strata of a lake inhibits the complete circulation of the water body in the spring and fall seasons preventing reoxygenation of this zone. This is turn forces organisms requiring oxygen for respiration to move to oxic environments or die. Fish may have to retreat to less desireable warmer water during the summer months, placing unnecessary stress on the species. Another effect of increased levels of sodium chloride is the suitability of the resource as a drinking water supply. At present, the Royal Nova Scotia Yacht Squadron and the Saraguay Club on the Purcell's Cove Road use the overflow of Williams Lake as a water supply. The Canadian Drinking Water Guideline for chloride is less than 250 mg/L, above which a salty taste is detectable. If the lake concentration were to increase to this level, the downstream users may be required to secure an alternate water supply. A final effect involves the lakes' fishery. A chloride concentration of 400 mg/L has been shown to be harmful to trout (McKee and Wolf, 1963). This figure, however, is arbitrary and is related to levels of other salts in the water. Without the fishery, wildlife utilizing this food source, may be forced to relocate.

The treatment of roads in the watershed with salt is at the present time does not impact Williams Lake in any way to suggest there are problems. It is suggested that any further development of roads in the watershed be treated with an inert material, such as sand, during the winter months to maintain sodium chloride concentrations in Williams lake at present levels.

Urban Runoff

The characteristics of urban runoff generally associated with runoff pollution solids, substances exerting oxygen demand, toxic substances and nutrients (Ellis, 1986). Three types of water quality impacts which are associated with urban runoff are:

- short term changes in water quality - following storm events. May result in aquatic organisms mortality as a result of increases in concentrations of toxics during storm events.

- contaminants associated with suspended solids that settle and by nutrients with longer detention times.

- resuspension of sediments and the associated pollutants - scour of stream courses.

Williams Lake receives urban runoff via six stormsewers at approximately five locations and Martins Pond from five drains at two locations. Discharging stormwater at times transforms Martins Pond into a brownish-coloured, turbid body of water. The source of fecal bacteria, which at times has been high enough to force closure of the beach located on the pond, most likely originates with the stormwater. Fecal colifoms are characteristic of stormwater. The level of these bacteria in the stormwater can be controlled somewhat by source controls on stormwater quality, i.e. "cleaning up " after family pets. The cause of the silted look of the pond is likely due to the resuspension of bottom sediments by turbulence caused by incoming stormwater. Another source would be erosion of soils from developing residential/commercial lots draining to the sewers. The author is not certain of the contribtion of the latter but feels this load to be minor where no new development is taking place in the Martins Pond watershed.

The Williams Lake Conservation Company conducted a survey in the spring of 1991 identifying types of development and potential sources of pollutants, such as lawn-fertilizers, contained in the Williams Lake watershed. The survey results are as follows:

Single Family Dwellings	604
Duplexes and Condominiums	82 for 186 units
Apartments	44 for 324 units
Service Stations	4
Restaurants	1
Fast Food Outlets	7
Corner Stores	3
Grocery Stores	1
Other Commercial Outlets	25
Churches	3
Schools	1
Playgrounds	1
Tennis Courts	2
Ball Fields	2
Supervised Beaches	1
Pump Houses	2

Stormwater quality sampling performed during the study was minimal. The results of the two rainfall events monitored for Inlets 2 and 4 were elevated for those parameters selected (specific conductance, total phosphorus, chloride and bacteria). Stormwater constituent concentrations observed for this study fall within the range of those measured at First Lake in Sackville, Nova Scotia. Bacteriological sampling of lake and inlet water for fecal coliform and fecal streptococcus was insufficient to identify the source of bacteria as either human or animal. The ratio of fecal coliform to fecal streptococcus bacteria, if less than 1.0, is indicative of an animal source. A ratio greater than 4.0 is suggestive of a human source.

Questions arose during the study regarding the bacterial counts being observed at the Acorn Drive storm drain site. It is the contention of some members of the Williams Lake Conservation Company Ltd that a few homes situated on Acorn Drive are not as yet connected to the City sewerage system and still operate septic systems. It is the understanding of the City of Halifax Engineering Department that all homes are connected to the connector line and that all septic systems have been abandoned. Water and sewer was made available by the City to all properties on Acorn Drive. If a property wished to connect to the water, they were required by the City to also connect to the sewer. Properties not wishing to connect to the City water supply and not experiencing problems with their septic systems, are not obligated to connect to the City system. However, if a problem does exist with an individual septic system, and central sewage is available, connection to that system is mandatory. The City Engineering Department is willing to release information regarding individual water and sewer hook-ups if a street address is supplied.

Control of Stormwater

A number of controls can be applied to existing stormwater systems to improve the water quality and reduce the impact on the lake. These are:

- screening devices to collect trash and leaves coming from a stormwater outfall to the lake,

- pollution control devices (PCD) to control sediments and their attached pollutants i.e. metals, nutrients (screens, underground exfiltration pipes and catch basins),

- routine maintenance of storm sewer inlets and manholes,

- street sweeping,

- development of guidelines relative to municipal and private activities such as fertilizing, maintaining shoreline vegetation, litter control, etc., and

- publicize the problems associated with stormwater runoff to promote public awareness.

It is recommended that stormwater runoff from any future development be diverted from the lake. However, it is occasionally impractical and financially not feasible to divert all urban runoff from surface water courses. For these instances, incorporation of other forms of water quality controls are available and recommended. For instance:

- on-line retention/detention - stored prior to discharge to surface waters,

- off-line retention - diversion and infiltration basins with no discharge to surface waters, and

- vegetated swales - transports and infiltrates runoff (land required for efficient swale is usually restrictive for residential developments, therefore, swale berms or on-line retention/detention ponds are necessary).

- wetland areas - act as natural retention/detention ponds (physical and biological removal of stormwater pollutants)

The use of buffer zones or green belts bordering surface waters should be incorporated into the design of any future development.

Fishing Potential

The morphoedaphic index (MEI) is a useful fish yield indicator developed by Ryder (1965) and later redefined by Ryder et al (1974). It is simplistic in its application as only basic limnological measurements are required for the calculation. The MEI is obtained by dividing the total dissloved solids (TDS) in milligrams per litre, by the mean depth (z) in metres, of a lake. It is expressed simply as:

$$MEI = \frac{TDS}{z}$$

For the purpose of calculating MEI, TDS may be equated with salinity. Where salinity was not measured directly during the study, it can be estimated with acceptable accuracy from values of specific conductance (Hutchinson, 1957).

