Province of British Columbia
Ministry of Environment
ASSESSMENT AND PLANNING DIVISION

DOMESTIC WATER SUPPLY POTENTIAL OF BLACKBURN, BULLOCK'S, FORD AND STOWELL LAKES, SALTSPRING ISLAND

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WORKING REPORT

by

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SUMMARY

Blackburn Lake, Bullock's Lake, Ford Lake, and Lake Stowell are marginal sources of domestic drinking water because of their present eutrophic status. Their respective geophysical characteristics are summarized in Table S.1 and discussed in further detail in Sections 2.1, 3.1, 4.1 and 5.1. Table S.2 summarizes each lake's domestic, irrigation, and recreational suitability. The hypolimnetic water in Blackburn, Bullock's and Stowell Lakes met the recommended water quality objective for temperature, but did not meet the recommended standards for dissolved oxygen, water clarity, and water colour. The epilimnion for these same lakes, exceeded both the recommended standards for water temperature and colour (Table S.2). Consequently, for these three lakes the best quality domestic water can be obtained from the interface between the epilimnion and hypolimnion (Sections 2.4, 3.4, and 5.4). Domestic intakes for Ford Lake can be situated at any depth because summer thermal stratification of the water column does not occur. Domestic water supplies from all lakes should be chlorinated and filtered. Lake Stowell has the best quality water, followed by Blackburn Lake, then Ford Lake. Bullock's Lake had the poorest quality water.

All lakes met recommended water quality standards for irrigation and industrial water supply. If water from Blackburn, Bullock's and Stowell Lakes is used for irrigation or industrial purposes, installation of intakes below the thermocline, and removal of reasonable amounts of hypolimnetic water, would improve the water quality of each lake after fall overturn (See Sections 2.4, 3.4 and 5.4). It is recommended that irrigation or industrial withdrawal, from May to October should not exceed more than one-third of the lake's volume.

Recreational suitability ranged from 'good' for Lake Stowell, to 'poor' for Bullock's Lake (Table S.2). These subjective judgements are based on the lake's present water quality and geophysical characteristics, and do not consider possible conflicts between recreational and drinking water supply uses.

The preservation or management of lake watersheds designated for domestic use is very important in maintaining or even improving the water

quality of each lake. It is recommended that future studies focus on non-point nutrient sources in the watershed. As a general rule, the reduction of nutrient loading to a lake will lead to improved water quality.

TABLE S.1: SUMMARY OF GEOPHYSICAL LAKE CHARACTERISTICS

LAKE CHARACTERISTICS	BLACKBURN	BULLOCK'S	FORD	STOWELL
Elevation (metres)	101	26	82	71
Lake Surface Area (hectares)	4.5	10.2	4.5	5.6
Maximum Depth (metres)	5	8	3.5	7.5
Mean Depth (metres)	3	5	3	4.6
Lake Volume (cubic decametres)	135	510	140	260
Watershed Area (hectares)	620	212	780	389
Ratio Between Watershed Area and Lake Volume (hectares/cubic decametres)	4.6:1	0.4:1	5.6:1	1.5:1
Watershed Runoff (cu. decametres)	3760	756	4430	2010
Flushing Rate (times/year)	27	1.5	32	7.7

TABLE S.2: SUMMARY OF WATER QUALITY CHARACTERISTICS AND DOMESTIC, RECREATIONAL, AND IRRIGATION SUITABILITIES[1]

CATEGORY	BLACKBURN	BULLOCK'S	FORD	STOWELL
Temperature Above Thermocline	poor	poor	poor	poor
Temperature Below Thermocline	good	good	n/a	good
Dissolved Oxygen Above Thermocline	good	good	good	good
Dissolved Oxygen Below Thermocline	poor	poor	n/a	poor
Water Colour Above Thermocline	poor	poor	poor	poor
Water Colour Below Thermocline	poor	poor	n/a	poor
Water Clarity Above Thermocline	moderate	moderate	mod.-poor	good-mod.
Water Clarity Below Thermocline	mod.-poor	mod.-poor	n/a	mod.-poor
Bacteria (Requires Chlorination)	yes	yes	yes	yes
Other Water Quality Parameters	good	good	good	good
Domestic Suitability of Surface Water	moderate	poor	moderate	moderate
Domestic Suitability of Bottom Water	poor	poor	n/a	poor
Recreation Suitability	moderate	poor	poor	good
Irrigation or Industrial Suitability	good	good	good	good
Possibility of Creating Additional Storage	moderate	poor	good	good

1 Subjective scale based on B.C. Ministry of Health recommended water quality standards and objectives

Good = results were within the water quality recommended objectives
Moderate = results lie between water quality recommended objectives and standards
Poor = results fell below or exceeded the water quality recommended standards

INTRODUCTION

This report fulfills the March 10, 1978, request by Islands Trust to the Minister of Environment (then Hon. James A. Nielson) to study the suitability of Blackburn, Bullock's, Ford, and Stowell Lakes for domestic drinking water suitability. This report is a collection of four separate reports which summarizes the water quality of each lake as it relates to the Ministry of Health recommended water quality standards and objectives; the hydrological budgets of each watershed; the morphometric data for both the lake and respective watershed; and other possible uses for the lake. Water quality information was gathered over the period June 1978 to October 1979. Sufficient data and information is believed to be presented to enable planners to designate the future use of the four lakes and their watersheds.

2. BLACKBURN LAKE

2.1 Lake Characteristics

Blackburn Lake is located 13.6 kilometres (km) (8.5 miles) north of Fulford Harbour, on the Ganges-Fulford Road (Figure 2.1). The lake is 101 metres (m) (330 ft) above geodetic datum, and has a maximum depth of 5.0 m (17 ft). It has a surface area of 4.5 hectares (11 acres), and a maximum volume of 135 cubic decametres (dam^3) (110 acre-feet:af). The lake outlet is situated at the south-east side of the lake and flows, during the winter and spring months, under the Ganges-Fulford Road to Cusheon Lake. The largest surface inflow, located on the south-west side of the lake, drains 6.2 km^2 (1,530 acres) of watershed (Figure 2.2). Development around the lake is minimal with an inactive farm bordering the north-west shore, while recreational lake use is restricted to swimming from a wharf at the south end (Figure 2.2).

Water and bacteriological samples were taken at the lake's center (Ministry of Environment computer and data storage reference number: 1100136) and at the north-west inflow (Figure 2.2).

2.2 Hydrology

Rainfall for the Blackburn Lake watershed was estimated directly from data recorded at Environment Canada's Cusheon Lake Weather Station, Saltspring Island. The 1977-1979 monthly precipitation values are listed in Appendix 1, and mean monthly precipitation values are listed in Appendix 2.

The Hydrology Section of the Inventory and Engineering Branch (previously known as Hydrology Division of the Water Investigations Branch) calculated the watershed runoff for Blackburn Lake (Obedkoff, 1980); Appendix 2 lists the monthly runoff volumes based on an average precipitation year. Our study year however was 55 percent below the norm. Therefore instead of 3760 dam^3 (3048 af) which would normally enter Blackburn Lake, only 1692 dam^3 (1371 af) entered from November 1978 to April 1979. Based on a

FIGURE 2.1
LOCATION OF BLACKBURN LAKE, SALTSPRING ISLAND.

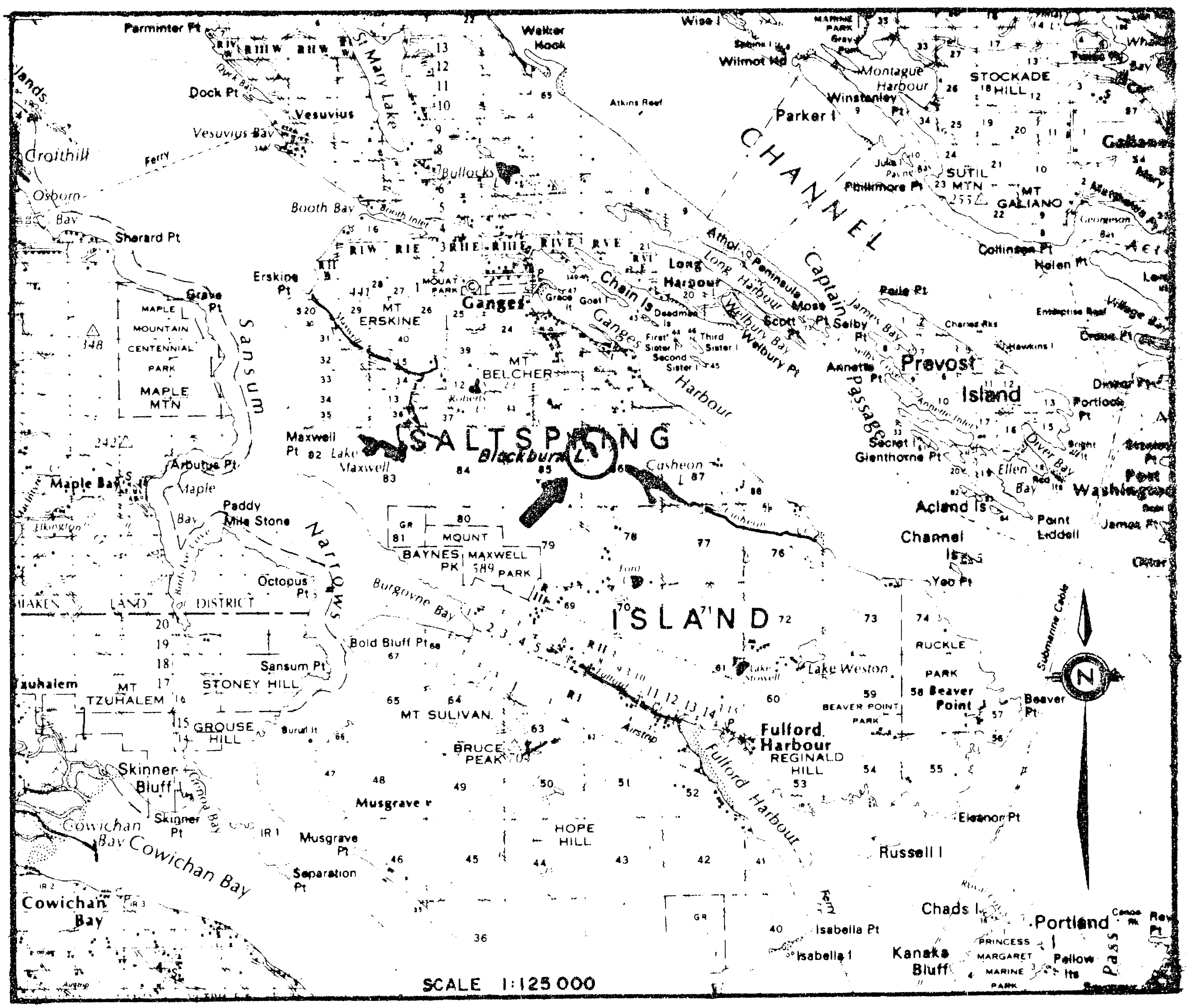
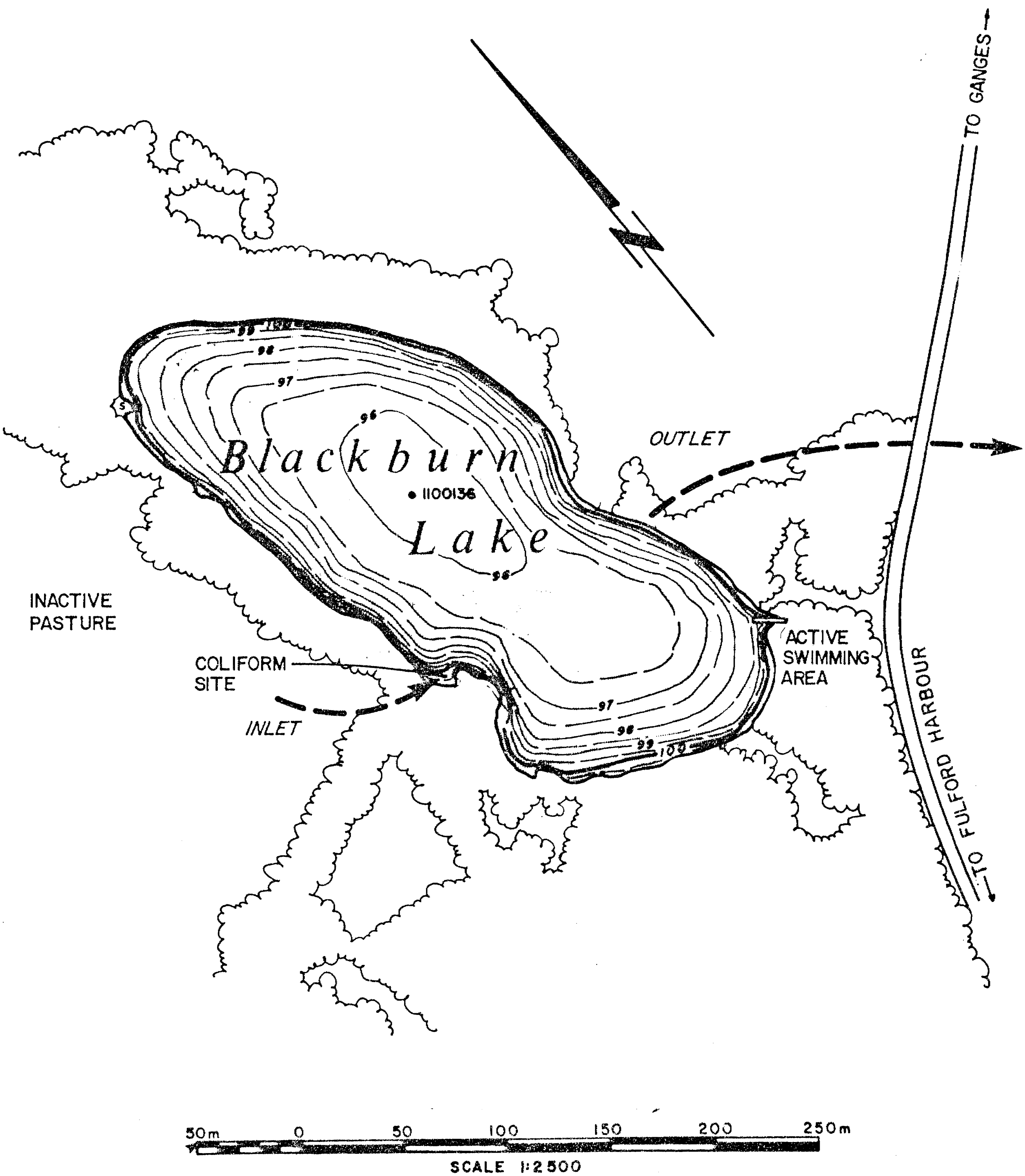


FIGURE 2.2: SAMPLING STATIONS, LAND USE, AND BATHYMETRY OF BLACKBURN LAKE.



lake volume of 135 dam^3 (110 af) the estimated average flushing rate is 27 times/year, but because of low precipitation the flushing rate for the study year was only 12.5 times. The high flushing rates are the result of the high ratio between the Blackburn Lake watershed area and the lake volume (4.6 ha: 1 dam^3).

The zone of water above the thermocline, the epilimnion, has a depth of 2.1 m (6.9 ft) in April, and 3.5 m (11.5 ft) in September (Figure 2.3). The epilimnion volumes are 75 dam^3 (61 af), and 98 dam^3 (79 af) respectively, or 56 percent and 73 percent of the lake's total volume. The zone of rapid temperature change, the metalimnion, extends from 2.1 m (6.9 ft) to 3.0 m (9.8 ft) in April, and from 3.5 m (11.5 ft) to 4.5 m (14.8 ft) in September. This zone represents 25 dam^3 (20 af) in April and 16 dam^3 (13 af) in September or 18.5 percent and 12 percent respectively, of the lake's total volume. The zone of water below the thermocline, the hypolimnion, has a volume of 35 dam^3 (28 af) in April, and was eliminated in early August by the downward entrainment of the metalimnion (Figure 2.3). The hypolimnion represents 26 percent of the lake's total volume in April, and 0 percent by early August.

Currently there are two unused conditional water licences and one proposed water licence on Blackburn Lake. The unused water licences are CL 29181 issued to Mrs. K.R. Luton for 1,000 gallons per day (4.5 cubic metres per day) domestic water, and 50 af (61.7 dam^3) irrigation water; and CL 42049 issued to N. Hays for 7,000 gallons per day (32 cubic metres per day) industrial water. The proposed water licence (0355016) is from the Blackburn Lake Country Club Ltd. for 10,000 gallons per day (45 cubic metres per day) domestic use, 3,000 gallons per day (13.5 cubic metres per day) industrial use, and 50 af (61.7 dam^3) for irrigation.

Reduction of the lake surface water level from May to October is caused by three factors: evaporation, water utilization and groundwater losses (not measured). Evaporation is estimated to be 0.19 m (7.5 inches) per year or a loss of 6.7 dam^3 (5.4 af) of surface water (Appendix 2). Although there is no present utilization of Blackburn Lake water, the proposed water licence would utilize 69.5 dam^3 (56.3 af) of water from May 1 to Oct. 31,

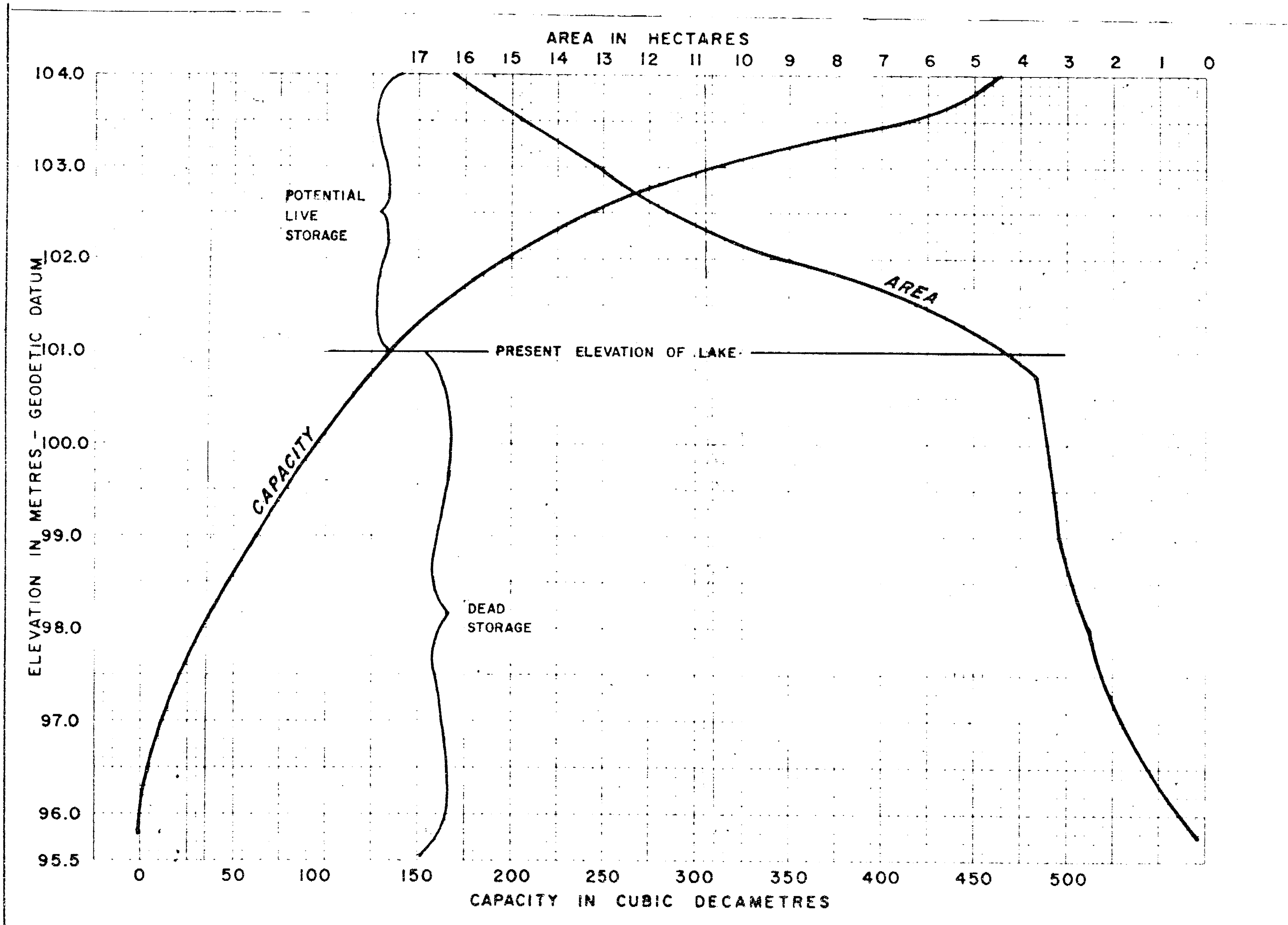


FIGURE 2.3 : STORAGE CAPACITY CURVES FOR BLACKBURN LAKE.

which is a drawdown of 2.0 m (6.6 ft.). If the licence is approved, the depth of water in Blackburn Lake, at the end of October, on an average precipitation year, is estimated at only 3 m. The affect of the large drawdown on water quality is discussed in Section 2.4.

Storage potential in Blackburn Lake is judged 'good', as a 1.25 m (4.1 ft.) rise in lake height would double the lake's present volume. The storage capacity and area curves for Blackburn Lake are illustrated in Figure 2.3.

2.3 Water Quality

2.3.1 Temperature

Thermal stratification of the water column was present from mid-April to late September, and during periods of ice cover. The epilimnion had a maximum summer temperature of 24°C (75°F) in late July, which exceeds the recommended standard of 15° C (59° F) set by the B.C. Ministry of Health (Table 2.1). The thermocline had a small 3°C temperature gradient in April, and had a maximum gradient of 11°C in late June. In the fall, cooling of the surface water produced unstratified conditions which allowed surface and bottom water to mix. Unstratified conditions will remain throughout the winter, unless exceptionally cold winter temperatures cause ice formation.

