Water Quality

State of Water Quality of St. Mary Lake 1975-1995

Canada - British Columbia Water Quality Monitoring Agreement

Water Quality Section
Water Management Branch
Ministry of Environment, Lands and Parks

April, 1996

Executive Summary

St. Mary Lake is located on Saltspring Island (Figure 1). The watershed for this small lake is 7.07 km².

This report assesses 20 years of water quality data and made the following conclusions:

- Total phosphorus values in the water column have decreased since 1980. However, phosphorus values exceeded the criteria for recreation and aquatic life.
- Phosphorus has been the limiting nutrient for algal growth in St. Mary Lake since 1986.
- Total organic carbon values exceeded the criterion for drinking water. Chlorinated drinking water may produce trihalomethanes which exceed the drinking water criterion (0.10 mg/L) when total organic carbon values are greater than 4 mg/L.
- The Capital Regional District's Health Protection and Environmental Division determined that the public beach on St. Mary Lake was suitable for bathing between 1988 and 1995.
- All mean summer chlorophyll a values collected between 1979 and 1989 exceeded the upper limits for protecting drinking water (2.5 µg/L) and aquatic life (3.5 µg/L).
- Extinction depth values from St. Mary met the criterion (> 1.2 m) for recreational use in 65% of the measurements.
- Turbidity values from St. Mary were outside the limits (5 NTU and 1 NTU) for drinking water. North Saltspring Water Works uses a sand filter to reduce the turbidity of the water to meet the drinking water criterion (1 NTU).

We recommend that a remediation plan be developed and implemented to improve water quality in St. Mary Lake.

We recommend monitoring:

- to identify changes in water quality attributed to biological activity in the lakes, to activities within the watershed such as urbanization, and to changes in nonpoint discharge.

The monitoring program could be implemented by an St. Mary Lake stewardship group with assistance from the Ministry of Environment, Lands and Parks.

- to determine whether the public beach is suitable for bathing.

The monitoring program will continue to be implemented at the bathing beach by the Capital Regional District's Health Protection and Environmental Division. In future, local interest groups (e.g., St. Mary Lake stewardship group, Island Trust) could assist with this ongoing monitoring.

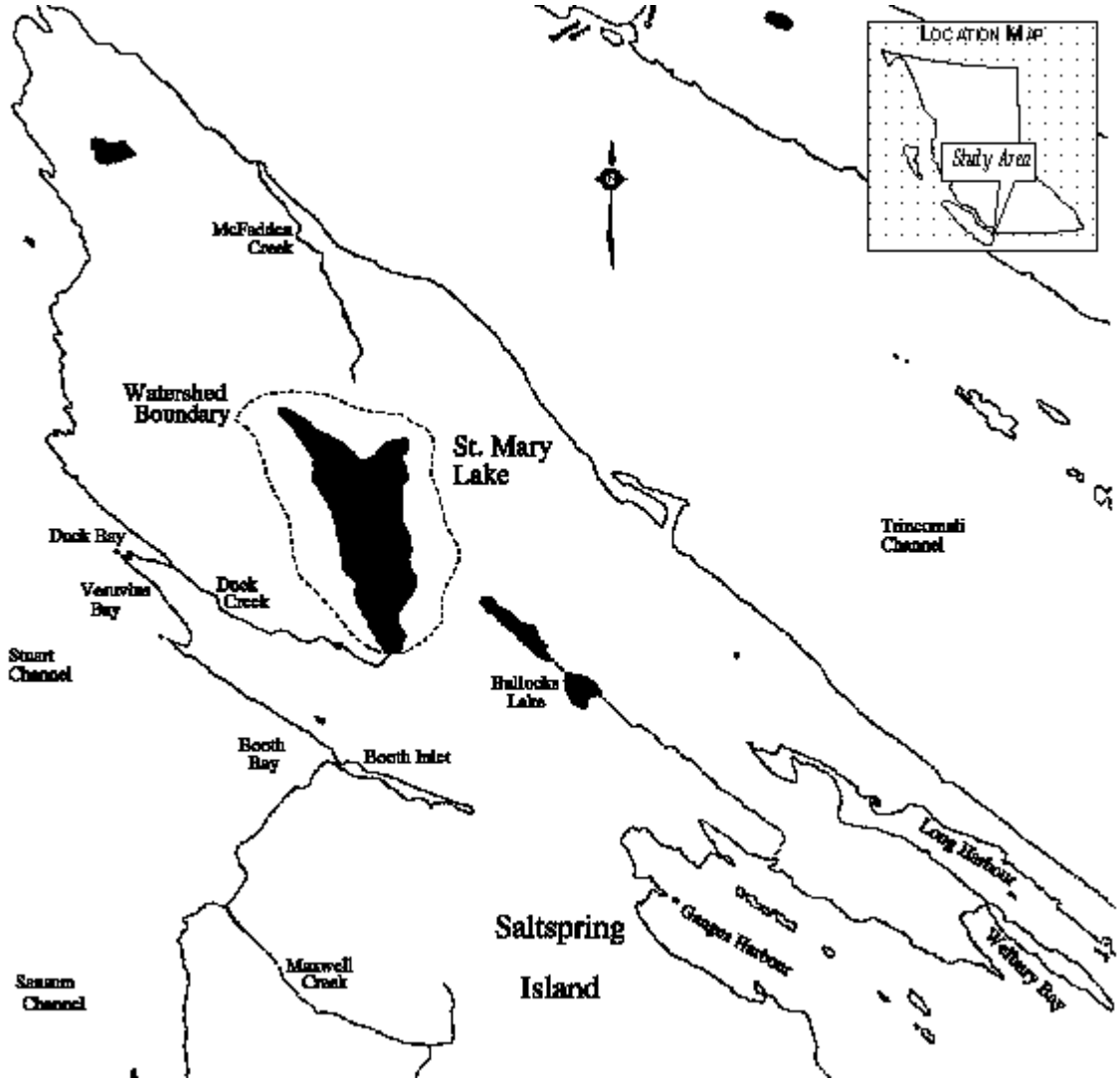
- to determine whether drinking water from the lake meets the fecal coliform criterion.