Once the MEI is obtained, the potential angling yield per unit surface area (kg/ha/yr) can be determined from the graph in Figure 11. The annual yield is the product of the angling yield per unit area and the lake surface area. The MEI-angling yield relationship gives an approzimation only. Up to eight-fold differences occurred between estimates and realized yields in the original data set used to generate the index. Also, the yields calculated for Williams Lake may be a slight over-estimate due to the excess concentrations of chloride from road deicing. Chloride is essentially unrelated to fish yield, yet it is a major contributor to TDS. The fish yield estimate does not differentiate between species of fish. American eel, catfish, carp, rainbow trout and speckled trout, all known inhabitants of Williams Lake (McKinnon)

FIGURE 11

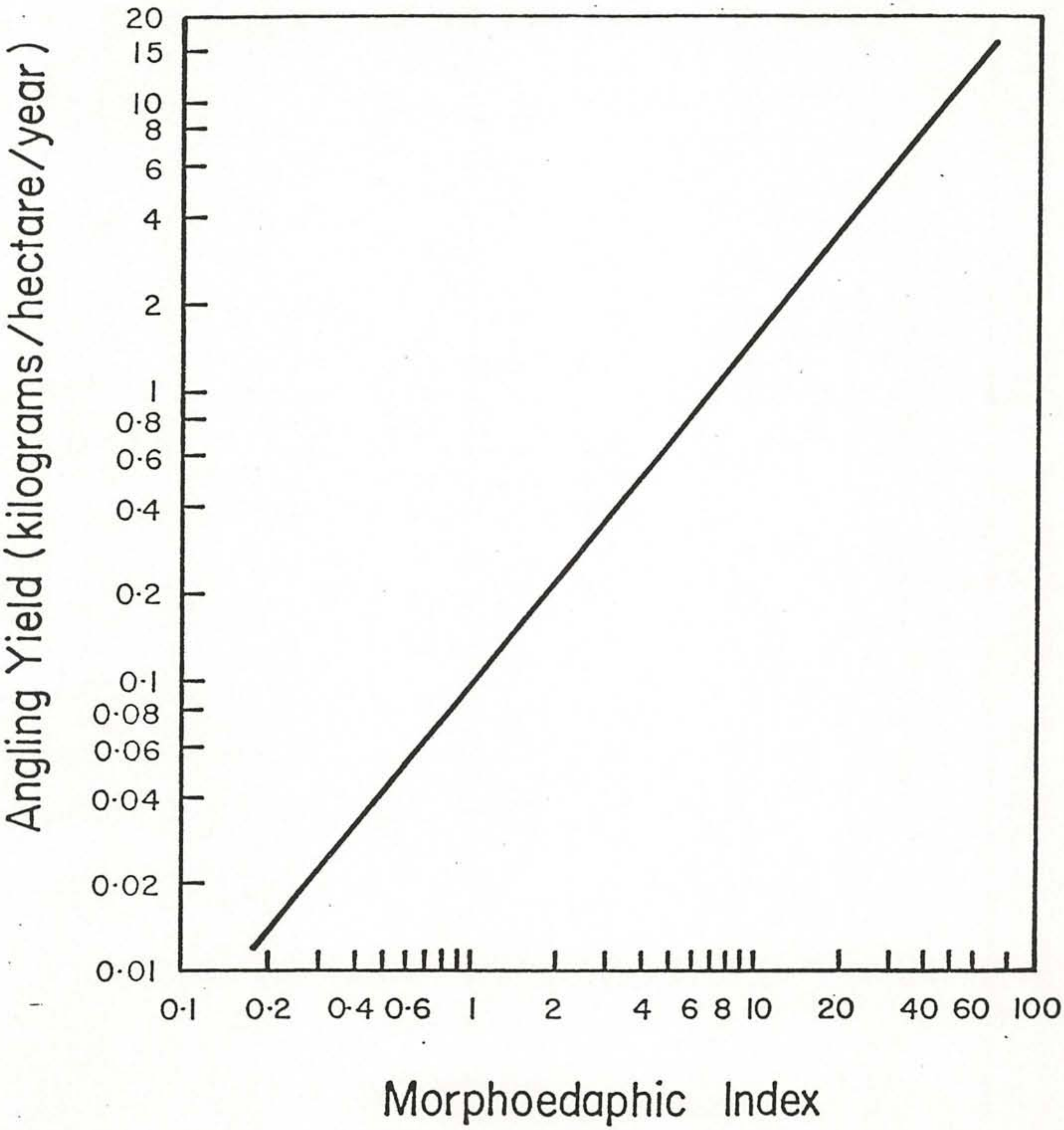


Figure . Suggested relationship between annual angling yield and the morphoedaphic index in a group of nine Precambrian lakes in Algonquin Park, Ontario, after Ryder et al (1974).

are the species of fish making up the bulk of the potential yield. Two sources of addition angling yield to lakes are anadromous species (Atlantic salmon, sea trout, gaspereaux, shad, etc.) and stocked fish. Both are not included in the estimate. The contribution of anadromous species, in all likelyhood, is zero due to the presence of the dam structure at the outlet of the lake. Hatchery stocking, however, has contributed between 0.7 and 13.6 kg/ha/yr since 1976 (Table A-6, Appendix). These figures translate into 29.2 and 593.6 kg of speckled trout released into the lake annually.

The MEI for Williams Lake in 1991 (based on a mean of annual specific conductance volume-weighted means for Stations 1, 3 and 4 of 210 umhos/cm or salinity (TDS) equalling 121 mg/L and a whole-lake mean depth of 4.0 m) is 30 (unchanged from values calculated from data contained in reports produced by Dean and Lister (1971) and Underwood and Josselyn (1979) of 28.5 and 29.5, respectively, equivalent to an estimated angling yield per unit surface area of 5.7 kg/ha/yr. The estimated lake angling yield, not including fish released into the lake by the provincial Department of Fisheries as part of the stocking program, is 250 kg/yr. It should be remembered that this estimation of angling yield is based on a salinity measurement which is influenced by deicing salts. A more accurate estimate may be that based on sodium chloride levels observed in similar lakes which do not have salt applied to their watersheds in the winter months. Underwood and Josselyn (1979) suggested that sodium chloride levels in Williams Lake are up to ten times higher than such lakes, in which case, the estimated angling yield prior to hatchery stocking would be 30 kg/yr.