2.3.2 Dissolved Oxygen

During the summer the epilimnion dissolved oxygen concentrations ranged from 62 to 117 percent saturation, while anaerobic conditions (which do not meet the recommended standard of 3.0 mg/L dissolved oxygen), dominated the hypolimnion from May through September (Figure 2.5). During the same period, the metalimnion had oxygen concentrations ranging from 0 mg/L near the hypolimnion interface, and 6.7 mg/L near the epilimnion interface.

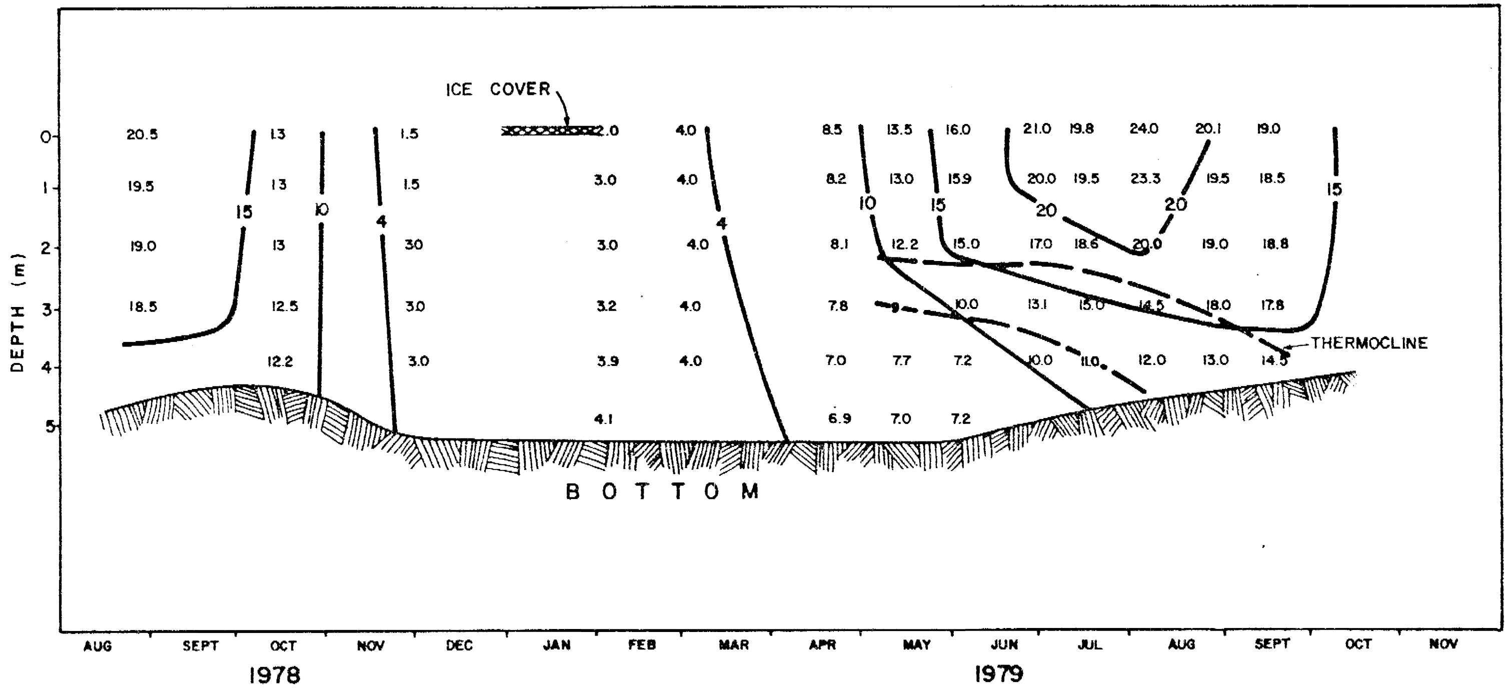


FIGURE 2.4: TEMPERATURE PROFILES AND ISOTHERMS FOR BLACKBURN LAKE.

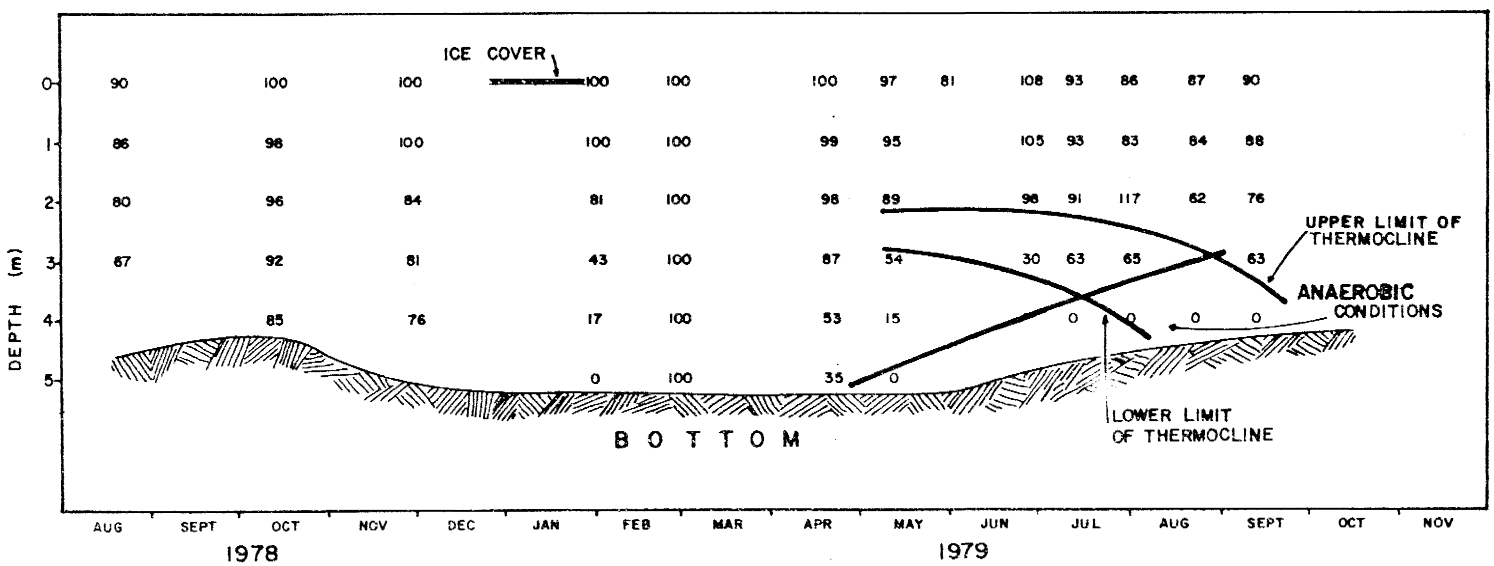


FIGURE 2.5: OXYGEN PROFILES (Percent saturation) FOR BLACKBURN LAKE.

TABLE 2.1: RECOMMENDED WATER QUALITY STANDARDS AND OBJECTIVES, AND RESULTS FOR BLACKBURN LAKE

PARAMETER	RESULTS		STANDARD	OBJECTIVE	AGENCY
	EPILIMNION	HYPOLIMNION			
PHYSICAL PARAMETERS					
1) Temperature (°C)	[2]22 (Max.)	[1]14.5 (Max.)	15	10	B.C. Health
2) Oxygen-Dissolved (mg/L)	6.9 (Min.)	[2]0 (Min.)	3		[4]SSPA; [5]WQMO
GENERAL IONS					
1) Alkalinity (mg/L)	34.1 ±8.3 (n=9)	38.9±10.9 (n=7)	—	—	—
2) Carbon-Inorganic (mg/L)	9.0 ±1.2 (n=7)	14.2± 2.5 (n=6)	—	—	—
3) Calcium (mg/L)	11.25±1.2 (n=7)	12.8± 2.4 (n=6)	200	L75	B.C. Health
4) Chloride (mg/L)	7.6 ±0.8 (n=2)	7.6 (n=1)	250	L250	B.C. Health
5) Hardness (mg/L)	40.5 ±4.5 (n=7)	45.0± 8.4 (n=6)	180	120	B.C. Health
6) Magnesium (mg/L)	3.0 ±0.4 (n=5)	3.1± 0.5 (n=5)	150	L50	B.C. Health
7) PH (Relative Units)	7.4 ±0.3 (n=16)	7.0± 0.3 (n=14)	6.5→8.5		B.C. Health
8) Potassium (mg/L)	5.5 ±0.7 (n=2)	5 (n=1)	—	—	—
9) Silicate (mg/L)	9.4 ±0.9 (n=4)	10.2± 0.7 (n=4)	—	—	—
10) Sodium (mg/L)	5.95±0.6 (n=2)	5.2 (n=1)	—	—	—
11) Specific Conductance (μmhos/cm)	121.4 ±8.2 (n=15)	137.4±21.5 (n=14)	—	—	—
12) Sulphate (mg/L)	11.2 ±1.9 (n=2)	10.1 (n=1)	500	250	B.C. Health
13) Total Dissolved Solids (mg/L)	90.4 ±7.2 (n=9)	101.3±13.4 (n=8)	1000	L500	B.C. Health
14) Total Inorganic Solids (mg/L)	54.2 ±9.9 (n=9)	57.8±11.9 (n=8)	—	—	—
WATER CLARITY AND COLOUR					
1) True Colour (T.C.U.)	[2]36.4 ±9.3 (n=14)	[2]46.9±19.3 (n=13)	15	L5	B.C. Health
2) Secchi Disc Depth (meters)	2.1 ±0.9 (n=12)	-	—	—	—
3) Tannins and Lignins (mg/L)	1.0 ±0.2 (n=3)	1.07±0.29 (n=3)	—	—	—
4) Total Suspended Solids (mg/L)	6.1 ±7.5 (n=8)	6.8± 6.2 (n=7)	—	—	—
Total Suspended Solids	21 (Max.)	18 (Max.)			
5) Turbidity (N.T.U.)	[1]2.8 ±2.2 (n=12)	[2]7.9± 9.9 (n=10)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	[2]9.3 (Max.)	[2]34 (Max.)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	1.0 (Min.)	[1]1.5 (Min.)	5.0	L1.0	B.C. Health
METALS					
1) Aluminum (mg/L)	0.25±0.3 (n=2)	0.45 (n=1)	—	—	—
2) Arsenic (mg/L)	-	-	0.05	L0.005	B.C. Health
3) Cadmium (mg/L)	-	-	0.01	L0.0005	B.C. Health
4) Chromium (mg/L)	-	-	0.05	L0.005	B.C. Health
5) Copper (mg/L)	0.005 ±0.001(n=2)	0.009±0.01 (n=2)	1.0	L0.01	B.C. Health
6) Iron (mg/L)	[2]0.68±0.23 (n=4)	1.2± 0.7 (n=3)	0.3 (Diss)	L0.05 (Diss)	B.C. Health
7) Lead (mg/L)	-	L0.001 (n=1)	0.05	L0.001	B.C. Health
8) Nickel (mg/L)	L0.01 (n=1)	L0.01 (n=1)	—	—	—
9) Zinc(mg/L)	L0.005 (n=1)		5.0	L1.0	B.C. Health
NUTRIENTS					
1) Nitrogen-Ammonia (mg/L)	[1]0.036±0.013(n=12)	[1]0.18±0.34 (n=11)	0.5	[1]L0.01	B.C. Health
2) Nitrogen-Nitrate (mg/L)	0.3±0.5 (n=14)	0.26±0.44 (n=13)	10	L10	[6]WQC
3) Nitrogen-Total (mg/L)	1.03±0.64 (n=11)	1.3 ±0.75 (n=10)	—	—	—
4) Phosphorous - Ortho (mg/L)	0.004±0.003(n=14)	0.061±0.18(n=13)	0.065	0.065	B.C. Health
5) Phosphorous - Total (mg/L)	0.036±0.1 (n=14)	0.126±0.261(n=13)	—	—	—
6) Carbon-Organic (mg/L)	8.6±2.1 (n=9)	10.6 ±3 (n=8)	—	—	—
BACTERIA					
1) Coliforms - Faecal (M.P.N.)	[2]3.9±3.7 (n=10)	-	[7]0	—	B.C. Health
2) Coliforms - Total (M.P.N.)	[2]22.3±24.9 (n=10)	-	0	—	B.C. Health

NOTES:

[1]Parameter exceeds the recommended water quality objective.
[2]Parameter exceeds the recommended water quality standard.
[3]Iron concentration listed as total iron.
[4]S.S.P.A.: Scientific Stream Pollution Analysis, 1974.
[5]W.Q.M.O.: Guidelines and Criteria for Water Quality Management in Ontario, 1979
[6]W.Q.C.: Water Quality Criteria. E.P.A., 1972.
[7]B.C. Ministry of Health recommended drinking water standard requires 'Most Probable Number' (M.P.N.) of coliform bacteria to be 0 cells/100 ml for untreated water, and 50 cells/100 ml for 'Class A' water.

Oxygen was re-introduced to the hypolimnion in October, by the downward mixing of the oxygenated surface water. Oxygen concentrations near 100 percent saturation persisted throughout the water column during the winter months, although anaerobic conditions near the bottom were briefly present during a prolonged period of ice cover in 1979 (Figure 2.5).

2.3.3 Water Clarity

Water clarity was determined by the nephelometric turbidity test, field Secchi disc readings, and field light attenuation profiles. The main factor effecting the winter and spring water clarity of Blackburn Lake was suspended inorganic particulates. Watershed runoff raised the suspended inorganic particulates in the epilimnion to 12 mg/L in late February 1979, which increased the epilimnion turbidity levels to 9.3 Nephelometric Turbidity Units (N.T.U.); lowered the Secchi disc readings to 0.7 metre (2.25 ft); and raised the light extinction coefficient to 1.9 relative units. Throughout the remainder of the spring and summer, the suspended inorganic particulates were below detectable limits (Figure 2.6), and the summer epilimnion turbidity, Secchi, and light extinction readings fluctuated independently of both suspended inorganic and suspended organic particulates.

The light attenuation profiles, measured as extinction coefficients, were negatively correlated (r=-0.97) with the Secchi disc readings (Figure 2.6). The extinction coefficients averaged 1.4±0.23[1] relative units (n=10)[2], and ranged from a low of 1.07 relative units to a high of 1.94 relative units. The Secchi disc reading averaged 2.2 ± 0.67 m(n=12), and ranged from a low of 0.7 metre (2.25 ft) in February 1979, to a high of 3.1 m (10.25 ft) in late August 1979 (Figure 2.6). The epilimnion turbidity levels averaged 2.8±2.2 N.T.U. (n=12), and ranged from a high of 9.3 N.T.U. in the spring to a low of 1.0 N.T.U. in the early summer, while the hypolimnion turbidity values were consistently higher averaging 7.9±9.9 N.T.U. (n=10), and ranged from a high of 34 N.T.U. in late summer to a low of 1.5 N.T.U. in early summer.

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[1] standard deviation

[2] n=sample size

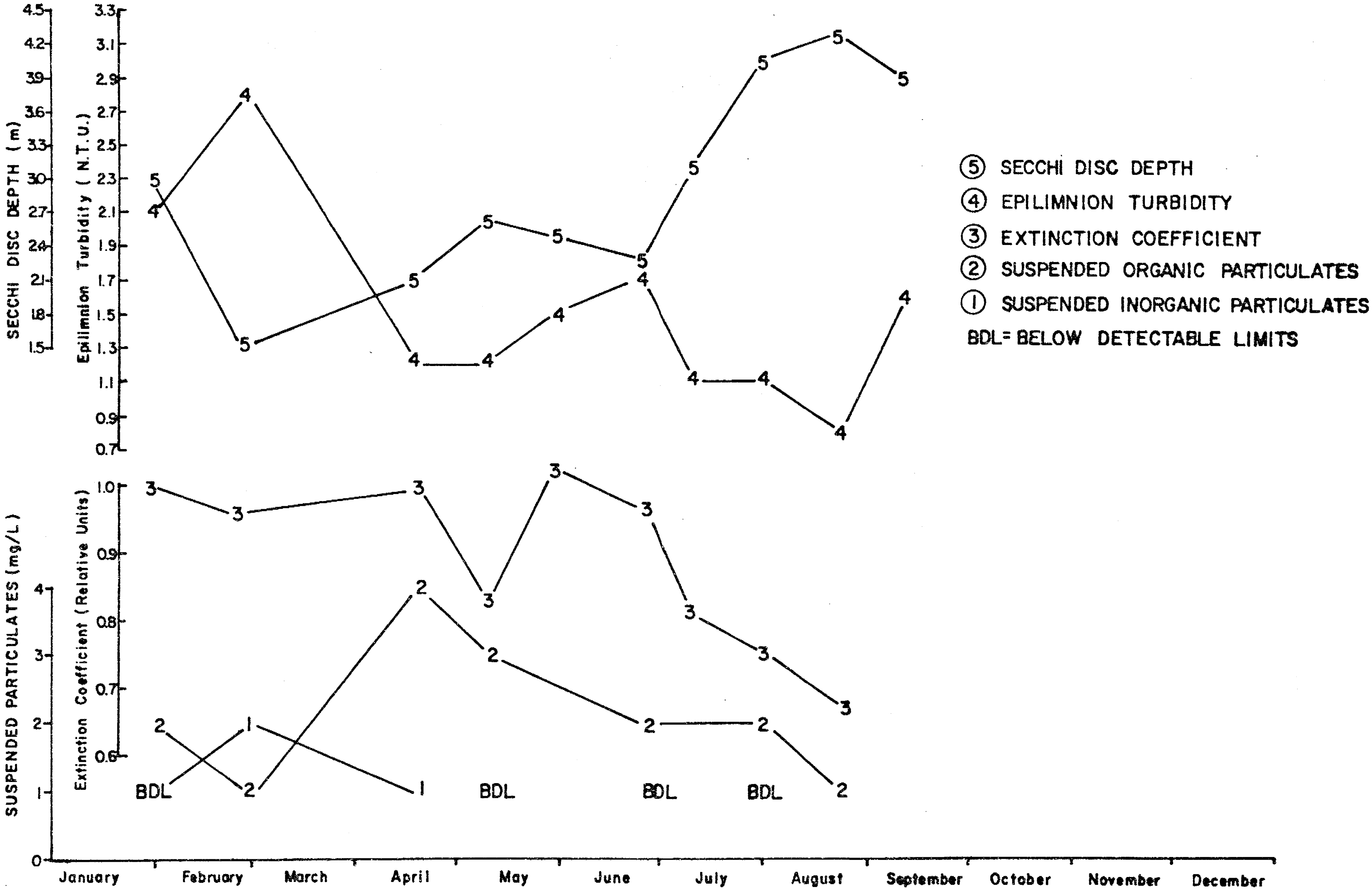

FIGURE 2.6 : TEMPORAL CHANGES IN THE WATER CLARITY OF BLACKBURN LAKE, 1979.

The water clarity of Blackburn Lake can only be considered 'moderate' in quality, as the epilimnion and hypolimnion turbidity values exceed the recommended water quality objective of 1 N.T.U., and the epilimnion and hypolimnion periodically exceeded the 5 N.T.U. recommended water quality standard (Table 2.1).

2.3.4. Water Colour

Water colour, measured as 'true colour', averaged 36.4±9.3 True Colour Units (n=14) in the epilimnion, and 46.9±19.3 T.C.U. (n=13) in the hypolimnion. The epilimnion and hypolimnion both exceeded the 15 T.C.U. recommended drinking water standard (Table 2.1). High colour values are the result of high concentrations of dissolved organic compounds. Tannin and lignins (a specific group of dissolved organic compounds derived from the breakdown of plant matter) averaged 1.0 mg/L throughout the water column, which was not sufficient to give the lake a characteristically brown colour. The epilimnion and hypolimnion concentrations of other dissolved organic compounds averaged 41.5±9.3 mg/L (n=9), and 46.1±10.1 mg/L (n=8), which are slightly lower than the organic concentrations recorded in Bullock's Lake. Despite dissolved organic concentrations similar to Bullock's Lake, the Blackburn Lake colour values averaged 40 percent lower. Tannin and lignin concentrations, which were 50 percent higher in Bullock's Lake, caused the elevated colour values (Section 3.3.4).

The colour of Blackburn Lake water can only be considered 'poor' in quality as the epilimnion and hypolimnion consistently exceed the recommended 15 T.C.U. water quality standard for drinking water.

2.3.5 Water Hardness and General Ions

The dissolved ions present in the epilimnion of Blackburn Lake were calcium 11.25±1.2 mg/L (n=7), sulphate 11.2±1.9 mg/L (n=2), silicate 9.4±0.9 mg/L (n=4), inorganic carbon 9.0±1.2 mg/L (n=7), chloride 7.6±0.8 mg/L (n=2), sodium 5.95±0.6 mg/L (n=2), potassium 5.5±0.7 mg/L (n=2), and magnesium 3.0±0.4 mg/L (n=5). Collectively the ions produced

a total dissolved inorganic residue of 54.2±9.9 mg/L (n=9), (the total dissolved residue was 90.4±7.2 mg/L (n=9)), a pH of 7.4±0.3 relative units (n=16), and a specific conductance of 121.4±8.2 µmho/cm (n=15). The water hardness was calculated at 40.5±4.5 mg/L (n=5), and the alkalinity (total) was measured at 34.1±8.3 mg/L (n=9).

The dissolved ions present in the hypolimnion had slightly higher concentrations than the epilimnion. All hypolimnion and epilimnion values were well within the drinking water quality standards and objectives rcommended by the B.C. Ministry of Health (Table 2.1).

2.3.6 Metals

Most of the metals sampled in Blackburn Lake were undetectable except for aluminum[1] 0.31±0.35 mg/L (n=3), copper 0.007±0.005 mg/L (n=4), and iron 0.93±0.53 mg/L (n=7). All of the metals, except iron, were within their respective water quality objectives (Table 2.1). Because iron is highly associated with suspended and colloidal particulates (approximately 90 percent in natural systems, Demayo et al., 1978), the dissolved iron concentrations in Blackburn Lake can be judged within the recommended dissolved iron water quality standard of 0.3 mg/L.

2.3.7 Taste and Odour

High concentrations of organic compounds, phytoplankton, or hydrogen sulphide are the usual causes of taste and odour problems in drinking water. Hydrogen sulphide was present in the hypolimnion of Blackburn Lake throughout most of the summer. Taste and odour problems would be constant if domestic intakes were below the thermocline.

Epilimnetic and hypolimnetic organic concentrations were slightly lower than the concentrations recorded in Bullock's Lake, averaging 43.6±9.3 mg/L (n=9) and 52.5±15.1 mg/L (n=8). Organic carbon levels averaged 8.6±2.1 mg/L (n=9) or 20 percent of the total organic fraction. Although there are no officially recommended water quality standards for organics, Environment Canada (1975) notes that water containing organic carbon levels below 3 mg/L are clean, and unpolluted. This suggests that the

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[1] All metals listed as Total values.

organic content of Blackburn Lake may be above desirable levels for drinking water.

Taste and odour problems may also result from high concentrations of certain phytoplankton species. Blackburn Lake was sampled 9 times for phytoplankton, and 5 species were present that have been associated with taste and odour problems in other fresh water systems (Palmer, 1962). They are Anabaena planktonica, Aphanizomenon flos-aquae, Ceratium hirundinella, Dinobryon divergens, and Fragilaria construens. These species will cause taste and odour problems if high concentrations are present in the lake.

2.3.8 Nutrients

Blackburn Lake had a small phosphorus:nitrogen weight ratio of 1:60 at spring overturn, but the ratio decreased to 1:15 in September, and 1:10 by mid-November. A phosphorus:nitrogen ratio less than 1:15 implies that for most of the spring and summer, phosphorus availability is limiting phytoplankton growth. Dillon and Rigler (1975) and other authors, established a direct positive relationship between spring overturn phosphorus concentration, and the mean summer chlorophyll values. Large summer phytoplankton populations, associated with high phosphorus concentrations reduce water clarity and colour, and can promote the growth of taste and odour causing algae. It is therefore important to limit phosphorus concentrations in Blackburn Lake in order to maintain the present water quality.

The maximum epilimnion phosphorus concentration was 198 μg/L in November 1978, which is a 560 percent increase above the 30 μg/L fall overturn concentration. 80 percent of the 198 μg/L was associated with suspended phytoplankton cells, and the corresponding chlorophyll 'a' concentration was 142 μg/L. The source of phosphorus may have come from either watershed runoff, or the mixing of the accumulated light flocculant that hangs above the lake bottom. Subsequent winter and spring flushing reduced the phosphorus levels to 33 μg/L by late February and 20 μg/L in March 1979.

Epilimnion phosphorus concentrations decreased to a low of 12 μg/L in early May, but extension of the epilimnion into the metalimnion by wind mixing (Figure 2.4), raised the epilimnion phosphorus levels to 42 μg/L by

September. Ortho-phosphorus in the eplimnion was undetectable throughout most of the summer until August, from which time detectable concentrations persisted through the fall. The presence of ortho-phosphorus suggests that phytoplankton growth was limited by physical and/or chemical factors other than phosphorus.

Hypolimnion phosphorus concentrations ranged from a low of 21 µg/L in April to a high of 101 µg/L in August. 986 µg/L was recorded in September but it is believed that the sample included some light flocculant that hangs above the bottom, and consequently the phosphorus concentration is not representative of the hypolimnion. Ortho-phosphorus, recycled from the sediments during anaerobic conditions, increased steadily in the hypolimnion to a maximum of 35 µg/L (35 percent of the total phosphorus concentration) by late August. Decomposing phytoplankton cells, that had sunk through the thermocline, increased the hypolimnion suspended phosphorus concentrations to an average of 50 percent or more of the total phosphorus concentrations.

The 1979 spring overturn nitrogen concentration was 1980 µg/L, of which 80 percent was inorganic nitrate, 18 percent was organic nitrogen, and 2 percent was ammonia. Biological utilization steadily reduced the nitrate concentration to below 20 µg/L by late June, and nitrogen incorporated into organic molecules was the dominate nitrogen form. Sedimentation of suspended organic nitrogen decreased the total nitrogen concentration to a low of 480 µg/L in July, which is a 75 percent reduction in the spring overturn concentration.

All nutrients meet the recommended water quality standards, and only the epilimnion and hypolimnion ammonia concentrations exceeded the recommended 10 µg/L water quality objective (Table 2.1).

Because of extensive winter and spring flushing each year's spring overturn phosphorus and nitrogen concentrations are totally independent of their fall overturn concentrations. In an average precipitation year, Blackburn Lake will be flushed about 27 times from November to April (an average retention time of 6.8 days). Vollenweider

(1971) noted that "a body of water is in danger with regard to its trophic level when its springtime concentration of assimilable phosphorus compounds and inorganic nitrogen compounds exceed 10 μg/L P and 200-300 μg/L N." Any increase in nutrient loading from the watershed would increase the summer phytoplankton biomass and reduce the water quality of Blackburn Lake.

2.3.9 Bacteriological

The coliform concentrations recorded at the center station (1100136), and the north-west inflow station (Figure 2.2), are listed in Table 2.2.

TABLE 2.2: TOTAL AND FAECAL COLIFORM CONCENTRATIONS IN BLACKBURN LAKE

DATE	CENTER STATION (1100136)		NORTH-WEST INFLOW STATION	
	Total Coliforms (M.P.N.)	Faecal Coliforms (M.P.N.)	Total Coliforms (M.P.N.)	Faecal Coliforms (M.P.N.)
October 12, 1978	540	-	540	-
November 27, 1978	13	8	11	7
February 27, 1979	79	13	33	13
April 18, 1979	2	2	49	13
May 9, 1979	4	4	33	23
May 29, 1979	4	L2	G2400	G2400
June 25, 1979	17	2	23	5
July 11, 1979	17	2	14	2
July 31, 1979	5	2	33	L2
August 22, 1979	49	L2	130	5
September 10, 1979	33	2	-	-

Notes: Numbers represent 'Most Probable Number' (M.P.N.) of coliform bacteria cells per 100 ml.

Blackburn Lake does not meet the B.C. Ministry of Health recommended coliform bacteria standards for untreated potable water (Table 2.1), but does meet the recommended Class 'A' standard of 50/100 ml in any month. Water that meets the Class 'A' standard requires disinfection by chlorination before drinking.

2.3.10 Aquatic Macrophytes

Aquatic macrophytes occupy 100 percent of the lake's shoreline. Nuphar polysepalum and Potamogeton amplifolius were the dominant species. Table 2.3 lists all aquatic macrophytes found in Blackburn Lake on October 12, 1978.

TABLE 2.3: AQUATIC MACROPHYTES FOUND IN BLACKBURN LAKE

SPECIES	
Nuphar polysepalum	Dominant
Ceratophyllum demersum	
Potamogeton robbinsii	
Typha latifolia	
Potamogeton amplifolius	Dominant
Utricularia vulgaris	

NOTES: - Samples collected by C. McKean and R. Harcombe, October 12, 1978.
- Plants identified by Dr. P. Warrington, B.C. Ministry of Environment.

2.3.11 Phytoplankton

Seasonal changes in phytoplankton biomass, measured by chlorophyll 'a', in Blackburn Lake are illustrated in Figure 2.7. The 1979 average chlorophyll concentration averaged 6.0±4.4 μg/L (n=9), with a high of 16.2 μg/L in September and a low of 2.4 μg/L in late May. Blackburn Lake does not follow the typical pattern of a high spring phytoplankton population followed by a summer low and a small fall peak. Instead, the spring phytoplankton population was proportionately low; the summer readings were marked by a mid-summer peak; and the fall populations were the highest for the year (Figure 2.7). Fall chlorophyll readings were recorded as high as 142 μg/L in November 1978. This type of irregular phytoplankton growth pattern was due to the high spring turbidity values, and the large amount of phosphorus recycled

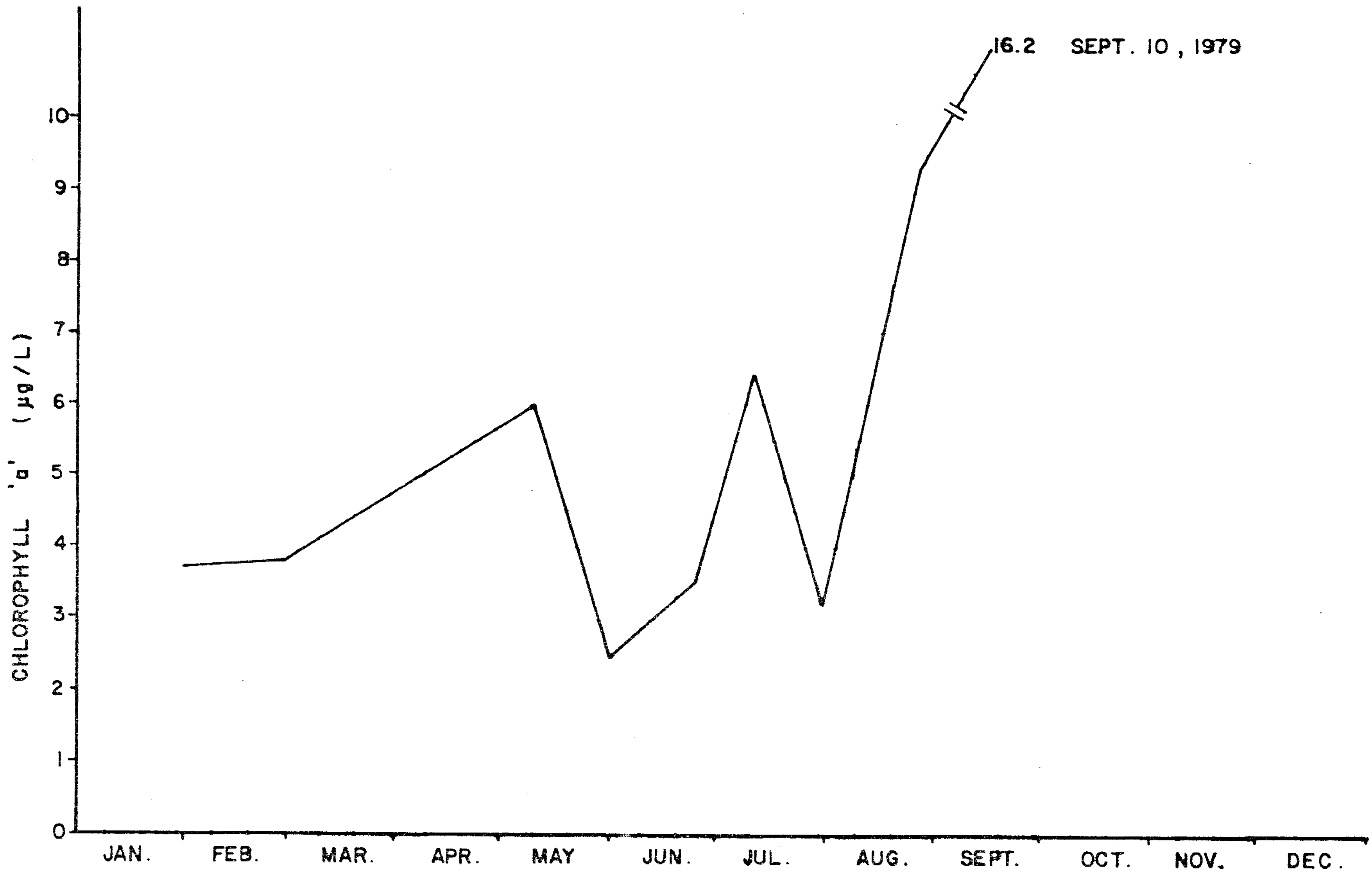


FIGURE 2.7 : SEASONAL CHANGES IN PHYTOPLANKTON BIOMASS FOR BLACKBURN LAKE, 1979 (MEASURED AS CHLOROPHYLL 'a').

from anaerobic sediments, which became available for phytoplankton growth after fall overturn.

Identification of the 9 phytoplankton samples showed that the phytoplankton community of Blackburn Lake was dominated by several species of blue green algae. Aphanocapsa delicatissima, A. elachista, Microcystis, Aphanizomenon flos-aquae, Gomphosphaeria aponina, and Anabaena planktonica were the dominant algae present in Blackburn Lake. Diatom species were present, but their numbers were low throughout the year.

2.4 Discussion

Blackburn Lake experiences summer surface water temperatures, hypolimnion dissolved oxygen concentrations, water colour values, winter water clarity measurements, and coliform bacteria populations that did not meet the recommended water quality standards (Sections 2.3.1, 2.3.2, 2.3.3, 2.3.4, and 2.3.9). Consequently chlorination and filtration techniques would be desirable before Blackburn Lake is used as a domestic drinking water source. If domestic intakes are installed they should float 2.5 metres below the surface to obtain the best quality water available, throughout the year.

Other uses for Blackburn Lake include recreation and as a source of irrigation water. Weed growth around the edge and marginal water quality would reduce the popularity of the lake for recreation, while the utilization of nutrient rich water from the hypolimnion for irrigation would reduce the nutrient and phytoplankton concentrations at fall overturn, as well as reduce the nutrient loading to Cusheon Lake. The result would be improved conditions in both Blackburn and Cusheon Lakes. The only drawback is the irrigation water would have a slight hydrogen sulphide odour towards the end of the summer.

Removal of significant amounts of surface water will create two problems. Firstly, the erosion of the thermocline by wind mixing will be increased as the distance between the surface and the top of the thermocline is reduced. In a shallow lake like Blackburn, the consequence is an earlier

destruction of the thermocline (normally eroded in late September). Secondly, the capacity of the surface water to dilute the high nutrient concentrations in the hypolimnion, after the thermocline has been eroded, decreases proportionately with the amount of water withdrawn. In my opinion, to prevent this water quality decline, use of water for irrigation should not exceed one-third of the lake volume.

Restoration techniques aimed at improving the water quality of Blackburn Lake should be directed at reducing nutrient concentrations in the inflow stream.

3. BULLOCK'S LAKE

3.1 Lake Characteristics

Bullock's Lake is situated approximately 2 kilometres (km) (1.25 miles) north of Ganges Harbour, and is approximately 26 metres (m) (85 ft) above geodetic datum, with a maximum depth of 8 m (26 ft). The lake's surface area is 10.2 hectares (25.2 acres). Based on an estimated mean depth of 5.0 m (16.4 ft), Bullock's Lake has a volume of 510 cubic decametres (dam^3) (413 acre-feet:af). The outlet is located at the south-east end, and drains 212 hectares (525 acres) directly to the sea during the winter and spring months. The main tributary stream originates from an upstream lake, and enters Bullock's Lake with a diffuse inflow at the north-west end. There is minimal development surrounding the lake. Houses lie along the north-east shore, and a small farm is situated lake's south end. The remainder of the shoreline is surrounded by a forest of Douglas fir (Figure 3.2).

Water and bacteriological samples were taken from the lake's center, (Ministry of Environment computer and data storage reference number: 1100137), and at the north-west inflow (Figure 3.2).

3.2 Hydrology

Rainfall in the Bullock's Lake watershed was based directly on the data recorded at Environment Canada's, St. Mary Lake Weather Station, Saltspring Island. Appendix 1 lists the monthly precipitation values for 1977-1979, and Appendix 2 lists the mean monthly precipitation values.

Watershed runoff volumes for Bullock's Lake were calculated by the Hydrology Section of the Inventory and Engineering Branch (Obedkoff, 1980). Appendix 2 lists the monthly runoff volumes based on an average precipitation year. The study year, however, was 55 percent below the norm, and instead of 756 dam^3 (612 af), only 340 dam^3 (275 af) entered Bullock's Lake. Based on the lake's volume of 510 dam^3 (413 af) the average flushing rate is 1.5 times per year, but for the study year the flushing rate was only 0.67

FIGURE 3.1

LOCATION OF BULLOCK'S LAKE, SALTSPRING ISLAND.

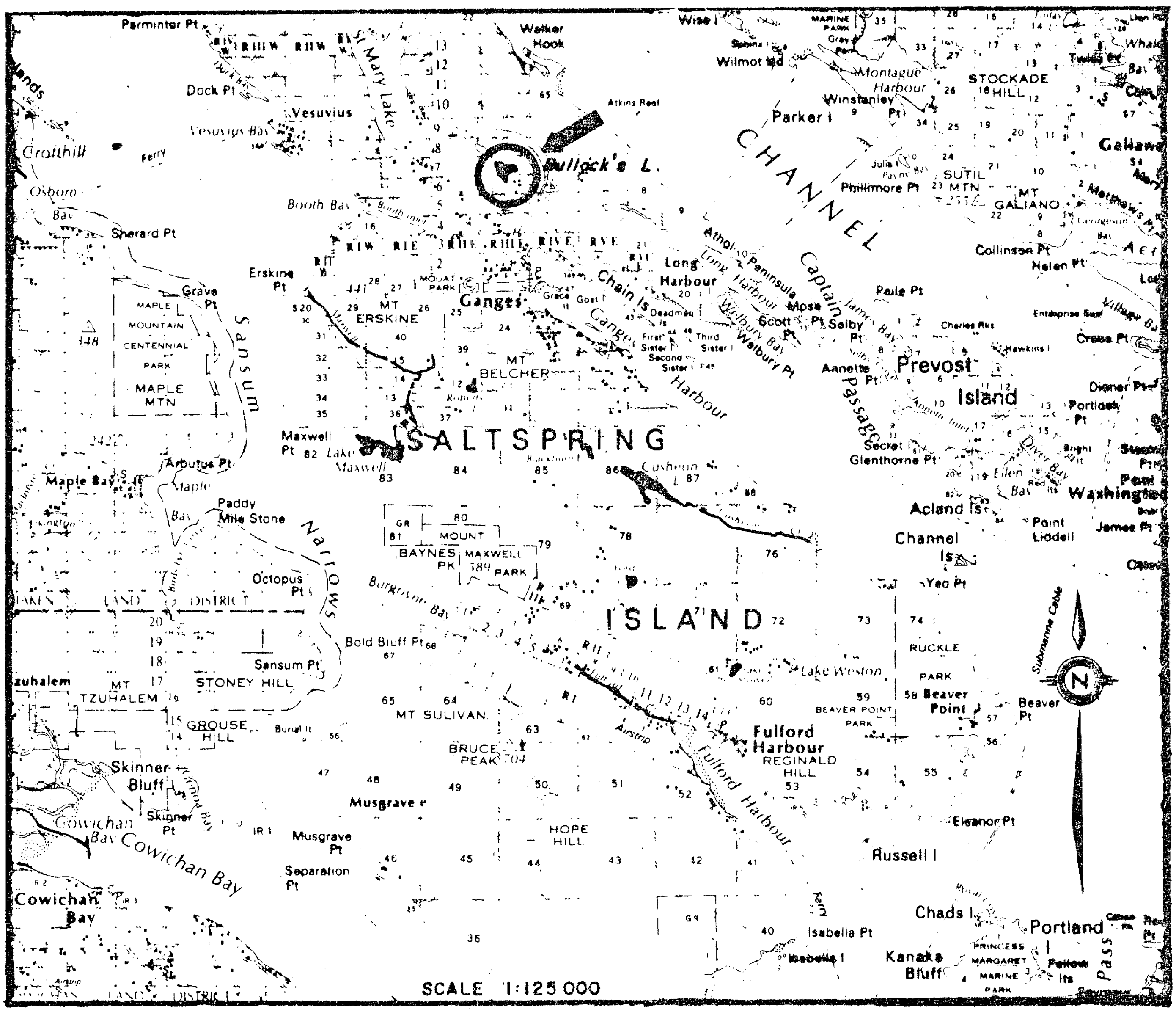
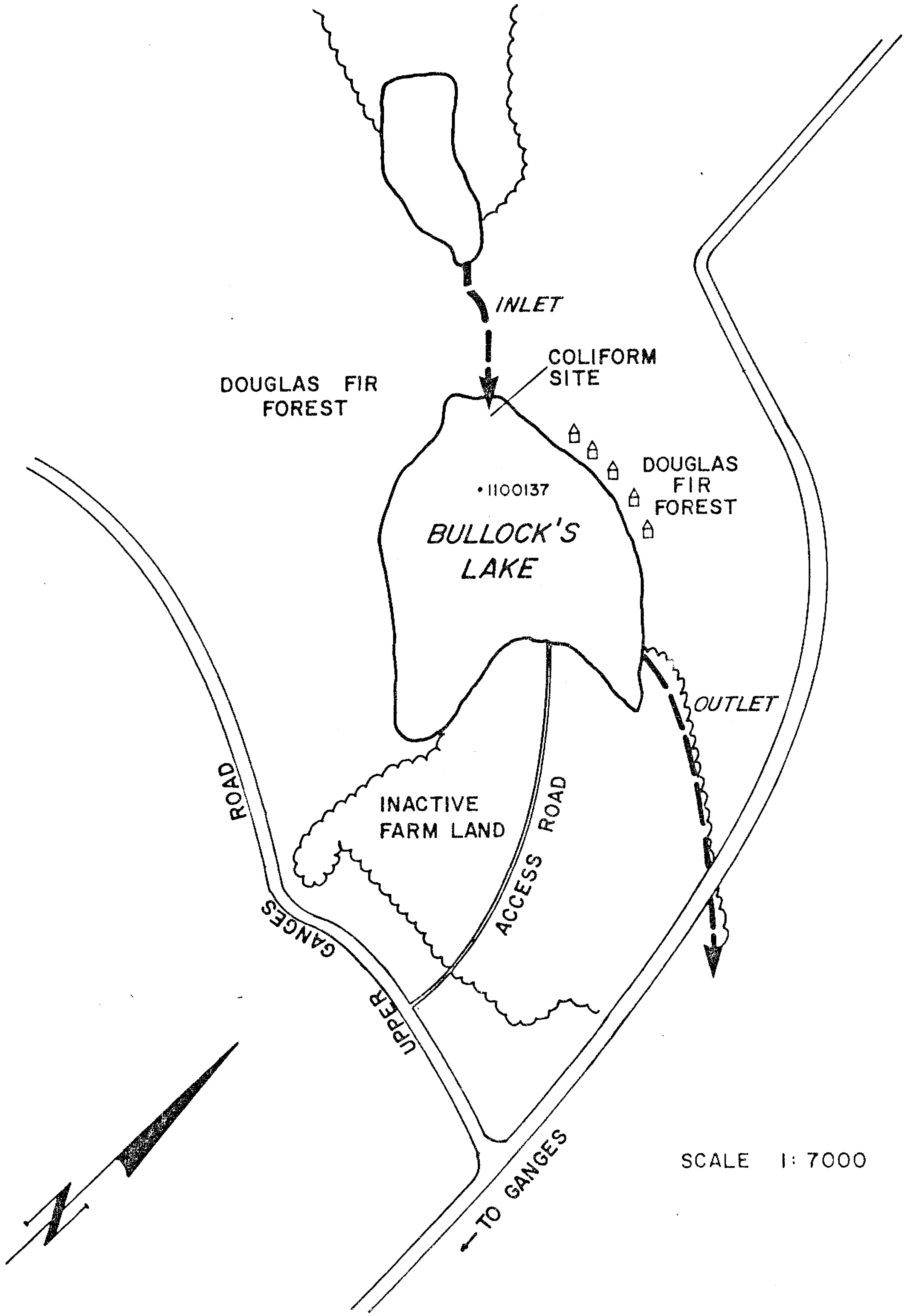


FIGURE 3.2 : SAMPLING STATIONS AND LAND-USE OF BULLOCK'S LAKE.



times. The low flushing rates are the results of the low ratio between the watershed area of Bullock's Lake and the lake volume (0.4 ha:1 dam^3).