Comments received from residents suggested that the fishery in Williams Lake is secure in that the recreational demand is being satisfied. The return of a pair of common loons to the lake each year is an indication that the supply of fish for occupancy and reproduction is adequate. It is estimated that a pair of breeding loons requires 160 kg of fish to fledge one chick or 240 kg for two chicks (Kerekes, 1989). The demand on the resource by the remaining consumptive components (humans, wildlife i.e. mink, herons etc.) is uncertain and should be investigated. A creel census is one form of monitoring which can easily be implimented by the Williams Lake Conservation Company.

Dam Structure

The current functions of the dam structure at the outlet of Williams Lake are to maintain some form of lake level consistency (observed fluctuations of up to 60 cm for this study) and allowance of a discharge to maintain a source of water supply for the Royal Nova Scotia Yacht Squadron (RNSYS) and the Saraguay Club downstream from the lake. If a new spilling structure were to be constructed (one in which water flows over the dam), it should reduce the maximum water level to which the lake lowers each year by eliminating losses due to dam leakage. Maintaining a higher lake level during the summer months may reduce plant growth in the shallower basins and also the area of exposed sediments from which odours eminate. The implication of this leakproof structure, however, is that a low or no flow situation may occur downstream at the intake supplying the RNSYS and the Saraguay Club during times when Williams Lake is not spilling. These facilities could be forced to install a water supply line to the lake itself or seek an alternate source.

Summary

Williams Lake consists of two main sub-basins. The trophic status of the larger and deeper basin is oligotrophic. The shallower basin is sectioned into three areas which are seen to support extensive amounts of plant growth during the growing season. This area, as well as Martins Pond, an area separated from the lake proper by Wyndrock Drive, receive the majority of urban runoff from the watershed and act as retention/detention ponds for the main, deep basin of Williams Lake. One part of Williams Lake located at the base of Acorn Drive is under stress caused by the high nutrient and bacteria levels contained in stormwater draining to it.

Sodium chloride levels in Williams Lake have declined over the last 15 years. A study performed in 1976-77 observed a mean chloride value of 58.9 mg/L, while this study found a mean chloride content of 45.0 mg/L. The main reasons for this change are thought to be related to the adoption of sand instead of salt as a traction agent used during the winter months and the removal of a Deprtment of Transportation salt storage facility from the watershed.

The impact of stormwater drainage at the present time seems to be localized and restricted to Martins Pond and those areas of Williams Lake in close proximity to the outfalls. Water quality controls which could reduce the current impact of storm drainage on Williams Lake and Martins Pond include: street sweeping, maintenance of catchbasins, development of guidelines relative to municipal and private activities, in particular, fertilizing, litter control, pet maintenance and public feeding of water fowl, and publicize the problems associated with stormwater runoff to promote public awareness. With respect to any future developments, it is recommended that stormwater be diverted from Williams Lake and surface waters draining to the lake. If inappropriate, controls should include on-line retention/detention ponds, off-line retention ponds, vegetated swales and utilization or development of wetland areas. The incorporation of buffer zones or green belts is also suggested.

A freshwater fishery exists in Williams Lake. It is supplemented by annual hatchery stocking by the Department of Fisheries. Since 1976, speckled trout stocking has added between 0.7 and 13.6 kg/ha/yr to the lake. The estimated angling yield of the lake based on the morphoedaphic index, which does not include stocking amounts, is 5.7 kg/ha/yr. An estimate adjusted for the effects of salinity derived from deicing activities, which may be closer to the actual case, is 0.7 kg/ha/yr. The existence of a breeding pair of loons and remarks of residents suggest that the supply of fish, both natural and stocked, is adequate to satisfy the current demand level on this resource. It would be beneficial to the Williams Lake Conservation Company Ltd. if a representative was to contact the Department of Fisheries to obtain and discuss information pertaining to the fishery of Williams Lake. Of particular interest to the Company may be the status and purpose of the stocking program, the ability of the lake to maintain a natural fish stock, the merits of incorporating a fish-ladder into the design of any new dam structure, and specific efforts of the Company which would benefit the resource.

The replacement of the current dam with a spilling structure would probabily reduce the maximum level to which the lake lowers each year by eliminating the current losses due to leakage. The higher summertime lake levels may reduce the plant growth in the shallower basin and the area of exposed sediments from which obnoxious odours originate. The implication of the new structure, however, is that low or no flow periods may occur downstream in the brook draining Williams Lake from which the Royal Nova Scotia Yacht Squadron and the Saraguay Club draw their water supply. These facilities may be forced to run a supply line directly to the lake or develop a groundwater well.

References

Ryder, R.A.. 1965. A Method for Estimating the Potential Fish Production of North-Temperate Lakes. Trans. Am. Fish. Soc. 94: 214-218.

Ryder, R.A., S.R. Kerr, K.H. Loftus and H.A. Regier. 1974. The Morphoedaphic Index. A Fish Yield Estimator - Review and Evaluation. J. Fish. Res. Board Can. 31: 663-688.

Hutchinson, G.E.. 1957. A Treatise on Limnology. Vol 1 pg 558: Table 69. John Wiley and Sons Inc. N.Y..

Dean, P.B. and D.B. Lister. 1971. Description of the Intrinsic Values of the Natural Environment Around Greater Halifax- - Dartmouth. Report to Metropolitan Area Planning Committee.

Underwood, J.K. and D.M. Josselyn. 1979. The Extent of Road Salt and Nutrient Stressing of Williams Lake, Halifax, N.S. NSDOE Report # 1960-Hal-W7-79.

Terstriep, M.L., D.C. Noel and G.M. Bender. 1986. Sources of Urban Pollutants - Do We Know Enough? In: Urban Runoff Quality - Impact and Quality Enhancement Technology. Proceedings of an Engineering Foundation Technology. Henniker, N.H.. Edited by Urbonas and Larry A. Raesner.

McKee, J.E. and H.W. Wolf. 1963. Water Quality Criteria. State Water Quality Control Board Resources Agency of California. Publication 3-A.

Appendix

Included in this section are the following Tables:

Table A-1 Chemical and Bacteriological Water Quality for 5 Sampling Dates.

Table A-2 Stormwater Quality, Inlets 2 and 4.

Table A-3 Station 1 Volume-Weighted Composite Metal Scan Data.

Table A-4 Lake and Stream Mean Values for Selected Water Quality Parameters.

Table A-5 N.S.D.H. Fecal Bacteria Data, 1986-91.

Table A-6 Fish Stocking History of Williams Lake, 1976-90.

Table A-7 Acceptable Raw Water Quality Levels for Drinking Water Supplies.