The epilimnion (zone of water above the thermocline) extended from the surface to 2.5 m (8.2 ft.) throughout the summer of 1979, and had a constant volume of 260 dam^3 (210 af). This represents 50 percent of the lake's total volume. The metalimnion (thermocline) extended from 2.5 m (8.2 ft) to 4 m (13.2 ft), and accounts for 30 percent of the lake's total volume or 153 dam^3 (124 af). The hypolimnion (zone water below the thermocline) had a volume 102 dam^3 (83.7 af), which represents the remaining 20 percent of the lake's total volume.

Currently there is a 10,000 gallons per day conditional water licence (CL 49173) granted to E.F. and B.A. Lowe, for fish culture. According to Mr. Lowe the water licence is not used, consequently the summer drop in the lake water level is due exclusively to evaporation and groundwater losses (not measured). The average summer evaporation loss is calculated at 18 centimetres (cm) (7 in.) (Appendix 2) which is 18.1 dam^3 (14.7 af) of surface water.

The storage potential of Bullock's Lake is 'poor' because any major increase in the lake's volume would require the relocation of the existing cabins on the east shore, and would cause an increase in the present water retention time of the lake. An increase of the water retention time to one year or more would result in a further reduction of the water quality (and domestic suitability) of Bullock's Lake.

3.3 Water Quality

3.3.1 Temperature

Bullock's Lake is thermally stratified from mid-April to late September, and during periods of ice cover. The epilimnion had a maximum summer temperature around 20^{o} C (66^{o} F), which exceeded the recommended water temperature standard of 15^{o} C (57^{o} F). The metalimnion had a maximum temperature gradient of 13^{o} C during July and August, while

the hypolimnion had a minimum temperature of 5° C (39° F), in April, and a maximum temperature of 7° C (42.6° F) in August.

The thermal gradient (thermocline) was eliminated in the fall when the surface water cooled to the same temperature as the hypolimnion. Unstratified conditions will remain throughout the winter, unless exceptionally cold weather causes ice formation.

3.3.2 Dissolved Oxygen

The epilimnetic dissolved oxygen concentrations in 1979 ranged from 11.0 mg/L to 13.4 mg/L, while the hypolimnion values ranged from 0 mg/L to 13.0 mg/L. Dissolved oxygen concentrations, below the recommended 3.0 mg/L drinking water standard, dominated the hypolimnion from April to October, and during prolonged periods of ice cover. Oxygen was re-introduced into the hypolimnion by the downward mixing of oxygenated epilimnion water during fall overturn.

3.3.3 Water Clarity

Water clarity was determined by the nephelometric turbidity test and field Secchi disc readings (Table 3.1). Secchi disc depths and epilimnion turbidity readings, were relatively constant throughout 1979, averaging 1.4± 0.14[1] m (4.6± 0.4 ft) (n=6)[2], and 1.65±0.38 Nephelometric Turbidity Units (N.T.U.) (n=6). High concentrations of suspended organic particulates caused the surface water to exceed consistently the turbidity objective of 1 N.T.U. The influence of suspended inorganic particulates, associated with winter and spring runoff, on water clarity was not noticeable. It is believed that any inorganic suspended particulates settled out in the upstream lake.

The hypolimnion had consistently higher turbidity values averaging 5.1±4.1 N.T.U. (n=4), with a high of 11 N.T.U. on October 12, 1978. Suspended phytoplankton cells, that had sunk through the epilimnion, periodically caused the turbidity values to exceed the recommended water quality of 5 N.T.U. (Table 3.1).

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1 standard deviation

2 n=sample size

TABLE 3.1: RECOMMENDED WATER QUALITY STANDARDS AND OBJECTIVES, AND RESULTS FOR BULLOCK'S LAKE

PARAMETER	BULLOCK'S LAKE AT STATION 1100137		DRINKING WATER STANDARDS AND OBJECTIVES		
	EPILIMNION	HYPOLIMNION	STANDARD	OBJECTIVE	AGENCY
PHYSICAL PARAMETERS					
1) Temperature (°C)	[2]20 (Max.)	7 (Max.)	15	10	B.C. Health
2) Oxygen-Dissolved (mg/L)	11 (Min.)	[2]0 (Min.)	3	-	[4]SSPA, [5]WQMO
GENERAL IONS					
1) Alkalinity (mg/L)	31.7±6.9* (n=5)	43.1 ±14.4 (n=3)	-	-	-
2) Carbon-Inorganic (mg/L)	9.5±4.4 (n=4)	14.5±10.6 (n=2)	-	-	-
3) Calcium (mg/L)	13.9±2.6 (n=2)	14.1±2.4 (n=3)	200	L75	B.C. Health
4) Chloride (mg/L)	10.9±1.4 (n=2)	12.1 (n=1)	250	L250	B.C. Health
5) Hardness (mg/L)	43.5±6.9 (n=4)	46.5±7.6 (n=3)	180	120	B.C. Health
6) Magnesium (mg/L)	3.1±0.4 (n=3)	3.0±0.2 (n=3)	150	L50	B.C. Health
7) PH (Relative Units)	7.35±0.17(n=6)	7.0±0.3 (n=4)	6.5+8.5	-	B.C. Health
8) Potassium (mg/L)	0.65±0.07(n=2)	0.6 (n=1)	-	-	-
9) Silicate (mg/L)	7.7 (n=1)	7.7 (n=1)	-	-	-
10) Sodium (mg/L)	9.45±0.2 (n=2)	9.8 (n=1)	-	-	-
11) Specific Conductance (μmho/cm)	126±24.7 (n=6)	141±14 (n=4)	-	-	-
12) Sulphate (mg/L)	11.9±0.9 (n=2)	12.5 (n=1)	500	250	B.C. Health
13) Total Dissolved Solids (mg/L)	101.6±19.5 (n=5)	118±8.4 (n=2)	1000	L500	B.C. Health
14) Total Inorganic Solids (mg/L)	58.8±13.7 (n=5)	68.7±4.6 (n=3)	-	-	-
WATER CLARITY AND COLOUR					
1) True Colour (T.C.U.)	[2]51.7±17.2 (n=6)	[2]90±25 (n=4)	15	L5	B.C. Health
2) Secchi Disc Depth (meters)	1.4±0.0 (n=6)	-	-	-	-
3) Tannins and Lignins (mg/L)	1.9±0.1 (n=2)	2.2±0.6 (n=2)	-	-	-
4) Total Suspended Solids (mg/L)	2.6±0.9 (n=5)	7.3±6.6 (n=3)	-	-	-
Total Suspended Solids (mg/L)	4.0 (Max.)	15.0 (Max.)	-	-	-
5) Turbidity (N.T.U.)	[1]1.65±0.4 (n=6)	[2]5.1±4 (n=4)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	[1]2.1 (Max.)	[2]11 (Max.)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	[1]1.0 (Min.)	[1]2.2 (Min.)	5.0	L1.0	B.C. Health
METALS					
1) Aluminum (mg/L)	0.065±0.036(n=2)	0.11 (n=1)	-	-	-
2) Arsenic (mg/L)	[1]0.006 (n=1)	-	0.05	L0.005	B.C. Health
3) Cadmium (mg/L)	L0.0005 (n=1)	-	0.01	L0.0005	B.C. Health
4) Chromium (mg/L)	L0.005 (n=1)	-	0.05	L0.005	B.C. Health
5) Copper (mg/L)	L0.001 (n=1)	-	1.0	L0.01	B.C. Health
6) Iron (mg/L)	0.25±0.07 (n=2)	0.4 (n=1)	0.3 (Diss)	L0.05 (Diss)	B.C. Health
7) Lead (mg/L)	L0.001 (n=1)	-	0.05	L0.001	B.C. Health
8) Manganese (mg/L)	[1]0.045±0.0007(n=2)	[1]0.05 (n=1)	0.05	L0.01	B.C. Health
9) Nickel (mg/L)	L0.01 (n=1)	L0.01 (n=1)	-	-	-
10) Zinc (mg/L)	L0.005 (n=1)	-	5.0	L1.0	B.C. Health
NUTRIENTS					
1) Nitrogen-Ammonia (mg/L)	[1]0.11±0.12 (n=6)	[2]0.84±1 (n=3)	0.5	L0.01	B.C. Health
2) Nitrogen-Nitrate (mg/L)	0.05±0.05 (n=6)	0.07±0.07 (n=4)	10	L10	[6]WQC
3) Nitrogen-Total (mg/L)	0.95±0.8 (n=5)	1.7±1.2 (n-3)	-	-	-
4) Phosphorous-Ortho (mg/L)	0.004±0.004 (n=6)	[2]0.079±0.11(n=4)	0.065	0.065	B.C. Health
5) Phosphorous-Total (mg/L)	0.04±0.12 (n=6)	0.138±0.2 (n=4)	-	-	-
6) Carbon-Organic (mg/L)	15.6±4.7 (n=4)	21±1 (n=2)	-	-	-
BACTERIA					
1) Coliforms-Faecal (M.P.N.)	[2]2. ±1(n=4)	-	[7]0	-	B.C. Health
2) Coliforms-Total (M.P.N.)	[2]46. ± 82 (n=4)	-	0	-	B.C. Health

*Standard Deviation

NOTES:

[1]Parameter exceeds the recommended water quality objective.
[2]Parameter exceeds the recommended water quality standard.
[3]Iron concentration listed as total iron.
[4]S.S.P.A.: Scientific Stream Pollution Analysis, 1974.
[5]W.Q.M.O.: Guidelines and Criteria for Water Quality Management in Ontario, 1979.
[6]W.Q.C.: Water Quality Criteria. E.P.A., 1972.
[7]B.C. Ministry of Health recommended drinking water standard requires 'Most Probable Numer' (M.P.N.) of coliform bacteria to be 0 cells/100 ml for untreated water, and 50 cells/100 ml for 'Class A' water.

The water clarity of Bullock's Lake can be considered only 'moderate' in quality, as the epilimnion exceeded the recommended water quality objective for turbidity, and the hypolimnion frequently exceeded the recommended water quality standard for turbidity.

3.3.4 Water Colour

Water colour, measured as 'true colour', averaged 51.7±17.2 True Colour Units (T.C.U.) (n=6) in the epilimnion, and 90±25.8 T.C.U. (n=4) in the hypolimnion. Both the epilimnion and hypolimnion are far above the 15 T.C.U. drinking water standard (Table 3.1). High colour values are the result of high concentrations of dissolved organic compounds. Tannins and lignins (a specific group of dissolved organic compounds derived from the breakdown of plant matter) averaged 1.9±1.9 mg/L (n=2) in the epilimnion, and 2.2±0.56 mg/L (n=2) in the hypolimnion. The concentrations are sufficiently high to give the lake a characteristically brown colour. The concentrations of other dissolved organic compounds averaged 46±8.6 mg/L (n=5) in the epilimnion and 53±9.5 mg/L (n=3) in the hypolimnion. Although these concentrations are high when compared with other B.C. lakes, they are in the same range as the other lakes discussed in this report.

The water colour of Bullock's Lake must be judged 'poor', as it is far above the recommended water colour standard, and has a distinctive brown colour.

3.3.5 Water Hardness and General Ions

The general ions present in the epilimnion of Bullock's Lake were calcium 13.9±2.6 mg/L (n=2), sulphate 11.9±0.9 mg/L (n=2), inorganic carbon 9.5±4.4 mg/L (n=4), sodium 9.4±0.2 mg/L (n=2), silicate 7.7 mg/L (n=1), magnesium 3.1±0.4 mg/L (n=3), and potassium 0.65±0.1 mg/L (n=2). Collectively the ions produce a total dissolved inorganic residue of 56.2±13.6 mg/L (n=5) (total dissolved solids 101.6±19 mg/L (n=5), a pH of 7.35±0.17 relative units (n=6), and a specific conductance of 126±24 µmho/cm (n=6). The water hardness was calculated at 43.4±6.9 mg/L (n=4), and the total alkalinity measured at 31.7±6.9 mg/L (n=5).

The general ions present in the hypolimnion had slightly higher concentrations than those found in the epilimnion. All hypolimnion and epilimnion values were well within the recommended water quality standards and objectives for drinking water (Table 3.1).

3.3.6 Metals

Most of the metals sampled in Bullock's Lake were undetectable except for aluminum[1] 0.065±0.035 mg/L (n=2), arsenic 0.0006 mg/L (n=1), manganese 0.045±0.007 mg/L (n=2), and iron 0.25±0.07 mg/L (n=2). All detectable metals were within their respective water quality objectives except for iron, manganese, and arsenic. These three, however, were below the recommended water quality standard.

3.3.7 Taste and Odour

High concentrations of dissolved organic compounds, phytoplankton, or hydrogen sulphide are the usual causes of taste and odour problems in potable water. Hydrogen sulphide was present in the hypolimnion of Bullock's Lake throughout most of the summer of 1979. Taste and odour would be a constant problem if domestic intakes were below the thermocline.

Dissolved organic concentrations in the epilimnion were high, averaging 46.0±8.6 mg/L (n=5), of which 30-35 percent (16 mg/L) was organic carbon. Environment Canada (1977) notes that waters containing organic carbon levels below 3 mg/L, are clean and unpolluted. This suggests that the organic content of Bullock's Lake may be above desirable levels. Tannins and lignins also can cause taste and odour problems. McKee and Wolf (1963) report that tannin and lignin concentrations of 2-4 mg/L (Bullock'sLake Av.=2.1 mg/L) will cause a woody taste and odour.

Taste and odour problems also may result from high concentrations of certain phytoplankton species in the water. Bullock's Lake was sampled twice for phytoplankton, and three species were present that have been associated with taste and ocour problems in other fresh water systems (Palmer, 1962). *Aphanizomenon flos-aquae*, *Dinobryon divergens* and *Fragilaria construens* are present in Bullock's Lake, and may cause taste and odour problems if periodic high concentrations develop.

[1] all metals listed as Total Values

3.3.8 Nutrients

Limited sampling on Bullock's Lake restricts a detailed analysis of a nutrient budget, however, Bullock's Lake had a 1979 spring overturn phosphorus:nitrogen weight ratio of 1:22, which implies phytoplankton growth is limited by the availability of assimilable phosphorus. Dillon and Rigler (1975), and other workers, have established a direct positive relationship between spring overturn phosphorus concentrations and the mean summer chlorophyll 'a' levels (an indirect measure of phytoplankton biomass), for phosphorus limited lakes. High concentrations of phytoplankton decrease the overall clarity and quality of lake water, and can create taste and odour problems. It is therefore important to limit phosphorus concentrations in Bullock'sLake, in order to maintain the present water quality.

Bullock's Lake had the highest spring phosphorus overturn concentration of the four lakes, 50 µg/L. Consequently Bullock's Lake was expected to support the largest phytoplankton population throughout the summer and fall. The summer phosphorus concentration decreased through the summer to 20 µg/L, as phytoplankton, containing phosphorus, settled from the epilimnion to the hypolimnion.

Phosphorus recycling in the hypolimnion, during anaerobic periods, was significant. Phosphorus levels of 350 µg/L, of which 75% was orthophosphorus, were recorded in the hypolimnion in late summer. Lake surface phosphorus levels were elevated from 20 µg/L to 45 µg/1, after the two zones had mixed at fall overturn.

Epilimnion nitrogen concentrations remained relatively constant at 1 mg/L (1000 µg/L) throughout the study period. During the winter, inorganic nitrogen concentrations increased to 30 percent of the total nitrogen concentration; nitrate and ammonia each represented 50 percent of the total inorganic concentration. By late August, the ammonia levels in the epilimnion were depleted to only 3 percent of the total nitrogen component, and nitrate was undetectable. Biological fixation of the inorganic compounds was responsible for the reduction.

Hypolimnion nitrogen concentrations increased from 1 mg/L in the spring, to 3 mg/L in late August. Because of persistent anaerobic conditions, all inorganic nitrogen was present as ammonia. Ammonia comprised 25 percent (0.286 mg/L) of the total nitrogen concentration in April, and increased by 1.8 mg/L to 2.1 mg/L, or 66 percent of the total nitrogen, in August. Organic nitrogen also increased in concentration through the summer, but the increase was only 0.3 mg/L.

Ammonia concentrations exceeded the recommended drinking water objective in the epilimnion, and ammonia and ortho-phosphorus exceeded the recommended water quality standards in the hypolimnion. All other nutrient compounds met the recommended water quality objectives and standards (Table 3.1).

Each year's spring overturn phosphorus and nitrogen concentrations are dependent on the concentration of nutrients at fall overturn, the inflow nutrient concentrations, and the amount of winter and spring flushing. In an average precipitation year Bullock's Lake will be flushed about 1.5 times, but in a low flow year (similar to the study year) the lake will not be completely flushed. Since hypolimnetic recycling of phosphorus is very significant in Bullock's Lake, spring overturn phosphorus concentrations are expected to be higher when the flushing rate is below once per year.

3.3.9 Bacteriological

Table 3.2 lists the total and faecal coliform concentrations recorded at the center station (1100137), and the north-west shore station (Figure 3.2).

TABLE 3.2: TOTAL AND FAECAL COLIFORM CONCENTRATIONS IN BULLOCK'S LAKE

	CENTER STATION 1100137		NORTH-WEST SHORE STATION	
	Total Coliforms	Faecal Coliforms	Total Coliforms	Faecal Coliforms
October 12, 1978	-	-	49	-
November 27, 1978	5	2	5	2
February 27, 1979	8	L2	28	8
April 18, 1979	L2	L2	L2	L2
August 22, 1979	170	2	920	L2

NOTES: - Numbers represent 'Most Probable Number' (M.P.N.) of coliform bacteria cells/100 ml

Bullock's Lake does not meet the B.C. Ministry of Health recommended coliform bacteria standards, for untreated potable water (Table 3.1), but does meet the Class 'A' standard of 50/100 ml in any month. Water that meets the Class 'A' standard requires disinfection by chlorination before drinking.

3.3.10 Aquatic Macrophytes

Aquatic macrophytes occupy 100 percent of the lake's shoreline. There were no dominant species to single out; most species listed in Table 3.3 were all relatively common.

TABLE 3.3

AQUATIC MACROPHYTES FOUND IN BULLOCK'S LAKE

Potamogeton berchtoldii
Nuphas polysepalum
Lemna minor
Ranunculus aquatilis
Utricularia vulgaris
Ceratophyllum demersum
Ceratophyllum echinatum
Typha latifolia
Potamogeton amplifolius
Najas flexilis
Utricularia
Polygonum
Eleocharis

NOTES: - Samples collected by C. McKean and R. Harcombe, October 1978.
- Plants identified by Dr. P. Warrington; B.C. Ministry of Environment.

3.3.11 Phytoplankton

Bullock's Lake, due to high phosphorus concentrations, had the highest phytoplankton biomass (measured as chlorophyll 'a') of any of the four lakes considered in this report. Large numbers of phytoplankton reduce water clarity, while large numbers of certain species can also create taste and odour problems (Section 3.3.7). The phytoplankton

biomass in Bullock's Lake was as high as 20 ug/L in February 1979, and estimated at 10 μg/L in late August.

Identification and quantification of phytoplankton species was limited to two samples. Although two samples are not sufficient to predict the dominant species on a yearly basis, it does give a preliminary indication of what species are present in the lake. The dominant species were *Aphanizomenon flos-aquae*, *Dinobryon divergens*, *Gloeocystis*, *Aphanocapsa delicatissima*, and *Fragilaria crotonensis*. Large concentrations of *Aphanizomenon flos-aquae*, *Dinobryon divergens*, and *Fragilaria crotonensis* have been associated with taste and odour problems in other domestic water systems (Palmer, 1962), and will probably cause similar problems if their high concentrations persist.

3.4 Discussion

The present and future potential of Bullock's Lake as a domestic water supply is low. The present water colour of the lake is rated as 'poor' (Section 3.3.4), and the water clarity is 'moderate' (Section 3.3.3); the lake experiences surface water temperatures and hypolimnion dissolved oxygen concentrations that did not meet the recommended water quality standards (Sections 3.3.1 and 3.3.2); and the water should be chlorinated before drinking to eliminate all bacteria (Section 3.3.9). In addition several phytoplankton species are present in the lake that may cause taste and odour problems if periodic high concentrations occur.

Bullock's Lake has a large amount of potential water storage, but the cost of relocating the houses along the north-east shore, and the possible degradation in water quality through the reduction of the flushing rate, limits the lake as a future inexpensive domestic water reservoir.

Alternate uses for Bullock's Lake include recreation and irrigation. Recreation would be limited as moderate turbidity levels, and the distinctive brown water colour would discourage water oriented recreational activities,

but the lake could be used as a source for irrigation water. In my opinion, an estimated 60 dam^3 (48 af) of surface water could be removed without effecting the present water quality of the lake. Removal of more than 60 dam^3 (48 af) of surface water would cause extensive erosion of the hypolimnion which would release nutrients into the epilimnion as well as reduce the amount of surface water available to dilute the high nutrient concentrations in the hypolimnion at fall overturn. Both mechanisms would encourage higher phytoplankton populations which would create less desirable water quality conditions. Removal of water from the hypolimnion avoids this problem and in fact may improve water quality after fall overturn by removing some of the nutrients that accumulate in the hypolimnion during the summer.

4. FORD LAKE

4.1 Lake Characteristics

Ford Lake is 6.9 kilometres (km) (4.3 miles) from Fulford Harbour, on the Fulford-Ganges Road (Figure 4.1). The lake is 82 metres (m) (269 feet) above geodetic datum, has a maximum depth of 3 m (10 ft), and a surface area of 4.53 hectares (ha) (11.2 acres). During the winter, the lake can attain a maximum volume of 225 cubic decametres (dam^3) (182.4 acre-feet: af), but in May the volume is only 140 dam^3 (113 af). The outlet is located at the south-west end of the lake. The main outflow occurs during the winter and spring, and drains to the ocean via Fulford Creek. Even though Ford Lake has the largest watershed, 7.8 km^2 (1936 acres), it has no major tributaries. Land use around the lake is extensive with active cow pasture surrounding 50 percent of the lake, and Douglas fir forest bordering the remainder of the lake (Figure 4.2).

Water and bacteriological samples were taken at the lake's center (Ministry of Environment computer and data storage reference number: 1100135),and at the north shore (Figure 4.2).

4.2 Hydrology

Rainfall for the Ford Lake watershed is based directly from data recorded at Environment Canada's Cusheon Lake Weather Station, Saltspring Island. Appendix 1 lists the monthly precipitation values. Watershed runoff for Ford Lake was calculated by Hydrology Section of the Inventory and Engineering Branch (Obedkoff, 1980). Appendix 2 lists the calculated monthly runoff volumes based on an average precipitation year. The study year however was 55 percent below the norm. Therefore, instead of 4430 dam^3 (3590 af), only 1990 dam^3 (1616 af) entered Ford Lake during the study year. Based on a lake volume of 140 dam^3 (113 af) the average flushing rate is 32 times per year, but the estimated flushing rate for the study year was only 14 times. The high flushing rates are the result of the high ratio between the watershed area of Ford Lake and the lake volume (5.6 ha:1 dam^3).

FIGURE 4.1

LOCATION OF FORD LAKE, SALTSPRING ISLAND.

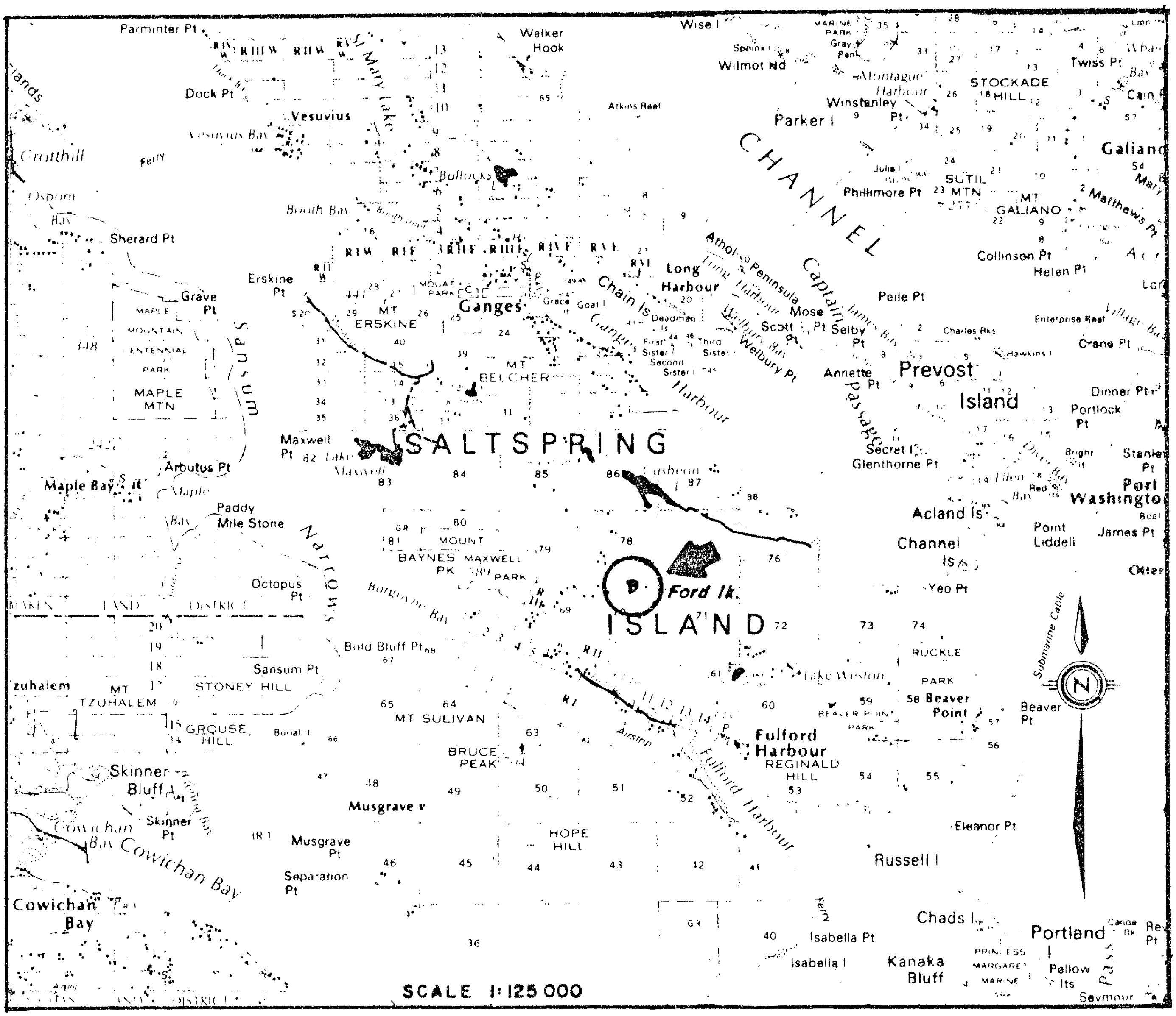
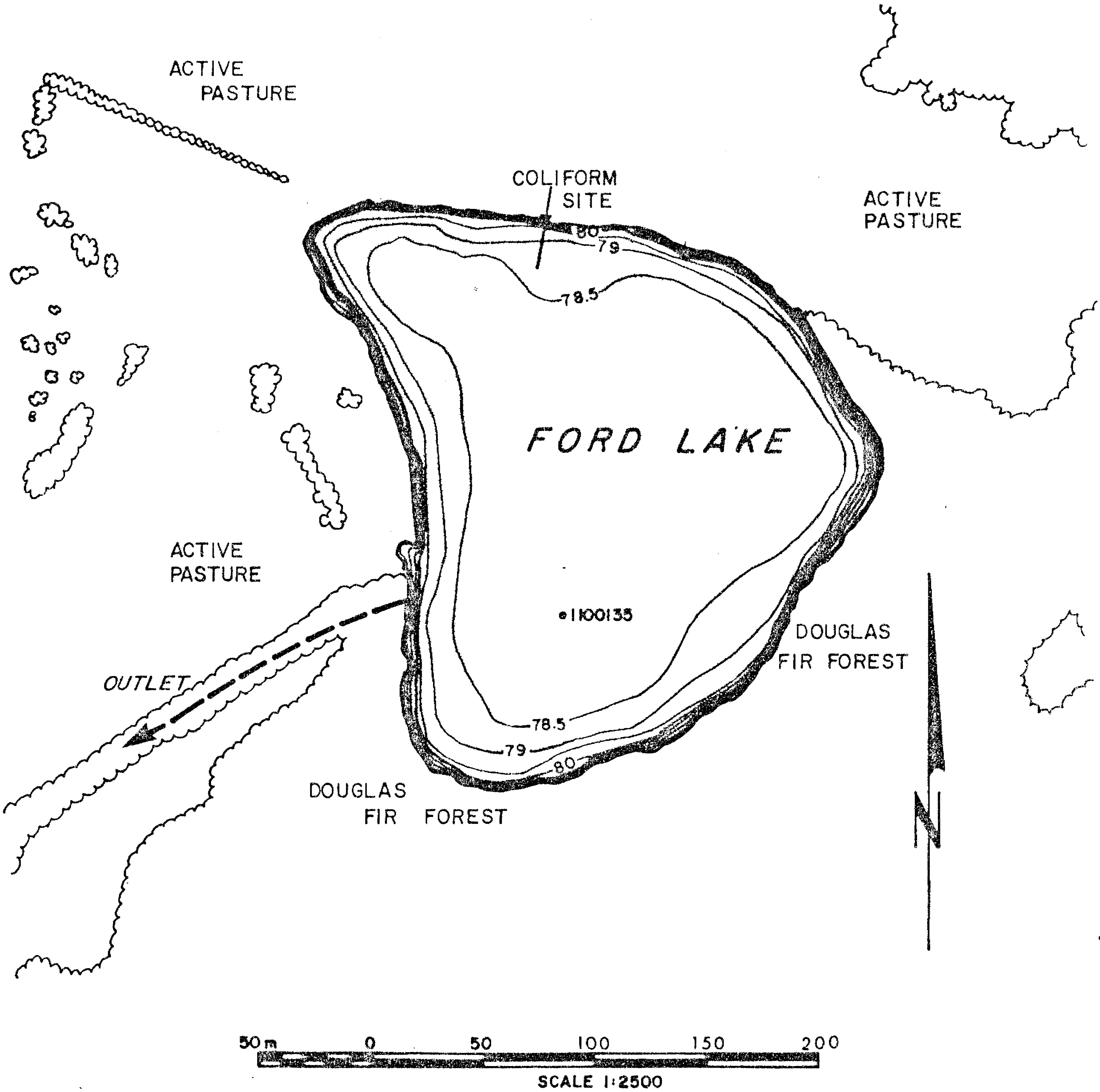


FIGURE 4.2: SAMPLING STATIONS, LAND USE, AND BATHYMETRY OF FORD LAKE.



There is only one existing water licence on Ford Lake. British Securities Ltd. has a conditional water licence (CL 30497) for 50 af (61.7 dam^3) of irrigation water, but their estimated utilization is only 10 af (12.3 dam^3) per year.

Drawdown of Ford Lake, during the summer, is due to evaporation, water utilization, and groundwater losses (not measured). From May to October the net evaporation losses averaged 0.19 m (7.5 in.) (Appendix 2), which is a loss of 9 dam^3 (7.3 af). The current water utilization is 10 af (12.5 dam^3) which accounts for an additional 0.2 m (8 in.) drawdown. The present water drawdown to both evaporation and irrigation, totals 21.3 dam^3 (17 af) of water, or 15% of the lake's total volume. A proposed domestic water licence 365820 will use an additional 500 gallons per day, or 1.75 dam^3 (1.4 af) of water from May to October, which is only 1.5% of the lake volume.

Ford Lake has 'good' potential for water storage, as the lake's volume can be increased by 75% with only a 2 m (6.3 ft) increase in water elevation (Figure 4.3).

4.3 Water Quality

4.3.1 Temperature

Ford Lake, because of its shallowness, does not experience thermal stratification in the water column during any part of the year. Maximum temperatures of 20-23^o C (66-71^o F) were recorded in late July and early August, which exceeds the B.C. Ministry of Health's recommended water quality standard of 15^o C (57^o F). Winter temperatures range from 1-3^o (34-37^o), with ice forming during prolonged periods of cold weather.

4.3.2 Dissolved Oxygen

Because Ford Lake does not experience thermal stratification, circulation of bottom water is continuous. Consequently, anaerobic conditions, a common problem in shallow productive lakes, are not found. The minimum summer oxygen concetration was 6.1 mg/L, which meets the recommended water quality standard of 3.0 mg/L (Table 4.1).

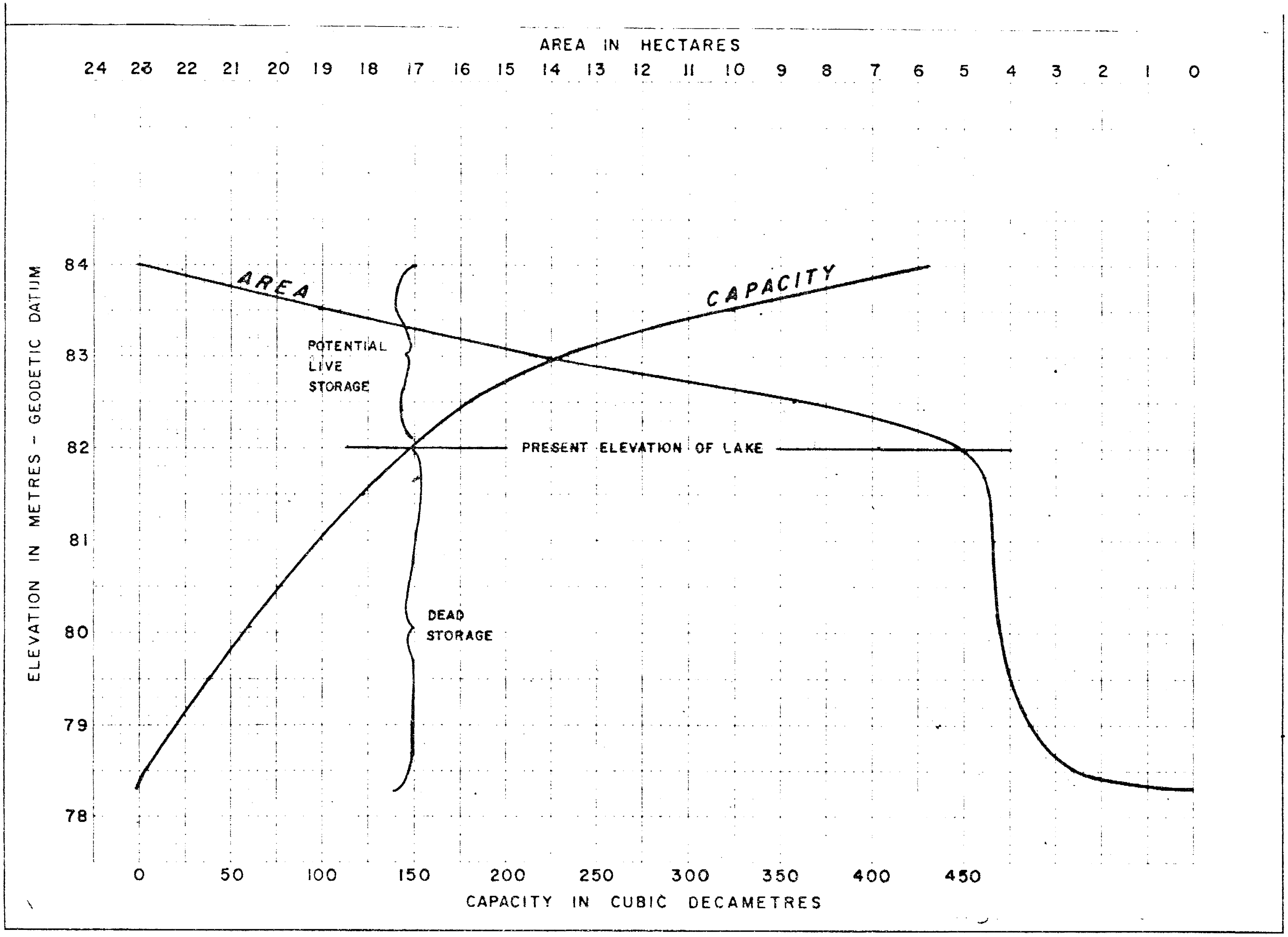


FIGURE 4.3 : STORAGE CAPACITY CURVES FOR FORD LAKE.

TABLE 4.1: RECOMMENDED WATER QUALITY OBJECTIVES AND STANDARDS, AND RESULTS FOR FORD LAKE

PARAMETER	FORD LAKE	STANDARD	OBJECTIVE	AGENCY
PHYSICAL PARAMETERS				
1) Temperature (°C)	[2]22 (Max.)	15	10	B.C. Health
2) Oxygen-Dissolved (mg/L)	6.1 (Min.)	3	-	[4]SSPA, [5]WQMO
GENERAL IONS				
1) Alkalinity (mg/L)	34.2 ±9.0* (n=9)	-	-	-
2) Carbon-Inorganic (mg/L)	9.25±1.4 (n=8)	-	-	-
3) Calcium (mg/L)	12.9 ±1.7 (n=7)	200	L75	B.C. Health
4) Chloride (mg/L)	11.2 ±3.7 (n=3)	250	L250	B.C. Health
5) Hardness (mg/L)	41.3 ±5.3 (n=7)	180	120	B.C. Health
6) Magnesium (mg/L)	2.6 ±0.28 (n=7)	150	L50	B.C. Health
7) PH (Relative Units)	7.4 ±0.44 (n=13)	6.5 → 8.5	-	B.C. Health
8) Potassium (mg/L)	0.5 (n=1)	-	-	-
9) Silicate (mg/L)	9.3 ±0.75 (n=3)	-	-	-
10) Sodium (mg/L)	8.2 (n=1)	-	-	-
11) Specific Conductance (µmho/cm)	134.6±23.4 (n=11)	-	-	-
12) Sulphate (mg/L)	9.7 ±0.56 (n=2)	500	250	B.C. Health
13) Total Dissolved Solids (mg/L)	103.1±24 (n=7)	1000	L500	B.C. Health
14) Total Inorganic Solids (mg/L)	66.0±20 (n=7)	-	-	-
WATER CLARITY AND COLOUR				
1) True Colour (T.C.U.)	[2]42.3±19.7 (n=11)	15	L5	B.C. Health
2) Secchi Disc Depth (meters)	2.1± 1.1 (n=7)	-	-	-
3) Tannins and Lignins (mg/L)	1.14±0.23 (n=5)	-	-	-
4) Total Suspended Solids (mg/L)	6.8±10.0 (n=6)	-	-	-
Total Suspended Solids (mg/L)	27 (Max.)	-	-	-
5) Turbidity (N.T.U.)	[2]7.2 ±3.7 (n=7)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	[2]33 (Max.)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	[1]1.8 (Fall av.)	5.0	L1.0	B.C. Health
METALS				
1) Aluminum (mg/L)	1.66±2.3 (n=2)	-	-	-
Aluminum (mg/L)	3.3 (Max.)	-	-	-
2) Arsenic (mg/L)	L0.005 (n=1)	0.05	L0.005	B.C. Health
3) Cadmium (mg/L)	L0.0005 (n=1)	0.01	L0.0005	B.C. Health
4) Chromium (mg/L)	L0.005 (n=1)	0.05	L0.005	B.C. Health
5) Copper (mg/L)	0.006 (Max.)	1.0	L0.01	B.C. Health
6) Iron (mg/L)	[3]2.7 (Max.)	0.3 (Diss.)	L0.05 (Diss.)	B.C. Health
7) Lead (mg/L)	0.0025±0.002(n=2)	0.05	L0.001	B.C. Health
8) Nickel (mg/L)	L0.01 (n=2)	-	-	-
9) Zinc (mg/L)	L0.005 (n=1)	5.0	L1.0	B.C. Health
NUTRIENTS				
1) Nitrogen-Ammonia (mg/L)	[1]0.035±0.011 (n=7)	0.5	L0.01	B.C. Health
2) Nitrogen-Nitrate (mg/L)	0.44 ±0.54 (n=10)	10	L10	[6]WQC
3) Nitrogen-Total (mg/L)	1.26 ±0.61 (n=6)	-	-	-
4) Phosphorous-Ortho (mg/L)	0.005±0.002(n=10)	0.065	0.065	B.C. Health
5) Phosphorous-Total (mg/L)	0.025±	-	-	-
6) Carbon-Organic (mg/L)	8.8 ±2.6 (n=9)	-	-	-
BACTERIA				
1) Coliforms-Faecal (M.P.N.)	25.5±33.2 (n=2)	[7]0	-	B.C. Health
2) Coliforms - Total (M.P.N.)	31.3±41.6 (n=3)	0	-	B.C. Health

* Standard Deviation

NOTES:

[1] Parameter exceeds the recommended water quality objective.
[2] Parameter exceeds the recommended water quality standard.
[3] Iron concentration listed as total iron.
[4] S.S.P.A.: Scientific Stream Pollution Analysis, 1974
[5] W.Q.M.O.: Guidelines and Criteria for Water Quality Management in Ontario, 1979
[6] W.Q.C.: Water Quality Criteria. E.P.A., 1972.
[7] B.C. Ministry of Health recommended drinking water standard requires 'Most Probable Number' (M.P.N.) of coliform bacteria to be 0 cells/100 ml for untreated water, and 50 cells/100 ml for 'Class A' water.