Table A-8 Objective Levels for Raw Water Used as a Drinking Water Source.

Table A-9 Guidelines for Livestock and Wildlife Watering.

Table A-10 Guidelines for the Protection of Freshwater Aquatic Life

TABLE A-1
Chemical and Bacteriological Water Quality for 5 Sampling Dates

Williams Lake, November 29, 1990   Secchi disk: 6.2m. lake level: +3.5cm

Location	Temp C	Diss O2 mg/L	% Air Sat'n	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chloro-phyll a mg/m3	Fecal Coliforms /100 mLs
Station 1												
0	4.7	12.0	97	6.6	0.45	228.0		9.9	0.26	51.5	0.92	[illegible]
5	4.7	12.0	97	6.6	0.45	228.0		10.6	0.26	51.5	1.38	[illegible]
10	4.5	11.8	94	6.6	0.45	228.0		9.6	0.27	51.5	1.32	
13	4.3	11.8	93									
15	4.3	11.8	93	6.5	0.45	228.0		8.7	0.26	51.5	1.38	
20	4.3	11.8	93	6.5	0.44	227.0		8.1	0.26	52.0	1.38	
Station 2												
0	6.0	11.9	99	6.6	1.00	275.0		14.1	0.75	51.0	1.30	[illegible]
Station 3												
0	5.8	11.9	98	6.5	0.47	228.0		9.6	0.35	50.0	0.17	
Station 4												
0	5.2	12.0	98	6.5	0.41	227.0		8.6	0.28	51.0	0.11	
Inlet 1	6.5			5.3	0.39	177.0		10.6	0.33	39.0	1.12	[illegible]
Inlet 2	8.0			4.8	0.16	66.9		5.6	0.09	11.7	1.27	[illegible]
Inlet 3	5.8			6.8	0.43	414.0		7.0	0.60	77.0	1.17	[illegible]
Outlet	6.0			6.5	0.37	226.0		6.9	0.28	51.5	1.81	[illegible]

TABLE A-1

Williams Lake. March 11, 1991 Secchi disk: 4.5m. ice thickness: 19cm. lake level: +6.0cm

Location	Temp C	Diss O2 mg/L	% Air Sat'n	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chloro-phyll a mg/m3	Fecal Coliforms /100 mLs	Fecal Strep /100mLs
Station 1													
0.2	3.3	12.6	98	5.1	0.70	110.0	22	9.3	0.24	23.5	0.65	2	
1	4.1	12.5	99										
2	4.1	12.3	97	5.5	0.66	152.0	22	7.4	0.29	34.0	0.45		
3	3.8	12.2	96										
4	3.2	11.7	90										
5	3.2	11.4	88	5.9	0.45	198.0	22	6.7	0.36	43.5	0.26	2	
6	3.2	11.4	88										
7	3.3	11.4	88										
8	3.3	11.2	87										
9	3.1	11.2	86										
10	3.1	10.9	84	6.0	0.53	217.0	22	7.9	0.38	47.5	0.13		
12	3.2	10.8	83										
14	3.2	10.4	80										
15	3.2	10.4	80	6.0	0.67	260.0	22	8.9	0.41	58.5	0.07		
16	3.3	10.4	80										
18	3.3	10.4	80										
20	3.3	10.4	80	6.0	0.97	276.0	22	9.9	0.42	63.0	0.11		
Station 4													
0.2	1.5	12.2	90										
1	2.9	12.2	93										
2	3.9	12.0	94	5.2	0.77	134.0	32	12.0	0.25	30.0	0.67	4	
3	3.8	11.8	92										
4	3.5	11.6	90										
5	3.5	11.6	90										
6	3.7	11.5	90	5.9	0.70	204.0	22	8.3	0.37	45.5	0.32		
7	3.7	11.5	90										
Inlet 1	2.5			4.8	0.55	123.0	35	9.6	0.22	27.5	0.30	2	
Inlet 2	1.8			5.1	0.33	134.0	7	6.1	0.17	29.0	0.07	0	
Inlet 3	3.5			6.5	0.97	328.0	0	6.0	0.61	59.0	0.35	0	
Inlet 4	3.0			6.3	4.20	855.0	7	20.0	1.03	214.0	0.24	1800	
Outlet	4.5			5.2	0.65	127.0	22	9.0	0.26	28.0	0.45	2	

TABLE A-1

Williams Lake, May 21, 1991   Secchi disk: 6.9m, lake level: +5.5cm, 1 adult loon

Location	Temp C	Diss O2 mg/L	% Air Sat'n	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chloro-phyll a mg/m3	Fecal Coliforms /100 mLs	Fecal Strep /100mL
Station 1													
0	13.9	12.6	98	6.4	0.48	192.0	12	6.7	0.29	43.5	0.50	0	
1	13.7	9.8	98										
2	13.6	9.9	99										
3	13.6	9.8	97										
4	13.6	9.8	97										
5	13.4	9.8	97	6.4	0.51	192.0	12	8.4	0.29	44.0	0.39	0	
6	13.4	9.8	97										
7	13.2	9.8	96										
8	12.4	9.7	94										
9	11.5	9.7	92										
10	7.8	9.7	84	6.3	0.54	190.0	12	6.7	0.29	43.5	0.34		
11	7.1	9.7	82										
12	6.9	9.7	82										
13	6.8	9.7	82										
14	6.7	10.1	85										
15	6.6	10.0	84	6.1	0.45	186.0	12	5.7	0.31	43.0	0.20		
16	6.4	10.0	83										
17	6.3	9.9	82										
18	6.3	9.9	82										
19	6.3	9.7	81										
20	6.3	9.7	81	6.1	0.48	187.0	12	7.1	0.31	43.0	0.26		
Station 2													
0	14.4	9.4	95	6.5	0.96	212.0	12	15.4	0.34	48.0	0.76	194	
Station 3													
0	14.2	9.5	96	6.4	0.53	195.0	12	11.7	0.30	45.0	0.56	4	
Station 4													
0	13.4	9.7	96	6.4	0.52	193.0	12	7.0	0.29	44.0	0.56	2	
1	13.4	9.7	96										
2	13.3	9.7	96										
3	13.2	9.7	96										
4	13.1	9.7	95										
5	13.0	9.7	95										
6	12.9	9.7	95	6.3	0.54	194.0	12	7.3	0.30	44.0	0.54		
Inlet 1	13.0			5.5	0.55	212.0	35	10.0	0.25	52.5	1.21	24	
Inlet 2	12.0			5.1	0.28	59.4	15	4.6	0.10	10.5	0.40	0	
Inlet 3	15.0			6.6	0.70	367.0	2	6.9	0.57	69.5	0.69	0	
Inlet 4	7.0			6.4	0.48	481.0	2	11.0	1.59	101.0	0.13	320	
Outlet	13.8			6.3	0.47	192.0	12	6.0	0.30	44.0	0.56	0	