4.3.3 Water Clarity

Water clarity was determined by the nephelometric turbidity test and field Secchi disc readings (Table 2). Secchi disc depths averaged 3 m (10 ft) during the summer and fall months, and only 0.5 m (1.5 ft.) during the high runoff periods of the winter and spring. Ford Lake frequently exceeded the water standard of 5 Nephelometric Turbidity Units (N.T.U.), during the winter and spring, but ranged from 1 to 3 N.T.U. during the summer and fall (Table 4.2). Suspended solid concentrations were responsibile for the high turbidity values and low Secchi values during the winter and spring months (Table 4.2), while suspended phytoplankton cells were influencing water clarity during the summer and fall months.

TABLE 4.2: TURBIDITY, SUSPENDED SOLIDS AND SECCHI DISC READINGS FOR FORD LAKE

DATE	SAMPLE DEPTH (m)	TURBIDITY (N.T.U.)	TOTAL SUSPENDED SOLIDS (mg/L)	SECCHI DISC DEPTH (m)
Oct. 12, 1978	1	2.9	-	2.7
Nov. 27, 1978	1	0.9	L1.0	3.1
Jan. 29, 1979	1	2.7	1.0	1.7
Jan. 29, 1979	2.5	5.2	3.0	-
Feb. 27, 1979	1	33	27.0	0.15
Apr. 18, 1979	1	4.6	4.0	1.2
Apr. 18, 1979	2.5	6.2	5.0	-

The water clarity of Ford Lake can be rated only as 'moderate' during the summer and fall, as the turbidity values rarely met the recommended water quality objective of 1 N.T.U., and 'poor' during the winter and spring, as the turbidity values approached or exceeded the recommended 5 N.T.U. standard (Table 4.1).

4.3.4. Water Colour

Water colour measured as 'true colour' averaged 42.3 True Colour Units (T.C.U.) with a standard deviation of 19.7 (n=11), which is far

above the recommended water quality standard of 15 T.C.U. High colour values are a result of high concentrations of dissolved organic compounds. Tannins and lignins, a specific group of dissolved organic compounds derived from plant matter, averaged 1.14±0.23 mg/L (n=5), which is relatively high when compared to other B.C. lakes. The tannin and lignin concentration was not, however, sufficient to give the lake water a characteristically brown colour. The concentration of other dissolved organic compounds (44±9.9 mg/L (n=7)) was sufficiently high to account for the high colour results.

4.3.5 Water Hardness and General Ions

The major ions present in Ford Lake were calcium 12.9±1.7 mg/L (n=7), chloride 11.2±3.7 mg/L (n=3), sulphate 9.7±0.56 mg/L (n=2), silicate 9.3±0.75 mg/L (n=3), inorganic carbon 9.25±1.4 mg/L (n=8), sodium 8.2 mg/L (n=1), magnesium 2.6±0.28 mg/L (n=7), and potassium 0.5 mg/l (n=1). Collectively, the ions produce a total dissolved inorganic residue of 66.0±20 mg/L (n=7) (total dissolved solids averaged 103 ± 24 mg/L (n=7)), a pH of 7.4±0.4 relative units (n=6), and a specific conductance of 135±23.4 µmho/cm (n=6). The water hardness was calculated at 41.3±5.3 mg/L (n=7), and the total alkalinity measured at 34.2±9.0 mg/L (n=9). All parameters met the recommended water quality objectives and standards listed in Table 4.1.

4.3.6 Metals

A broad range of metals were tested in Ford Lake. All metals were measured as total values, and most were undetectable except for aluminium 1.66±2.3 mg/L (n=2), copper 0.0035±0.0035 mg/L (n=2), iron 1.5±1.7 mg/L (n=2), and lead 0.0025±0.002 mg/L (n=2). High iron and aluminium concentrations (2.7 and 3.3 mg/L) were recorded on February 22, 1979, a period of high suspended solids. Since both metals are highly associated with suspended particulates in natural systems (Demayo et al, 1978), the metal concentrations would be reduced when the suspended particulates had settled from the water column. The iron and aluminium values during periods of low suspended solids (August 28, 1978) were 0.3 and 0.02 mg/L respectively.

Because 90% of the iron concentration is associated with suspended particulates (Demayo et al, 1978), the iron concentrations for Ford Lake are expected to be within the 0.3 mg/L standard for dissolved iron. The remainder of the metals were well within their respective water quality standards and objectives (Table 4.1).

4.3.7 Nutrients

The phosphorus:nitrogen weight ratio for Ford Lake at spring overturn, is 1:33, which implies that phytoplankton growth is limited by the availability of assimilable phosphorus. Dillon and Rigler (1975), and other workers, have established a direct positive relationship between spring overturn phosphorus concentrations and the mean summer chlorophyll 'a' concentration (a direct measure of phytoplankton concentrations) for phosphorus limited lakes. High phytoplankton concentrations decrease the overall water clarity and quality and can create taste and odour problems. It is therefore important to limit the phosphorus concentration in order to maintain lake water quality.

Phosphorus and nitrogen loading from the watershed above Ford Lake is substantial, because most of the runoff enters the lake as surface runoff, which has filtered over active farm pasture. Total phosphorus values increased from 13 µg/L in November 1978 to 65 µg/L in February 1979, while total nitrogen concentrations increased from 540 µg/L to 1940 µg/L for the same time period. The increase in phosphorus and nitrogen concentrations was mainly due to the input of suspended particulate phosphorus and nitrate-nitrogen. The suspended phosphorus quickly settled from the water column, and by April 1979, the actual phosphorus concentration available for phytoplankton assimilation was 26 µg/L.

Each year's spring overturn phosphorus and nitrogen concentrations are totally independent of their fall overturn concentrations, because of extensive winter and spring flushing. In an average precipitation year, Ford Lake will be flushed about 32 times from October to April (an average retention time of 5.7 days). Vollenweider (1971) noted "that a body of

water is in danger with regard to its trophic level when its springtime concentration of assimilable phosphorus compounds, and inorganic nitrogen compounds exceed 10 µg/L P and 200-300 µg/L N". Any increase in nutrient loading from the watershed would increase the summer phytoplankton biomass and reduce the water quality of Ford Lake.

4.3.8 Bacteriological

Table 4.3 lists the coliform data obtained from the center station (1100135), and the north shore of Ford Lake.

TABLE 4.3: TOTAL AND FAECAL COLIFORM CONCENTRATIONS IN FORD LAKE

DATE	CENTER STATION 1100135		NORTH SHORE STATION	
	Total Coliforms	Faecal Coliforms	Total Coliforms	Faecal Coliforms
October 12, 1978	13	-	13	-
November 27, 1978	L2	L2	8	L2
April 18, 1979	79	49	79	27
August 22, 1979	-	-	23	13

NOTES:- Numbers represent 'Most Probable Number' (M.P.N.) of coliform bacteria cells/100 ml

Ford Lake does not meet the B.C. Ministry of Health recommended standards (Table 4.1), but does meet the Class 'A' standard of 50/100 ml in any month. Water that meets the Class 'A' standard requires disinfection by chlorination before drinking.

4.3.9 Aquatic Macrophytes

Aquatic macrophytes occupy 100% of the lake bottom. The dominant species are Elodea canadensis, Ceratophyllum demersum, and Nuphar polysepalum. The species list for Ford Lake is summarized in Table 2.4.

TABLE 4.4

AQUATIC MACROPHYTES FOUND IN FORD LAKE

Myriophyllum verticillatum	
Elodea canadensis	(Dominant)
Ceratophyllum demersum	(Dominant)
Potamogeton amplifolius	
Potamogeton robbinsii	
Typha latifolia	
Scirpus lacustris	
Nuphar polysepalum	(Dominant)
Utricularia vulgaris	
Natas flexilis	
Ceratophyllum echinatum	

Notes:- Samples collected by C. McKean and R. Harcombe, October 1978.
- Plants identified by Dr. P. Warrington; B.C. Ministry of Environment.

4.3.10 Phytoplankton

The phytoplankton biomass (measured as chlorophyll 'a'), in Ford Lake was estimated between 7 and 10 μg/L. These concentrations, persisting throughout the summer and fall, were sufficient to elevate the turbidity values above the recommended water quality objectives.

Identification and quantification of phytoplankton species was limited to two samples. Although two samples are not sufficient to predict the dominant species on a yearly basis, it does give a preliminary indication of what species are present in the lake. Species belonging to the genus Chroomonas and Synura dominated the phytoplankton community, while species associated with taste and odour problems were present in low numbers.

4.4 Discussion

Summer water temperatures, water colour measurements, coliform bacteria concentrations, and winter and spring turbidity levels, all exceeded the recommended water quality standards (Section 4.3.1, 4.3.3,

4.3.4 and 4.3.8), and summer turbidity levels and ammonia concentrations exceeded the recommended water quality objectives (Sections 4.3.3, and 4.3.7). Consequently Ford Lake could supply domestic water but chlorination and filtration would be required.

Ford Lake meets all the recommended water quality standards for irrigation or industrial use. In the writer's opinion, total utilization should not exceed one-third of the lake's volume in order to maintain the present integrity of the lake. Large amounts of live storage could be created with small increases in lake level (Section 4.2) but active farm land would be flooded.

5. LAKE STOWELL

5.1 Lake Characteristics

Lake Stowell is a small shallow lake 1.5 kilometres (km) (0.9 miles) north of Fulford Harbour, on the Beaver Point Road (Figure 5.1). The lake is 71 metres (m) (233 ft) above geodetic datum, and has a maximum depth of 7.5 m (25 ft.). It has a surface area of 5.64 hectares (14 acres), and a maximum volume of 260 cubic decameters (dam^3) (210 acre-feet:af). The outlet is located at the south end of the lake, and drains toward Fulford Harbour. The major outflow occurs during the winter and spring months. No major tributaries drain the 3.89 km^2 (983 acres) of watershed. Land use around the lake is moderately developed with active sheep pasture bordering the northern shore, cleared farm land on the south-west side, and a small recreational beach and wading area near the road access (Figure 5.2).

Water and bacteriological samples were taken at the center of the lake (Ministry of Environment computer and data storage reference number: 1100134), and at the north shore (Figure 5.2).

5.2 Hydrology

Rainfall for the Lake Stowell watershed is estimated directly from data recorded at Environment Canada's Cusheon Lake Weather Station, Salt-spring Island. Appendix 1 lists the monthly precipitation values for 1977-1979, and Appendix 2 lists the mean monthly precipitation values.

The Hydrology Section of the Inventory and Engineering Branch have calculated monthly watershed runoff volumes for Lake Stowell (Obedkoff, 1980). Appendix 2 lists the runoff volumes based on an average precipitation year. The study year, however, was 55 percent below the norm. Therefore instead of 2010 dam^3 (1630 af), only 904 dam^3 (733 af) entered Lake Stowell during our study year. Based on a lake volume of 260 dam^3 (210 af), the average flushing rate is 7.7 times per year, and the estimated flushing rate for the study year was 3.5 times. The high flushing rates are the result of the moderately high ratio between the watershed area of Lake Stowell and the lake volume (1.5 ha:1 dam^3).

FIGURE 5.1

LOCATION OF LAKE STOWELL, SALTSPRING ISLAND.

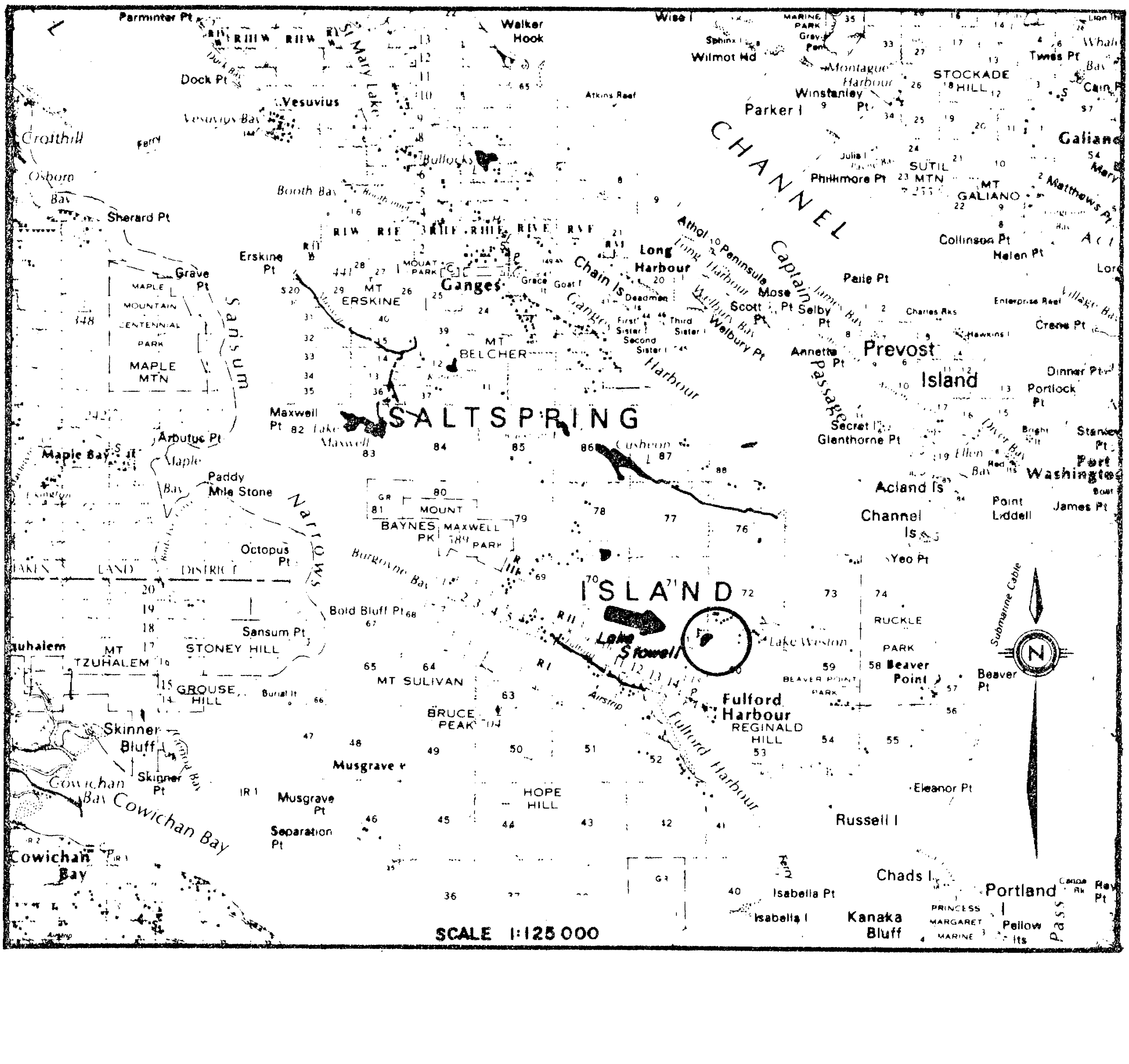
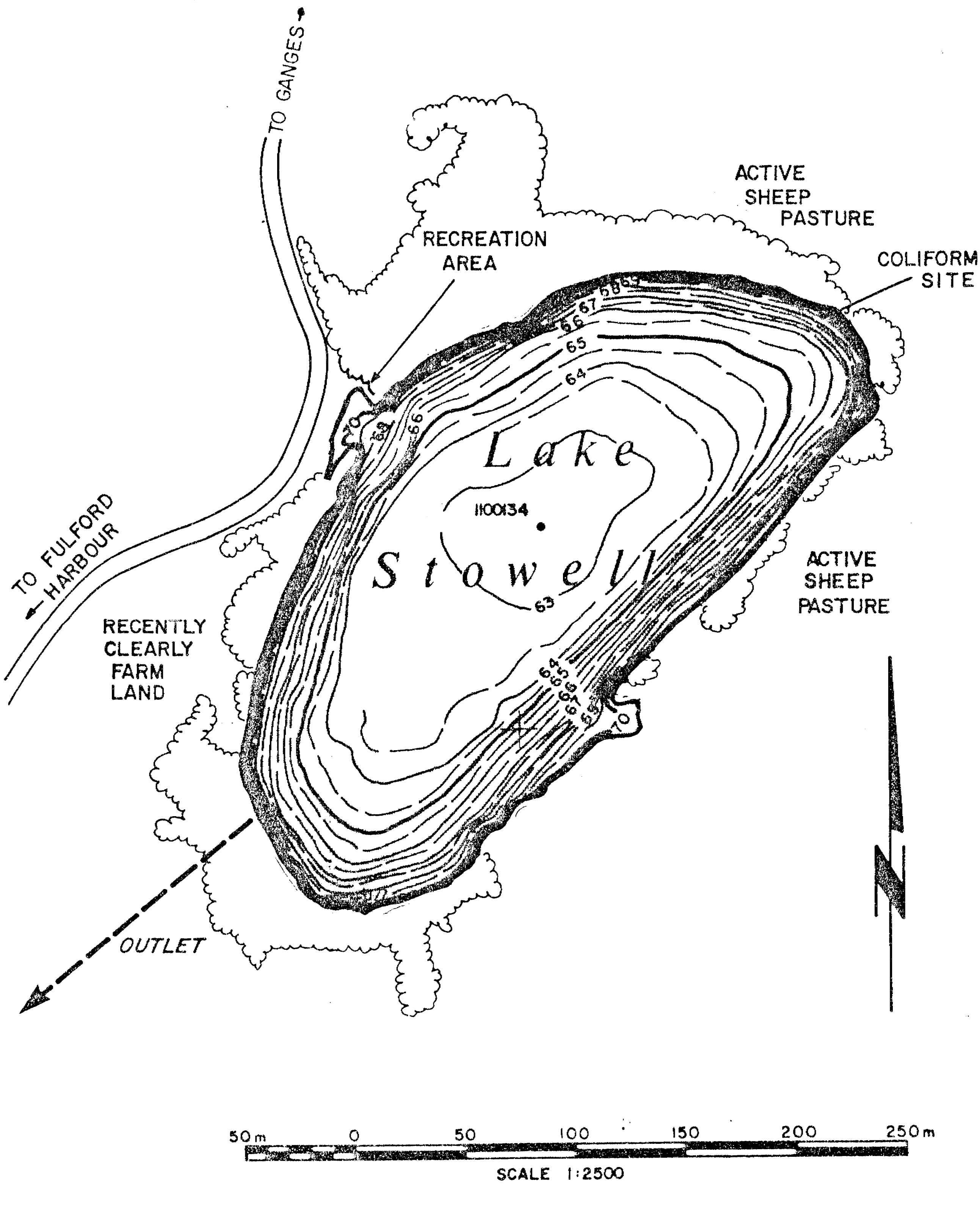


FIGURE 5.2: SAMPLING STATIONS, LAND USE, AND BATHYMETRY OF LAKE STOWELL.



The epilimnion (zone of water above the thermocline) has a depth of 2.5 m (8 ft.) in April, and 4.5 m (15 ft) in mid-September. The epilimnion volumes are 133 dam^3 (92 af) in April and 189 dam^3 (153 af) in September. These volumes constitute 43 percent and 73 percent of the lake's volume. The metalimnion (thermocline) extends from 2.5 m (8 ft) to 5 m (16.4 ft.) in April, and from 4.5 m (15 ft) to 6.5 m (21 ft) in September. This represents 92.5 dam^3 (75 af) in April, and 55 dam^3 (45 af) in September, or 36 percent and 21 percent respectively, of the lake's volume. The hypolimnion (zone of water below the thermocline) has a volume of 54.5 dam^3 (44 af) in April, and 16 dam^3 (13 af) in September. The hypolimnion represents 21 percent of the lake's volume in April, and only 6 percent in September.

The conditional water licences on Lake Stowell are listed in Table 5.1. Collectively, the water licences authorize a maximum utilization of 25 af (30.8 dam^3) of irrigation water and 46 af (56.8 dam^3) of domestic water per year.

TABLE 5.1: CONDITIONAL WATER LICENCES ON LAKE STOWELL

Conditional Lic. Number	Issued To	Purpose	Amount	Cubic Decameters per year
CL 043729	Stowell Lk. Holdings Corp.	Irrigation	10 Af	12.3
CL 043932	B. & F. Byron	Domestic	500 GD	5.2
		Irrigation	5 AF	6.2
CL 050696	Mr. Alan Twa	Domestic	500 GD	5.2
CL 050697	R. & A. Gonzalez	Domestic	500 GD	5.2
CL 050698	D. & C. Eyles	Domestic	1250 GD	12.8
		Irrigation	3.5 AF	4.3
CL 050699	R. B. Millar	Domestic	500 GD	5.2
CL 050700	Southwood Farms Ltd.	Domestic	1250 GD	12.8
CL 050701	B. L. Bartle	Irrigation	1.7 GD	2.1
CL 050702	B. L. Bartle	Domestic	500 GD	5.2
		Irrigation	4.8 AF	5.9
CL 050703	Southwood Farms Ltd.	Domestic	500 GD	5.2

Summer drawdown of the lake water level is caused by three factors, evaporation, water utilization, and groundwater loss (not measured).

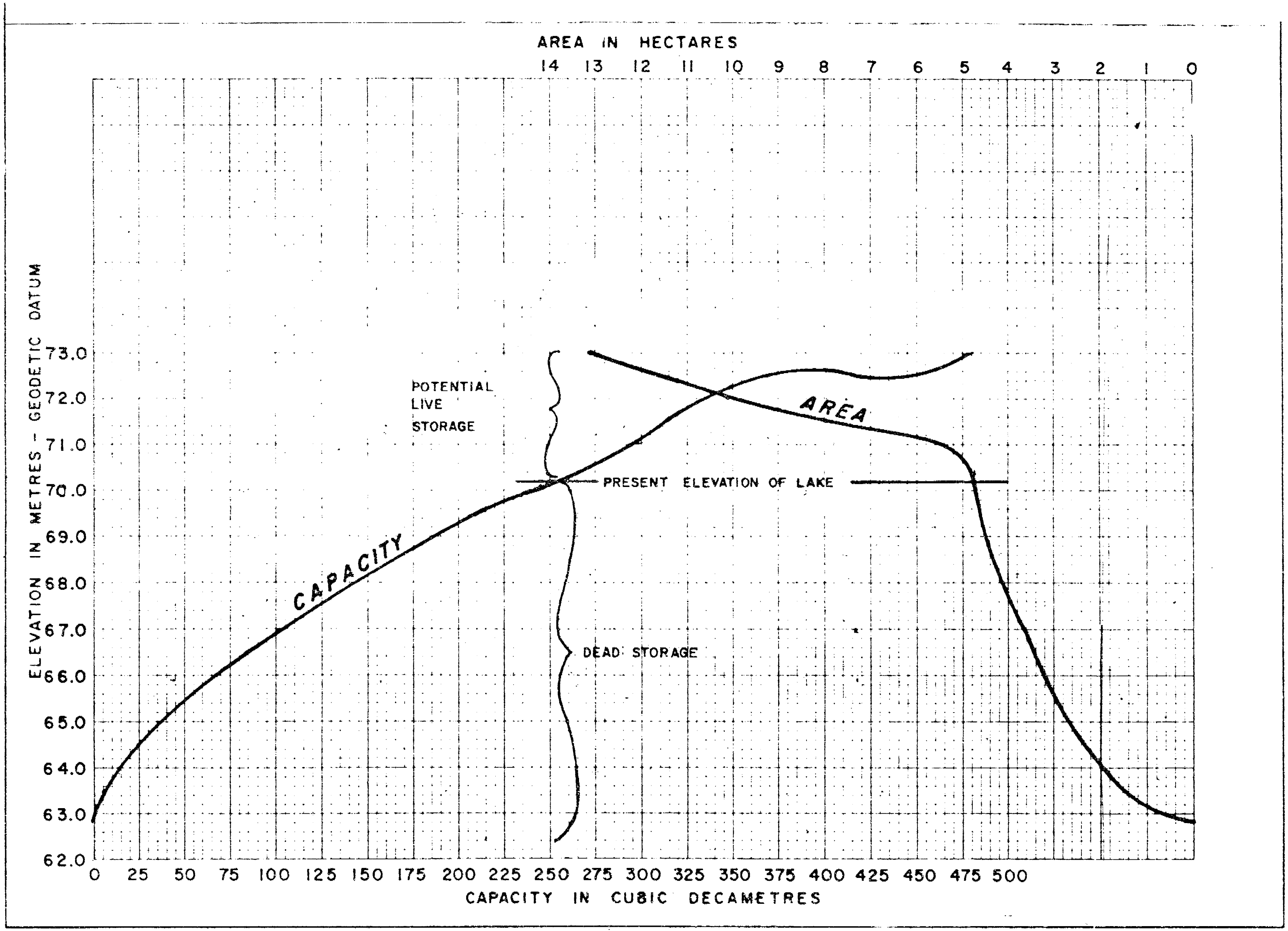


FIGURE 5.3: STORAGE CAPACITY CURVES FOR LAKE STOWELL.

Evaporation was calculated to average 0.19 m (7.5 in.) per year (Appendix 2) or 6.7 dam^3 (5.4 af) of surface water. The maximum summer irrigation and domestic utilization authorized by the conditional water licences is 54 dam (43.8 af) or 1.14 m (3.7 ft.) drawdown. The maximum estimated drawdown, exclusive of groundwater losses, is 1.33 m (4.4 ft.) per summer.

Lake Stowell has a 'good' water storage potential because a 1.5 m raise in the lake level will create 125 dam^3 (101 af) of additional live storage, which is a 50 percent increase in total lake volume. The storage capacity and area curves for Lake Stowell are represented in Figure 5.3.

5.3 Water Quality

5.3.1 Temperature

Lake Stowell was stratified thermally from mid-April to late September, and during periods of ice cover. The epilimnion had a maximum summer temperature of 23°C (73°F) in late July, which exceeds the B.C. Ministry of Health's recommended temperature standard of 15°C (59°F) (Table 5.2). The thermocline has a small 3°C temperature gradient in May, but a maximum gradient of 16°C in late August. The hypolimnion had a 3°C temperature increase, producing a maximum temperature of 8°C (46°F) in early September.

The strong thermocline was eliminated in the fall when the surface water cooled to the same temperature as the hypolimnion. When the lake had a uniform temperature, the surface and bottom were able to mix. This mixing process is called 'fall overturn'. Unstratified conditions will remain throughout the winter, unless exceptionally cold weather causes ice formation.

5.3.2 Dissolved Oxygen

During the summer the epilimnion dissolved oxygen concentrations ranged from 79 to 110 percent saturation, while anaerobic conditions, which

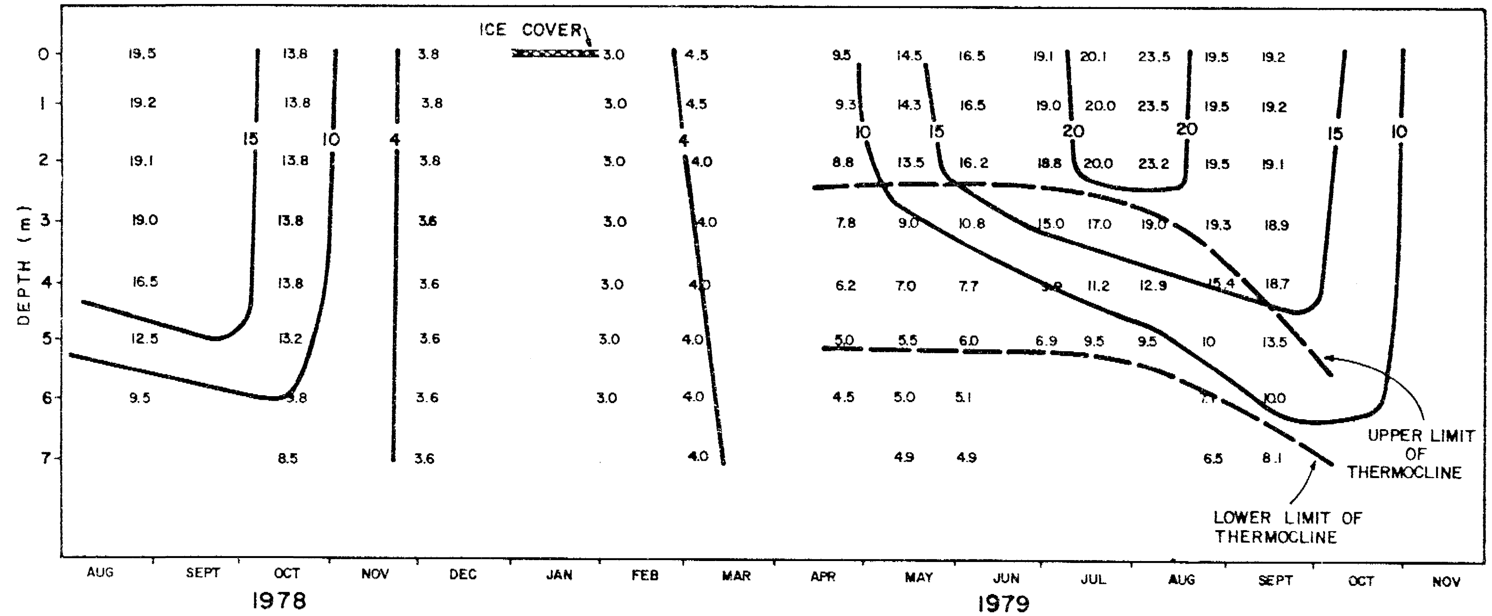


FIGURE 5.4: TEMPERATURE PROFILES AND ISOTHERMS FOR LAKE STOWELL.

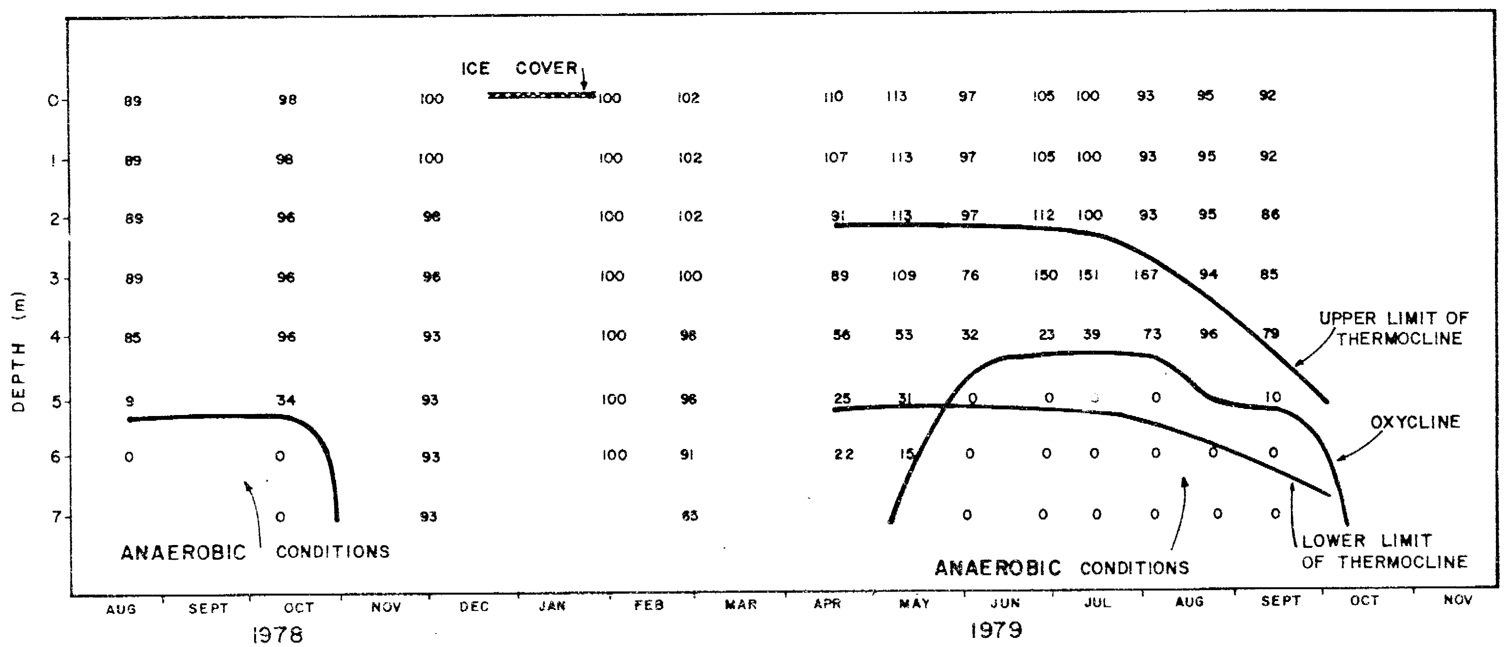


FIGURE 5.5: OXYGEN PROFILES (Percent saturation) FOR LAKE STOWELL.

TABLE 5.2: RECOMMENDED WATER QUALITY STANDARDS AND OBJECTIVES, AND RESULTS FOR LAKE STOWELL

PARAMETER	EPILIMNION	HYPOLIMNION	STANDARD	OBJECTIVE	AGENCY THAT SET THE STANDARDS & OBJECTIVES
PHYSICAL PARAMETERS					
1) Temperature (^{O}C)	[2]23.5 (Max.)	10.0 (Max.)	15	10	B.C. Health
2) Oxygen-Dissolved (mg/L)	8.7 (Min.)	[2]0 (Min.)	3	-	[4]SSPA, [5]WQMO
GENERAL IONS					
1) Alkalinity (mg/L)	22.9 ±6.0* (n=8)	25.0 ±7.8 (n=7)	-	-	-
2) Carbon-Inorganic (mg/L)	5.3 ±2.0 (n=6)	9.8 ±4.6 (n=6)	-	-	-
3) Calcium (mg/L)	8.6 ±0.7 (n=7)	10.0 ±1.6 (n=5)	200	L75	B.C. Health
4) Chloride (mg/L)	8.8 ±1.0 (n=2)	9.2 (n=1)	250	L250	B.C. Health
5) Hardness (mg/L)	28.0 ±2.5 (n=7)	31.2 ±4.1 (n=6)	180	120	B.C. Health
6) Magnesium (mg/L)	1.58±0.13 (n=5)	1.6 ±0.2 (n=5)	150	L50	B.C. Health
7) PH (Relative Units)	7.3 ±0.2 (n=17)	6.9 ±0.4 (n=14)	6.5→8.5	-	B.C. Health
8) Potassium (mg/L)	0.45±0.07 (n=2)	0.6 (n=1)	-	-	-
9) Silicate (mg/L)	7.7 ±1.4 (n=4)	8.5 ±1.9 (n=4)	-	-	-
10) Sodium (mg/L)	5.5 ±0.4 (n=2)	5.8 (n=1)	-	-	-
11) Specific Conductance (μmho/cm)	92.1 ±7.2 (n=15)	99.4±7.6 (n=14)	-	-	-
12) Sulphate (mg/L)	6.1 ±0.6 (n=2)	7.1 (n=1)	500	250	B.C. Health
13) Total Dissolved Solids (mg/L)	70.4 ±4.9 (n=9)	77.3±4.1 (n=6)	1000	L500	B.C. Health
14) Total Inorganic Solids (mg/L)	39.3 ±6.7 (n=9)	42.3±10.9 (n=7)	-	-	-
WATER CLARITY AND COLOUR					
1) True Colour (T.C.U.)	[2]23.2 ±8 (n=14)	[2]30 ±10 (n=13)	15	L5	B.C. Health
2) Secchi Disc Depth (meters)	2.8 ±0.8 (n=10)	-	-	-	-
3) Tannins and Lignins (mg/L)	0.9 ±0.1 (n=2)	0.9± 0.2 (n=3)	-	-	-
4) Total Suspended Solids (mg/L)	2.5 ±1.2 (n=8)	3.9± 2.4 (n=7)	-	-	-
Total Suspended Solids (mg/L)	5.0 (Max.)	8.0 (Max.)	-	-	-
5) Turbidity (N.T.U.)	[1]1.5 ±0.6 (n=11)	[1]3.5± 5.5 (n=11)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	[1]2.8 (Max.)	[2]20 (Max.)	5.0	L1.0	B.C. Health
Turbidity (N.T.U.)	0.8 (Min.)	0.7 (Min.)	5.0	L1.0	B.C. Health
METALS					
1) Aluminum (mg/L)	-	0.18 (n=1)	-	-	-
2) Arsenic (mg/L)	L0.005 (n=1)	-	0.05	L0.005	B.C. Health
3) Cadmium (mg/L)	L0.005 (n=1)	-	0.01	L0.0005	B.C. Health
4) Chromium (mg/L)	L0.005 (n=1)	-	0.05	L0.005	B.C. Health
5) Copper (mg/L)	0.009 ±0.009 (n=2)	[1]0.011±0.002 (n=2)	1.0	L0.01	B.C. Health
6) Iron (mg/L)	[3]0.27±0.5 (n=4)	[3]0.6± 0.14 (n=2)	0.3 (Diss.)	L0.05 (Diss.)	B.C. Health
7) Lead (mg/L)	L0.001 (n=1)	-	0.05	L0.001	B.C. Health
8) Manganese (mg/L)	0.03±0 (n=2)	0.03 (n=1)	0.05	L0.01	B.C. Health
9) Nickel (mg/L)	L0.01 (n=2)	L0.01 (n=1)	-	-	-
10) Zinc (mg/L)	L0.005 (n=1)	-	5.0	L1.0	B.C. Health
NUTRIENTS					
1) Nitrogen-Ammonia (mg/L)	[1]0.039 ±0.03 (n=12)	[1]0.05±0.03 (n=10)	0.5	L0.01	B.C. Health
2) Nitrogen-Nitrate (mg/L)	0.26±0.07 (n=14)	0.31±0.35 (n=13)	10	L10	[6]WQC
3) Nitrogen-Total (mg/L)	0.77±0.5 (n=11)	0.86±0.35 (n=10)	-	-	-
4) Phosphorous-Ortho (mg/L)	0.003 ±0.001 (n=14)	0.004 ±0.003(n=13)	0.065	0.065	B.C. Health
5) Phosphorous-Total (mg/L)	0.012 ±0.003 (n=14)	0.023 ±0.012(n=13)			
6) Carbon-Organic (mg/L)	6.1 ±1.5 (n=9)	7.8 ±3.5 (n=8)			
BACTERIA					
1) Coliforms-Faecal (M.P.N.)	[2]7.4 ±5 (n=10)	-	[7]0	-	B.C. Health
2) Coliforms-Total (M.P.N.)	[2]87 ±160 (n=11)	-	0	-	B.C. Health

*Standard Deviation

NOTES:

[1]Parameter exceeds the recommended water quality objective.
[2]Parameter exceeds the recommended water quality standard.
[3]Iron concentration listed as total iron.
[4]S.S.P.A.: Scientific Stream Pollution Analysis, 1974
[5]S.Q.M.O.: Guidelines and Criteria for Water Quality Management in Ontario, 1979.
[6]W.Q.C.: Water Quality Criteria. E.P.A., 1972.
[7]B.C. Ministry of Health recommended drinking water standard requires 'Most Probable Number' (M.P.N.) of coliform bacteria to be 0 cells/100 ml for untreated water, and 50 cells/100 ml for 'Class A' water.

do not meet the 3.0 mg/L recommended dissolved oxygen standard, dominate the hypolimnion from May through September (Figure 5.5). The metalimnion experienced supersaturated conditions near the epilimnion interface, and anaerobic conditions near the hypolimnion interface. This zone of rapid change in dissolved oxygen is called 'the oxycline'.

Oxygen was re-introduced into the hypolimnion by the downward mixing of the oxygenated surface water, at 'fall overturn'. Oxygen concentrations, near 100 percent saturation, persisted throughout the winter months until summer stratification formed, unless winter thermal stratification occurs during prolonged periods of ice cover. In 1979, Lake Stowell was subjected to seven weeks of ice induced stratification (Figure 5.4 and 5.5), but the hypolimnion dissolved oxygen concentrations did not drop below 13.5 mg/L or 90 percent saturation.

5.3.3 Water Clarity

Water clarity was determined by the nephelometric turbidity test and field Secchi disc readings. Suspended particulates, and to a lesser extent dissolved particulates are two factors which affect the water clarity of Lake Stowell. Winter and spring runoff raised the suspended inorganic particulates to 2 mg/L in late February, which increased the epilimnion turbidity levels to 2.8 N.T.U., and lowered the Secchi readings to 1.5 m (5 ft.) (Figure 5.6). In April and May, the suspended inorganic levels fell below 1 mg/L, but suspended organic levels increased to an average of 3.5 mg/L, which is 75 percent higher than the February suspended inorganic particulate levels. Despite the high concentrations of suspended organic particulates, the effects on turbidity and Secchi disc depth was not as extensive as suspended inorganic particulates (Figure 5.6).

Higher turbidity values were recorded in June and September, but concentrations of suspended inorganic and organic particulates were low. Indirect evidence suggests particulates, possibly of colloidal nature, decreased the water clarity. The remainder of the summer turbidity values ranged between a low of 0.8 N.T.U. in August, and a high of 1.2 in May (Figure 5.6).

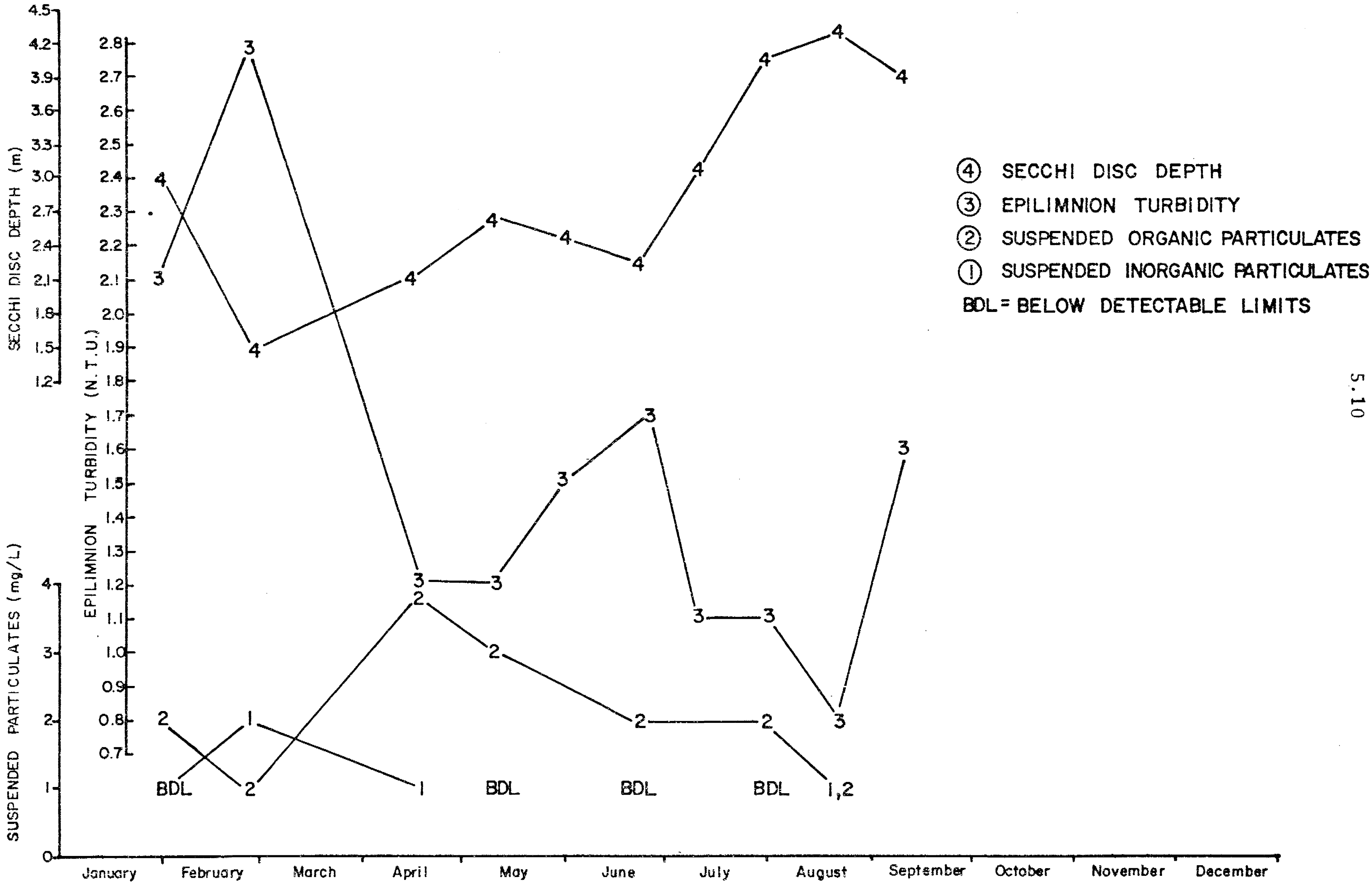


FIGURE 5.6 : TEMPORAL CHANGES IN THE WATER CLARITY OF LAKE STOWELL, 1979.