TABLE A-1

Williams Lake. July 15, 1991   Secchi disk: 7.5m. lake level: -54.0cm. 3 adult loons. Air: 15C. 100% cloud

Location	Temp C	Diss O2 mg/L	% Air Sat'n	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chloro-phyll a mg/m3	Fecal Coliforms /100 mLs	Fecal Strep /100mL
Station 1													
0	19.6	8.7	98	6.7	0.39	229.0	17	5.3	0.19	46.0	0.60	28	
2	19.6	8.7	98										
4	19.6	8.7	98										
5	19.6	8.7	98	6.7	0.37	228.0	17	9.1	0.21	46.0	0.58	28	
6	19.4	8.6	97										
7	17.2	8.0	85										
8	14.1	7.4	74	6.4	0.37	224.0	20	6.7	0.25	45.0	0.80		
9	11.7	7.2	68										
10	9.3	7.2	64	6.0	0.31	218.0	20	7.4	0.31	44.0	0.69		
11	8.4	7.2	63										
12	7.7	7.2	62										
13	7.2	7.1	60										
14	7.0	7.0	59										
15	6.9	6.9	58	5.9	0.35	214.0	25	9.4	0.34	43.0	0.34		
16	6.8	6.8	57										
17	6.8	6.5	54										
18	6.7	6.2	52										
19	6.6	5.7	48										
20	6.6	4.9	41	5.8	0.46	212.0	25	9.9	0.35	42.5	0.37		
Station 2													
0	18.5	6.9	75	6.7	3.30	328.0	70	41.6	0.46	65.0	10.70	2200	
Station 3													
0	19.3	9.7	97	6.6	0.37	228.0	20	5.7	0.18	46.0	0.88	40	
Station 4													
0	19.6	8.9	100	6.6	0.44	228.0	17	6.4	0.20	46.0	0.93	2	
2	19.6	8.9	100										
3	19.6	8.8	99										
4	19.6	8.8	99										
5	19.4	8.8	98										
6	19.3	8.6	96										
6.5	18.8	8.6	95	6.5	0.52	228.0	17	7.6	0.20	46.0	1.15		
Inlet 1	15.5			5.4	0.85	212.0	80	20.9	0.44	46.0	0.47		
Inlet 3	21.0			6.8	0.90	441.0	17	8.0	0.36	74.0	2.31		
Inlet 4	13.0			6.4	1.60	793.0	20	62.6	3.24	143.0	0.30	>3000	
Outlet	19.0			6.4	0.29	222.0	17	15.1	0.20	46.0	0.28	70	

TABLE A-1

Williams Lake, September 9, 1991   Secchi disk: 5.8m, lake level: -53.0cm, 3 adult loons, 50% cloud

Location	Temp C	Diss O2 mg/L	% Air Sat'n	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chloro-phyll a mg/m3	Fecal Coliforms /100 mLs	Fecal Strep /100mLs
Station 1													
0	18.4	9.1	100	6.7	0.29	208.0	12	5.8	0.14	45.5	2.68	8	
2	18.4	9.1	100										
3	18.4	9.1	100										
4	18.4	9.1	100										
5	18.4	9.0	99	6.7	0.32	208.0	12	8.0	0.15	45.5	2.52	12	
6	18.3	9.0	99										
7	18.1	8.6	94	6.7	0.29	208.0	12	6.4	0.16	45.5	2.10		
8	17.9	8.4	91										
9	14.8	4.6	47	6.7	0.28	208.0	17	6.1	0.16	45.5	1.28		
10	10.6	3.9	36										
11	9.3	4.0	36	5.9	0.33	199.0	22	8.7	0.31	43.0	3.18		
12	8.3	4.0	35										
13	7.8	3.5	30										
14	7.2	3.4	29										
15	7.1	3.1	26	5.8	0.28	198.0	25	9.0	0.37	42.5	0.44		
16	7.0	2.9	24										
17	6.9	2.4	20										
18	6.9	2.2	18										
19	6.8	2.2	18	5.8	1.05	199.0	33	12.8	0.42	42.5	0.25		
Station 2													
0	16.7	8.6	91	7.0	1.40	419.0	45	24.6	0.32	79.0	3.12	264	
Station 3													
0	17.9	8.4	91	6.6	0.33	225.0	17	8.1	0.18	58.5	1.72	16	
Station 4													
0	18.2	9.1	100	6.7	0.31	208.0	12	7.6	0.16	45.5	2.46	4	
2	18.2	9.1	100										
3	18.2	9.1	100										
4	18.2	9.1	100										
5	18.2	9.1	100										
6	18.2	9.1	100										
6.5	17.8	9.1	99	6.6	0.31	208.0	12	6.0	0.16	45.5	2.75		
Inlet 1	16.5			5.5	0.23	231.0	33	8.4	0.16	55.5	0.06	8	
Inlet 3	19.0			7.0	0.81	404.0	22	12.7	0.27	74.5	9.54	116	
Inlet 4	12.5			6.3	0.72	705.0	17	22.3	1.97	140.0	0.15	>3000	
Outlet	18.0			6.5	0.25	208.0	12	10.3	0.15	45.5	1.81	4	

TABLE A-2
Stormwater Quality, Inlets 2 and 4

	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chloro-phyll a mg/m3	Fecal Coliforms /100 mLs	Fecal Strep /100mLs
Rain Event: August 21, 1991										
Inlet 2: 0830hrs					30.3	0.23	18.0			
: 1130hrs					11.7	0.18	10.5			
Inlet 4: 1135hrs					43.7	1.65	76.0			
Rain Event: September 20-23, 1991										
Inlet 4 Sept 20: 1000hrs			120.0		108.0		19.5		>3000	86
: 1100			439.0		37.6		81.5			
: 1200			462.0		42.9		82.5			
: 1300			412.0		41.3		71.5			
: 1400			134.0		187.0		19.5		2500	160
: 1900			459.0		38.5		61.5			
Inlet 4 Sept 21: 1145hrs			520.0		33.5		63.5			
Inlet 4 Sept 23: 0930hrs			582.0		15.1		97.0			

TABLE A-3
Station 1 Volume-weighted Composite Metal Scan Data

Lake Station 1 Volume-weighted Composite

Date	Ca	Mg	Hardness	As	Fe	Mn	Cu	Zn	Al	B	Ba	Be	Cd	Cr	Co	Ni	Pb	Sb	Se	Sn	V
	- mg/L -		as mg CaCO3/L	- mg/L -																	
29/11/90	5.05	1.03	16.8	<.005	0.08	0.02	<.01	<.01	0.1	<.02	0.013	<.005	<.01	<.01	<.01	<.02	<.05	<.05	<.1	<.03	<.01
11/03/91	4.20	0.91	13.8		0.09	0.02	<.01	.01	0.2	<.10	0.014	<.005	<.01	<.02	<.05	<.02	<.05	<.05	<.1	<.05	<.01
21/05/91	4.38	0.82	14.3		0.05	0.02	<.01	.01	0.2	.20	0.013	<.005	<.01	<.02	<.05	<.02	<.05	<.05	<.1	<.05	<.01
15/07/91	4.65	0.88	15.2		0.04	0.02	<.01	<.01	0.1	<.10	0.011	<.005	<.01	<.02	<.05	<.02	<.05	<.05	<.1	<.05	<.01
9/09/91	5.40	0.98	17.5		0.04	0.09	<.01	.13	0.1	<.10	0.070	<.005	<.01	<.02	<.05	<.02	<.05	<.05	<.1	<.05	<.01

TABLE A-4

Lake and Stream Mean Values for Selected Water Quality Parmaters

Williams Lake volume-weighted means.

	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chlorophyll a mg/m3
Station 1								
Nov 29/90	6.6	0.45	228		10.0	0.26	51.5	1.22
Mar 11/91	5.6	0.58	185	22	7.6	0.34	40.3	0.31
May 21	6.3	0.50	191	12	7.3	0.29	43.7	0.40
Jul 15	6.4	0.37	225	18	7.4	0.23	45.4	0.61
Sept 9	6.4	0.31	206	14	7.1	0.18	45.1	2.29
arith. mean	6.1	0.44	207	17	7.9	0.26	45.3	0.97
Station 2								
Nov 29	6.6	1.00	275		14.1	0.75	51.0	1.30
Mar 11								
May 21	6.5	0.86	312	12	15.4	0.34	48.0	0.76
Jul 15	6.7	3.30	328	70	41.6	0.46	65.0	10.70
Sept 9	7.0	1.40	419	45	24.6	0.32	79.0	3.12
arith. mean	6.7	1.64	309	42	23.9	0.47	60.8	3.97
Station 3								
Nov 29	6.5	0.47	228		9.6	0.35	50.0	0.17
Mar 11								
May 21	6.4	0.53	195	12	11.7	0.30	45.0	0.56
Jul 15	6.6	0.37	228	20	5.7	0.18	46.0	0.88
Sept 9	6.6	0.33	225	17	8.1	0.18	58.5	1.72
arith. mean	6.5	0.43	219	16	8.8	0.25	49.9	0.83
Station 4								
Nov 29	6.5	0.41	227		8.6	0.28	51.0	0.11
Mar 11	5.3	0.75	157	29	10.8	0.29	35.0	0.56
May 21	6.4	0.53	193	12	7.1	0.29	44.0	0.55
Jul 15	6.6	0.48	228	17	7.0	0.20	46.0	1.03
Sept 9	6.7	0.31	208	12	6.9	0.16	45.5	2.59
arith. mean	5.9	0.50	203	18	8.1	0.24	44.3	0.97

TABLE A-4

Williams Lake volume-weighted means continued.

	pH	Turb NTU	Spec Cond umhos/cm	Colour Hazen Units	Total Phosphorus ug/L	Total Nitrogen mg/L	Chloride mg/L	Chlorophyll a mg/m3
Inlet 1								
Nov 29	5.3	0.39	177		10.6	0.33	39.0	1.12
Mar 11	4.8	0.55	123	35	9.6	0.22	27.5	0.30
May 21	5.5	0.55	212	35	10.0	0.25	52.5	1.21
Jul 15	5.4	0.85	212	80	20.9	0.44	46.0	0.47
Sept 9	5.5	0.23	231	33	8.4	0.16	55.5	0.06
arith. mean	5.2	0.51	191	46	11.9	0.28	44.1	0.63
Inlet 2								
Nov 29	4.8	0.16	67		5.6	0.09	11.7	1.27
Mar 11	5.1	0.33	134	7	6.1	0.17	29.0	0.07
May 21	5.1	0.28	59	15	4.6	0.10	10.5	0.40
Aug 21.0830					30.3	0.23	18.0	
Aug 21.1130					11.7	0.18	10.5	
arith. mean	5.0	0.26	87	11	11.7	0.15	15.9	0.58
Inlet 3								
Nov 29	6.8	0.43	414		7.0	0.60	77.0	1.17
Mar 11	6.5	0.97	328	0	6.0	0.61	59.0	0.35
May 21	6.6	0.70	367	2	6.9	0.57	69.5	0.69
Jul 15	6.8	0.90	441	17	8.0	0.36	74.0	2.31
Sept 9	7.0	0.81	404	22	12.7	0.27	74.5	9.54
arith. mean	6.7	0.76	391	10	8.1	0.48	70.8	2.81
Inlet 4								
Mar 11	6.3	4.20	855	7	20.0	1.03	214.0	0.24
May 21	6.4	0.48	481	2	11.0	1.59	101.0	0.13
Jul 15	6.4	1.60	793	20	62.6	3.24	143.0	0.30
Sept 9	6.3	0.72	705	17	22.3	1.97	140.0	0.15
arith. mean	6.3	1.75	709	12	29.0	1.96	149.5	0.21
Outlet								
Nov 29	6.5	0.37	226		6.9	0.28	51.5	1.81
Mar 11	5.2	0.65	127	22	9.0	0.26	28.0	0.45
May 21	6.3	0.47	192	12	6.0	0.30	44.0	0.56
Jul 15	6.4	0.29	222	17	13.1	0.20	46.0	0.28
Sept 9	6.5	0.25	208	12	10.3	0.15	45.5	1.81
arith. mean	5.8	0.41	195	16	9.1	0.24	43.0	0.98