The hypolimnion had consistently higher turbidity values averaging 3.5±5.5[1] N.T.U. (n=11)[2], with a high of 20 N.T.U. on October 12, 1978, and a low of 0.7 N.T.U. on August 22, 1979.

The water clarity of Lake Stowell can only be considered 'moderate' in quality, as the epilimnion and hypolimnion turbidity values usually exceeded the recommended water quality objective of 1 N.T.U., and the hypolimnion exceeded the 5 N.T.U. recommended water quality standard, in the fall of 1978 (Table 5.2).

5.3.4 Water Colour

Water colour, measured as 'true colour', averaged 23.2±8.0 True Colour Units (T.C.U.) (n=14) in the epilimnion, and 30.0±10.0 T.C.U. (n=13) in the hypolimnion. Both the epilimnion and hypolimnion exceeded the 15 T.C.U. drinking water standard (Table 5.2). High colour values are the result of high concentrations of dissolved organic compounds. Tannins and lignins (a specific group of dissolved organic compounds derived from the breakdown of plant matter) averaged 0.9±0.1 mg/L (n=2) throughout the water column, which is the lowest of the four lakes considered in this report. The concentrations of tannins and lignins were not sufficiently high to give the lake water a characteristically brown colour. The concentrations of other dissolved organics averaged 32.0±4.1 mg/L (n=8) in the epilimnion, and 36.0±10.1 mg/L (n=6) in the hypolimnion. Although these levels are the lowest of the lakes considered in this report, the levels were sufficient to elevate the colour values above the recommended water quality standard. Consequently the water colour of Lake Stowell can be considered only 'poor' in quality.

5.3.5 Water Hardness and General Ions

The dissolved ions present in the epilimnion of Lake Stowell were chloride 8.8±1.0 mg/L (n=2), calcium 8.6±0.7 mg/L, silicate 7.7±1.4 mg/L (n=4), sulphate 6.1±0.6 mg/L (n=2), sodium 5.5 mg/L (n=2), inorganic carbon 5.3±2.0 mg/L (n=6), magnesium 1.58±0.13 mg/L (n=5), and potassium 0.45±0.07 mg/L (n=2). Collectively the ions produce a total dissolved

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[1] standard deviation

[2] n=sample size

inorganic residue of 39.3±6.7 mg/L (n=9) (the total dissolved residue was 70.4±4.9 mg/L (n=9), a pH of 7.3±0.2 relative units (n=9)),and a specific conductance of 92.1±7.2 µmho/cm (n=15). The water hardness was calculated at 28.0±2.5 mg/L (n=7), and the alkalinity (total) was measured at 22.9±6.0 mg/L (n=8).

The dissolved ions present in the hypolimnion had slightly higher concentrations than those found in the epilimnion. All hypolimnion and epilimnion values were well within the recommended water quality standards and objectives for drinking water (Table 5.2).

5.3.6 Metals

Most of the metals sampled in Lake Stowell were undetectable except for aluminium[1] 0.18 mg/L (n=1), copper 0.010±0.008 mg/L (n=4), epilimnion total iron 0.28±0.5 mg/L (n=4), hypolimnion total iron 0.6±0.14 mg/L (n=2), and manganese 0.03±0 mg/L (n=3). High total iron concentrations were recorded in the hypolimnion during summer stratification. Because iron is highly associated with suspended and colloidal particulates (approximately 90 percent in natural systems, Demayo et al, 1978), the dissolved iron concentrations in the hypolimnion can be considered well within the water quality standard of 0.3 mg/L dissolved iron. The rest of the metals were also within the recommended water quality standards, and only copper values in the hypolimnion exceeded the recommended water quality objective (Table 5.1).

5.3.7 Taste and Odour

Taste and odour problems are caused usually by high concentrations of organic compounds, phytoplankton, or hydrogen sulphide. Hydrogen sulphide was present in the hypolimnion of Lake Stowell throughout most of the summer. Taste and odour problems would be a constant problem if domestic intakes were below the thermocline.

Dissolved organic concentrations in the epilimnion were the lowest of the four lakes considered in this report, averaging 33.5±5.3 mg/L (n=9).

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[1]All metals listed as Total values.

Organic carbon levels averaged 6.1±1.4 mg/L (n=9) or 16 per cent of the total organic fraction. Although there are no officially recommended water quality standards for organics, Environment Canada (1977) note that water containing organic carbon levels below 3 mg/L are clean and unpolluted. This suggests that the organic content of Lake Stowell may be above desirable levels for drinking water.

Taste and odour problems also may result from high concentrations of certain phytoplankton species. Lake Stowell was sampled 8 times for phytoplankton and 5 species were present that have been associated with taste and odour problems in other fresh water systems (Palmer, 1962). Dinobryon divergens, Aphanizomenon flos-aquae, Anabaena plantonica, Ceratium hirundinella, and Tabellaria fenestrata were present in Lake Stowell, but only Dinobryon divergens was recorded in sufficient numbers to have caused taste and odour problems.

5.3.8 Nutrients

Lake Stowell had a low phosphorus:nitrogen ratio of 1:140 at spring overturn, but the ratio decreased to 1:26 by late August. A low P:N ratio indicates phosphorus availability was limiting phytoplankton growth. Dillon and Rigler (1975) and other authors, established a direct positive relationship between spring overturn phosphorus concentration, and the mean summer chlorophyll values for phosphorus limited lakes. Large summer phytoplankton populations, associated with high phosphorus concentrations, reduce water clarity and colour, and can create taste and odour problems. Therefore, it is important to limit phosphorus concentrations in Lake Stowell, in order to maintain lake water that meets all water quality standards, and approaches or meets the water quality objectives. The 1979 spring overturn phosphorus concentration was 14 μg/L with a epilimnion summer average of 12 μg/L. Orthophosphorus was undetectable throughout most of the study period except 4 μg/L was present at spring overturn, and 7 μg/L was detected in early September 1979. The presence of ortho-phosphorus in September suggests phytoplankton growth was limited by physical and/or chemical factors other than phosphorus.

Total phosphorus concentrations in the hypolimnion averaged 20 µg/L during the summer months. Ortho-phosphorus was undetectable throughout the summer, indicating anaerobic recycling of phosphorus was insignificant despite nearly four months of continuous anaerobic conditions. Suspended particulate phosphorus comprised at least 50 percent of the hypolimnion phosphorus concentration. Decomposing phytoplankton cells, that have sunk through the thermocline produced the high suspended phosphorus values.

The 1979 spring overturn nitrogen concentration was 1,700 µg/L, of which 71 percent was inorganic nitrate, 25% was organic nitrogen, and 3.5% was ammonia. The high nitrate concentration and the high nitrogen-phosphorus ratio at spring overturn, indicates a large influx of near surface ground water (interflow) to the lake. Because phosphorus is bound effectively to soil particles and nitrate-nitrogen is not, the interflow was characteristically high in nitrate and low in phosphorus. Nitrate concentrations decreased to below 20 µg/L in the epilimnion by late May, because of reduced interflow, and increased biological utilization. Organic nitrogen became the dominant nitrogen form in May, averaging 565 ug/L in the epilimnion or 80 percent of the total nitrogen concentration.

All nutrients meet the recommended water quality standards, and only the epilimnion and hypolimnion ammonia concentrations exceed the 10 µg/L recommended water quality objective (Table 5.1).

Each year's spring overturn phosphorus and nitrogen concentrations are almost totally independent of their fall overturn concentrations, because of extensive winter and spring flushing. In an average precipitation year, Lake Stowell will be flushed about 7 times from November to March (an average retention time of 20 days). The nutrient concentrations prior to spring stratification are therefore almost totally dependent on the nutrient concentration of the watershed runoff. Vollenweider (1971) noted that "a body of water is in danger with regard to its trophic level when its springtime concentration of assimilable phosphorus compounds

and inorganic nitrogen compounds exceed 10 µg/L P and 200-300 µg/L N." Any increase in nutrient loading from the watershed would increase the summer phytoplankton biomass and reduce the water quality of Lake Stowell.

5.3.9 Bacteriological

Table 5.2 lists the coliform concentrations recorded at the center station (1100134), and the north-east shore station (Figure 5.2).

TABLE 5.2: TOTAL AND FAECAL COLIFORM CONCENTRATIONS IN LAKE STOWELL

DATE	CENTER STATION; 1100134		NORTH-EAST SHORE STATION	
	Total Coliforms (M.P.N.)	Faecal Coliforms (M.P.N.)	Total Coliforms (M.P.N.)	Faecal Coliforms (M.P.N.)
October 12, 1978	-	-	8	-
November 27, 1978	5	2	L2	L2
February 27, 1978	540	17	79	33
April 18, 1979	2	2	13	5
May 9, 1979	11	11	2	2
May 29, 1979	8	2	13	8
June 25, 1979	79	14	49	8
July 11, 1979	79	5	49	8
July 31, 1979	49	2	79	6
August 22, 1979	130	2	540	21
September 10, 1979	49	11	220	79

NOTES:- Numbers represent 'Most Probable Number' (M.P.N.) of coliform bacteria cells per 100 ml

Lake Stowell does not meet the B.C. Ministry of Health recommended coliform bacteria standards for untreated potable water (Table 5.), but does meet the recommended Class 'A" standard requires disinfection by chlorination before drinking.

5.3.10 Aquatic Macrophytes

Aquatic macrophytes occupy 100 percent of the lake's shoreline. Nuphar polysepalum and Potamogeton amplifolius were the dominant species. Table 5.3 lists the entire species list for aquatic macrophytes found in Lake Stowell on October 12, 1978.

TABLE 5.3: AQUATIC MACROPHYTES FOUND IN LAKE STOWELL

SPECIES	
Cicuta douglassii	
Nuphar polysepalum	Dominant
Potamogeton amplifolius	Dominant
Potamogeton robbinsii	
Scirpus lacustris	
Najas flexilis	
Ranunculus aquatilis	
Potamogeton natans	

NOTES: - Samples collected by C. McKean and R. Harcombe, October 12, 1978.
- Plants identified by Dr. P. Warrington; B.C. Ministry of Environment.

5.3.11 Phytoplankton

Temporal changes in phytoplankton biomass, measured by chlorophyll 'a', in Lake Stowell are illustrated in Firgure 5.7. The 1979 summer chlorophyll concentrations averaged 6.3±5.6 μg/L (n=9), with a high of 19.6 μg/L in early April and a low of 1.8 μg/L in late July. The lake follows the typical pattern of a high phytoplankton population in the spring, which declines through the summer and then increases again after fall overturn.

The dominant phytoplankton species were quantitatively identified and the data stored in the B.C. Ministry of Environment's EQUIS data storage computer. The phytoplankton community was dominated by the golden brown alga *Synura* in the spring, and several species of blue-green algae throughout the remainder of the year. Some diatoms species were present but their numbers were very low throughout the year.

5.4 Discussion

Lake Stowell has the best potential as a future domestic water supply, of the four lakes considered in this report. Although the lake

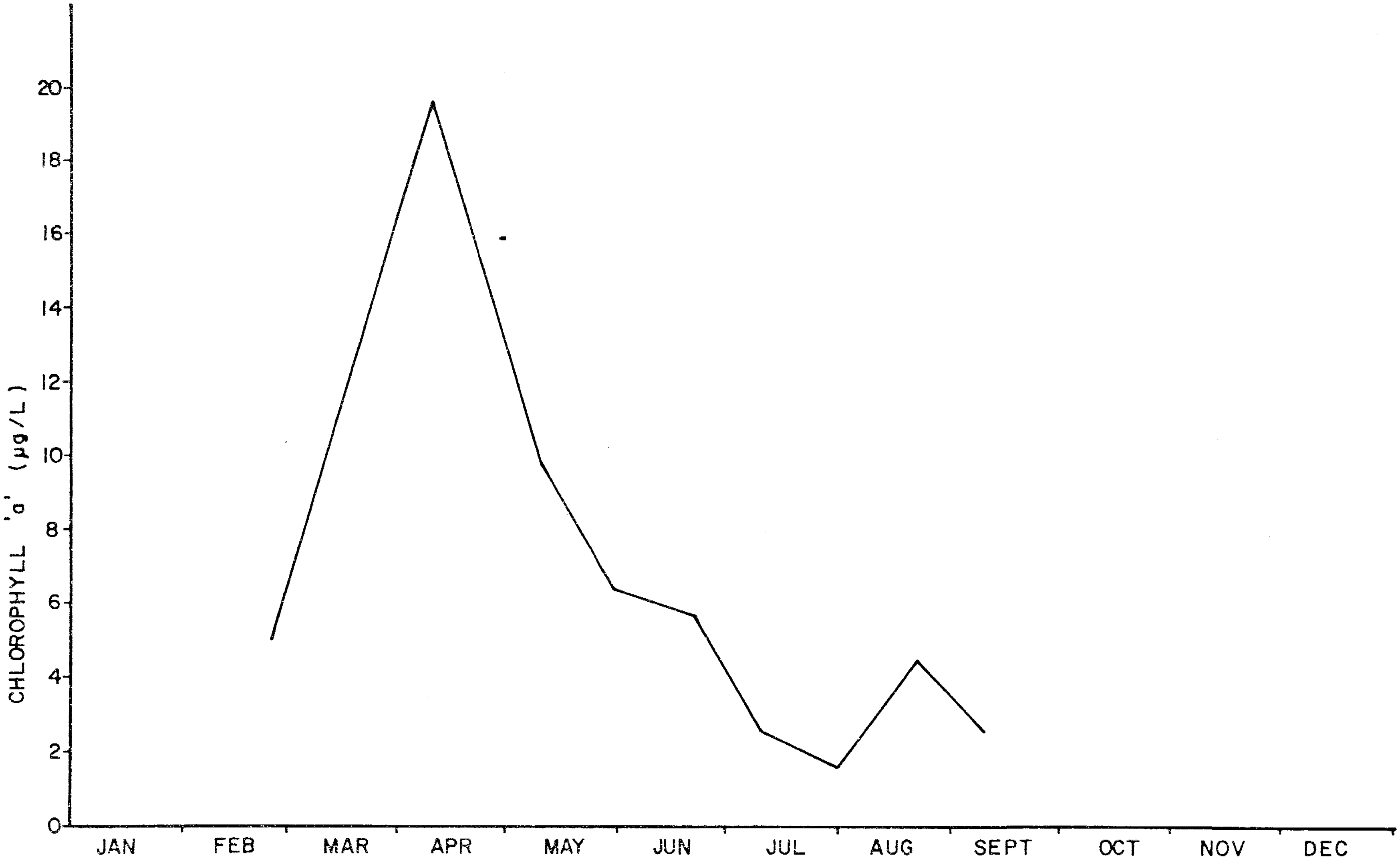

FIGURE 5.7 : SEASONAL CHANGES IN PHYTOPLANKTON BIOMASS (MEASURED AS CHLOROPHYLL 'a') IN LAKE STOWELL, 1979.

experiences summer surface water temperatures, hypolimnion dissolved oxygen concentrations, water colour values, and coliform bacteria populations that do not meet the recommended water quality standards (Sections 5.3.1, 5.3.2, 5.3.4, and 5.3.9), and water clarity measurements exceeded the 1.0 N.T.U. recommended water quality objective (Section 5.3.3), the lake can provide suitable domestic drinking water if intakes are strategically placed, and chlorination and filtering effectively remove bacteria and suspended particulates. Domestic water intakes are recommended to be located 4 m (13 ft) below the surface. Existing and future industrial irrigation intakes are recommended to be below the thermocline in order to remove some of the nutrients which accumulate in the hypolimnion of the lake. Better fall water quality will result from the utilization of signigicant amounts of hypolimnetic water. The only drawback is the water removed from the hypolimnion will have a slight hydrogen sulphide odour towards the end of the summer.

Lake Stowell has a 'good' potential for water storage because in an average precipitation year 2010 dam^3 (1630 af) of watershed runoff enters the lake, and the surrounding topography will enable 125 dam^3 (101 af) of live storage to be developed with a 1.5 m increase in the lake level.

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APPENDIX 2: AVERAGE WATERSHED RUNOFF VOLUMES AND AVERAGE PRECIPITATION AND EVAPORATION CALCULATIONS

Month	Average Year Runoff Volumes (Cubic Decamatres)				Average Precip.[1] (mm)		Net Average Evaporation[2] (mm)	
	Blackburn Lake Watershed	Bullock's Lake Watershed	Ford Lake Watershed	Lake Stowell Watershed	Cusheon Lake	St. Mary Lake	Cusheon Lake	St. Mary Lake
Jan.	1150	303	1400	663	64.5	71.6	-	-
Feb.	679	175	823	389	112.0	103.2	-	-
Mar.	446	106	535	249	88.3	82.5	-	-
Apr.	100	5	109	44	45.7	44.5	-	-
May	0	0	0	0	39.2	41.5	34.5	32.2
June	0	0	0	0	16.5	12.1	83.8	88.2
July	0	0	0	0	12.7	19.9	91.6	84.4
Aug.	0	0	0	0	34.8	40.5	48.5	43.2
Sept.	0	0	0	0	67.1	66.1	+23.8[3]	+22.8
Oct.	0	0	0	0	71.9	73.5	+47.8	+49.6
Nov.	244	0	176	9	100.4	116.4	-	-
Dec.	1140	167	1390	657	130.4	163.9	-	-
Tot. for Avg. Year	3760	756	4430	2010	783.5	835.7	186.8	175.6

[1]Averages calculated from column's 1 and 2 in Appendix 1.

[2]Averages calculated from column's 5 and 6 in Appendix 1.

[3]Positive values occur when precipitation exceeds evaporation

NOTE: - Average precipitation and net average evaporation values calculated on three years data, 1977, 1978 and 1979.
- Runoff volumes estimated by the Hydrology Section Inventory and Engineering Branch, B.C. Ministry of Environment.

APPENDIX 1: PRECIPITATION AND EVAPORATION RESULTS AND CALCULATIONS

MONTH	Precipitation[1] in Millimetres				
	Cusheon Lake	St. Mary Lake	Estimated Lake Summer Evap.[2] (mm)	Net Evaporation Losses (Evaporation - Precip.) in Millimetres: Cusheon Lake	Net Evaporation Losses (Evaporation - Precip.) in Millimetres: St. Mary Lake
January 1977	72.4	70.4			
February	83.3	76.7			
March	144.8	132.3			
April	29.5	20.3			
May	41.9	58.4	76.2	34.3	17.8
June	4.6	3.6	114.0	109.4	110.4
July	19.6	35.3	110.9	91.3	75.6
August	42.1	34.7	99.3	57.2	64.6
September	48.1	44.96	44.96	+ 3.14[3]	0
October	95.6	89.9	22.9	+ 72.7	+ 67
November	161.1	180.1	Tot=468.7	Tot=216.4	Tot=201.4
December	151.9	122.2			
January 1978	36.4	111.0			
February	71.8	75.4			
March	83.4	77.7			
April	69.2	54.3			
May	54.6	53.8	72.6	18.0	18.8
June	16.0	4.8	90.7	74.7	85.9
July	6.4	6.6	105.8	99.4	99.2
August	39.0	69.3	73.4	33.4	4.1
September	66.0	75.7	35.8	+ 30.2	+ 39.9
October	20.0	21.3	26.9	6.9	5.5
November	99.0	113.0	Tot=405.2	Tot=202.2	Tot=173.6
December	59.2	60.5			
January 1979	34.7	33.5			
February	180.9	157.5			
March	36.7	37.6			
April	38.4	58.9			
May	21.1	12.3	72.3	51.2	60.0
June	28.8	27.8	96.0	67.2	68.2
July	12.0	17.8	96.1	84.1	78.3
August	23.4	17.4	78.2	54.8	60.8
September	87.2	77.6	49.2	+ 38.0	+ 28.4
October	100.1	109.4	22.4	+ 77.7	+ 87.0
November	41.0	56.2	Tot=414.2	Tot=141.6	Tot=151.9
December	180.2	309.1	Av.=429.4	Av.=186.7	Av.=175.6

[1]Measured by Atmospheric Environment Service, Environment Canada

[2]Estimated lake evaporation calculated from Class 'A' pan evaporation measured at Agriculture Canada's Saanichton Research Center, Vancouver Island.

[3]Positive values occur when precipitation exceeds evaporation