TABLE A-5

FECAL BACTERIA COUNTS/100 ML FOR LAKE STATIONS
MONITORED BY NOVA SCOTIA DEPARTMENT OF HEALTH, 1986-91

Map Location (Figure 1) Date	1 Williams Lake Outlet (Dam)	2 Wyndrock Drive	3 Birchview Drive	4 Martins Pond Cunard Beach
June 18/86			6	
June 26	2	18		12
July 2	2			4
July 8	0	34	2	16
July 17				600
July 22	6	80	6	42
July 29	30			80
Aug 7	2	10	0	160
Aug 12	4			24
Aug 20	40	60	50	700
Aug 22				84
Aug 26	16			720
June 23/87	0		0	2
June 30	0	0		0
July 7	0		12	144
July 14	4	4		30
July 21	2		70	1,800
July 23				900
July 28	0	6		24
August 5	0		14	34
August 11	0	2		14
August 18	2		20	
August 25	4	22		400
September 1	10		20	10
June 24/88		24	20	30
July 5				90
July 12		22	22	100
July 19				120
July 26		4	100	700
July 18				124
July 24				80
August 2				1,000
August 9	10			66
August 16	6	18	28	600
August 18				30
August 23	10			60
August 30				60
June 28/89				76
July 6	2			6
July 11	10	10	126	60
July 18	12		6	
July 25	6	2	24	18
August 1	0			2
August 9		8		16
August 15	6		28	14
August 22	8			240

August 29	10	38	0
June 26/90	2	14	86
July 4			16
July 10	16	1,000	6
July 17			14
July 24	6	90	84
July 31			8
August 7	8	100	67
August 14			36
August 21	0	4	4
August 28			12
June 26/91	6	12	8
July 5			0
July 10	2	10	4
July 18			26
July 24	2	22	20
July 31			6
August 9	80	20	84
August 14			20
August 21	560	460	70
August 28			140

Guideline: Nova Scotia Department of Health beach closure limit is 200 counts/100 mL.

TABLE A-6
Fish Stocking History of Williams Lake
1976 - 90

Date	Class	Length	IWeight	TWeight	NumFish	TW/yr	NF/yr	kg/ha/yr
09/07/90	2	22.0	152	75.5	500			
25/06/90	2	22.0	152	91.0	600			
11/06/90	2	22.0	152	151.0	1000			
14/05/90	2	21.0	130	162.5	1250			
06/04/90	1	19.0	114	113.6	1000	593.6	4350	13.6
15/05/89	2	20.0	114	114.0	1000			
24/04/89	2	20.0	114	114.0	1000	228.0	2000	5.2
17/05/88	2	19.1	91	90.7	1000			
25/04/88	2	21.6	90	90.7	1000	181.4	2000	4.1
15/06/87	2	20.3	121	120.5	1000			
10/06/87	2	19.2	100	100.0	1000			
13/05/87	2	17.9	80	80.0	1000	300.5	3000	6.9
15/05/86	3	35.0	1000	94.0	94			
15/05/86	2	17.4	59	66.6	1126	160.6	1220	3.7
22/10/85	1	12.6	22	79.4	3541			
16/04/85	2	16.7	51	103.6	1999	183.0	5540	4.2
30/10/84	1	13.4	26	105.5	3998			
08/06/84	2	18.7	73	264.7	3600	370.2	7598	8.5
08/11/82	1	15.0	38	111.6	2868	111.6	2868	2.5
08/09/81	1	15.0	51	120.0	2328	120.0	2328	2.7
14/10/80	1	17.4	62	126.0	2003	126.0	2003	2.9
13/09/79	1	12.1	17	50.5	2924	50.5	2924	1.2
06/09/78	1	11.5	14	29.2	2000	29.2	2000	0.7
25/08/76	1	12.5	19	78.5	4011	78.5	4011	1.8
Totals						2533	41842	

Class= 1-fingerling, 2-yearling, 3-trophy
Length= fork length in centimetres
IWeight= average individual weight in grams
TWeight= total weight in kilograms
NumFish= number of fish released
TW/yr= total weight of fish released in a given year
NF/yr= total number of fish released in a given year
kg/ha/yr= kilograms of fish released per hectare per year

TABLE A-7
ACCEPTABLE RAW WATER QUALITY LEVELS FOR DRINKING WATER SUPPLIES

PARAMETER	LEVEL			REFERENCE
ALKALINITY, TOTAL, as $CaCO_3$	GE	30	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
	LE	500	mg/L	
AMMONIA, as N	LE	0.5	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
ARSENIC, as As	LE	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BACTERIA, FECAL COLIFORM	LT	100	No./dL	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BACTERIA, TOTAL COLIFORM	LT	1000	No./dL	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BARIUM, as Ba	LT	1.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BORON, as B	LT	5.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CADMIUM, as Cd	LT	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CALCIUM, as Ca	LE	200	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CHLORIDE, as Cl	LE	250	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CHROMIUM, as Cr(VI)	LT	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
COLOUR	LE	15	TCU	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
COPPER, as Cu	LE	1.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CYANIDE, as CN	LE	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
FLUORIDE, as F	LE	1.4	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
HARDNESS, TOTAL, as $CaCO_3$	LE	120	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
IRON, DISSOLVED, as Fe	LE	0.3	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
LEAD, as Pb	LT	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
MAGNESIUM, as Mg	LE	150	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
MANGANESE, as Mn	LE	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
MERCURY, as Hg	LE	2	$\mu g/L$	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
NITRATE + NITRITE, as N	LT	10.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
NITRITE, as N	LE	1.0	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
ODOUR	LE	4	TON	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
OIL AND GREASE		ND	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
pH	GE	6.5		DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
	LE	8.3		
PHENOLIC SUBSTANCES, as PHENOL	LE	0.001	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOT.INORG., as P	LE	0.065	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
PHOSPHATE, TOTAL, as P	LT	100	$\mu g/L$	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHORUS, as P	LE	0.2	mg/L	HART, 1974, AUSTRAL. WAT. RES. COUNCIL. TECH. PAPER 7
α– RADIATION, TOTAL	LE	0.5	pCi/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
β– RADIATION, TOTAL	LE	5	pCi/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
SELENIUM, as Se	LT	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SODIUM, as Na	LE	270	mg/L	HART, 1974, AUSTRAL. WAT. RES. COUNCIL. TECH. PAPER 7
SULPHATE, as SO_4	LE	500	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SULPHIDE, as H_2S	LE	0.3	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SURFACTANTS, as MBAS	LE	0.5	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TEMPERATURE, ^oC	LE	15	^oC	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TOTAL DISSOLVED SOLIDS	LE	1000	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TURBIDITY	LE	5	JTU	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
URANYL ION, as UO_2	LE	5000	$\mu g/L$	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
ZINC, as Zn	LE	5.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969

TABLE A-8
OBJECTIVE LEVELS FOR RAW WATER USED AS A DRINKING WATER SOURCE

PARAMETER	LEVEL			REFERENCE
AMMONIA, as N	LE	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
ARSENIC, as As		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BACTERIA, FECAL COLIFORM	LT	10	No./dL	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BACTERIA, FECAL STREPTOCOCCI	LT	1	No./dL	ONTARIO WATER RESOURCES COMMISSION, 1970
BACTERIA, TOTAL COLIFORM	LT	100	No./dL	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
BARIUM, as Ba		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CADMIUM, as Cd		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CALCIUM, as Ca	LT	75	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CHLORIDE, as Cl	LT	250	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CHROMIUM, as Cr(VI)		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
COLOUR	LT	5	TCU	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
COPPER, as Cu	LT	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
CYANIDE, as CN		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
FLUORIDE, as F	LT	1.2	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
HARDNESS, TOTAL, as $CaCO_3$	LT	120	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
IRON, DISSOLVED, as Fe	LT	0.05	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
LEAD, as Pb		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
MAGNESIUM, as Mg	LT	50	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
MANGANESE, as Mn	LT	0.01	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
NITRATE + NITRITE, as N	LT	10.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
ODOUR		ND	TON	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
PHENOLIC SUBSTANCES, as PHENOL		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
PHOSPHATE, TOT.INORG., as P	LT	0.065	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
RADIATION, TOTAL	LT	10	pCi/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SELENIUM, as Se		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SULPHATE, as SO_4	LT	250	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SULPHIDE, as H_2S		ND	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
SURFACTANTS, as MBAS	LT	0.2	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TEMPERATURE	LT	10	^oC	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TOTAL DISSOLVED SOLIDS	LT	500	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
TURBIDITY	LT	1	JTU	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
URANYL ION, as UO_2	LT	1000	μg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969
ZINC, as Zn	LT	1.0	mg/L	DEPT. OF NATIONAL HEALTH & WELFARE, CANADA, 1969

TABLE A-9
GUIDELINES FOR LIVESTOCK AND WILDLIFE WATERING

PARAMETER	LEVEL			REFERENCE
ALUMINUM, as Al	LE	5	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
ARSENIC, as As	LE	0.2	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
BORON, as B	LE	5.0	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
CADMIUM, as Cd	LE	0.050	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
CALCIUM, as Ca	LE	1000	mg/L	HART, 1974, AUSTRAL. WAT. RES. COUNCIL, TECH. PAPER 7
CHROMIUM, as Cr	LE	1.0	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
COBALT, as Co	LE	1.0	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
COPPER, as Cu	LE	0.5	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
FLUORIDE, as F	LE	2.0	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
LEAD, as Pb	LE	0.1	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
MERCURY, as Hg	LE	10	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
MOLYBDENUM, as Mo	LE	0.01	mg/L	HART, 1974, AUSTRAL. WAT. RES. COUNCIL, TECH. PAPER 7
NITRATE + NITRITE, as N	LE	100	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
NITRITE, as N	LE	10	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
α- RADIATION, TOTAL	LE	0.5	pCi/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
β- RADIATION, TOTAL	LE	5	pCi/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
SELENIUM, as Se	LE	0.05	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
SULPHATE, as SO_4	LE	1000	mg/L	HART, 1974, AUSTRAL. WAT. RES. COUNCIL, TECH. PAPER 7
TOTAL DISSOLVED SOLIDS	LE	3000	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
VANADIUM, as V	LE	0.1	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
ZINC, as Zn	LE	25	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033

TABLE A-10
GUIDELINES FOR THE PROTECTION OF FRESHWATER AQUATIC LIFE

PARAMETER	LEVEL			REFERENCE
ALDRIN	LE	0.001	µg/L	INTERNATIONAL JOINT COMMISSION, 1977
ALKALINITY, as $CaCO_3$	GT	20	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
ALUMINUM, as Al	LE	0.100	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
AMMONIA, UN-IONIZED, as NH_3	LE	0.02	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
BERYLLIUM, as Be	LE	0.011	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
γ- BHC, (LINDANE)	LE	0.01	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
CADMIUM, as Cd	LE	0.003	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
CHLORDANE	LE	0.01	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
CHROMIUM, as Cr	LE	0.100	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
COPPER, as Cu	LE	0.005	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
CYANIDE, as CN^-	LE	0.005	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
p,p′ – DDT	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
DIAZINON	LE	0.08	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
DIELDRIN	LE	0.001	µg/L	INTERNATIONAL JOINT COMMISSION, 1977
α– ENDOSULFAN	LE	0.003	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
β– ENDOSULFAN	LE	0.003	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
ENDRIN	LE	0.002	µg/L	INTERNATIONAL JOINT COMMISSION, 1977
GUTHION	LE	0.005	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
HEPTACHLOR	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
IRON, as Fe	LE	0.300	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
LEAD, as Pb	LE	0.03	mg/L	ENVIRONMENTAL STUDIES BOARD, 1973, EPA.R3.73.033
MALATHION	LE	0.1	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
MERCURY, as Hg	LE	0.2	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
p,p′ – METHOXYCHLOR	LE	0.03	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
MIREX	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
NICKEL, as Ni	LE	0.025	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976
OXYGEN, DISSOLVED, as O_2	GE	4.0	mg/L	DEPT. OF THE ENVIRONMENT, 1972, TECH. BULL. 67
PARATHION	LE	0.008	µg/L	GREAT LAKES WATER QUALITY BOARD, 1976
pH	GE	6.5		US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
	LE	9.0		
PHENOLIC SUBSTANCES, as PHENOL	LE	0.001	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOTAL, as P	LT	0.050	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOTAL, as P	LT	0.100	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
PHOSPHATE, TOTAL, as P	LT	0.025	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
POLYCHLORINATED BIPHENYLS	LE	0.001	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
SUSPENDED SOLIDS	LE	25	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
SULPHIDE, as H_2S	LE	0.002	mg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
SURFACTANTS, as MBAS	LE	0.5	mg/L	LITTLE, 1977
TOXAPHENE	LE	0.005	µg/L	US. ENVIRONMENTAL PROTECTION AGENCY, 440/9-76-023
ZINC, as Zn	LE	0.030	mg/L	GREAT LAKES WATER QUALITY BOARD, 1976