The monitoring program could be implemented by the Capital Regional District's Health Protection and Environmental Division, or by a St. Mary Lake stewardship group.

- to determine whether trihalomethanes values in chlorinated drinking water from St. Mary Lake met the drinking water criterion.

The monitoring program should be implemented by the two water works licencees (North Saltspring Waterworks District and Capital Regional District). The results of this monitoring should be reported, on a quarterly basis, to the Capital Regional District's Health Protection and Environmental Division.

Figure 1 St. Mary Lake Watershed (Scale 1:50,000)



Author

Holms, G. Bruce B.Sc. Research Officer. Water Quality Branch, Environmental Protection Department, Victoria, B.C.

Acknowledgements

Drafts of this report were sent to Lloyd Erickson and John Deniseger, Environmental Protection in Nanaimo, Mike Larmour North Saltspring Water Works District, Gary Gibson, Capital Regional District, Barry Boettger, Public Health Protection, Rick Nordin, R. Rocchini, and Larry Pommen, Water Quality Branch. Valuable comments were provided and incorporated into this report.

Introduction

St. Mary Lake is located on Saltspring Island (Figure 1). The watershed for this small lake is 7.07 km². The surface area of the lake is 1.82 km² and is comprised of one main basin. St. Mary Lake has an average flushing rate of once per 6 years (Nordin, McKean, and Wiens, 1983). The lake has a maximum depth of 16.7 m and a mean depth of 8.8 m (Figure 2). There are two inflow streams and the Duck Creek outlet drains St. Mary Lake into Stuart Channel (Pacific Ocean).

The Ministry of Environment, Lands and Parks monitored the water quality at the deepest point (16.7 m) of the basin between 1975 to 1995. The data are stored on the provincial data base, SEAM, under site number 1100104. This report assesses:

- long-term changes in water quality as a consequence of development within the watershed; and
- how these changes may impinge on certain uses of water from the lake.

The Capital Regional District's Health Protection and Environmental Division collects water samples for bacteriological analyses from one public beach (Blue Gables Resort) on the east side of St. Mary Lake. Weekly sampling begins in April each year and continues through the bathing season, ending in September. Fecal coliform results from five samples collected within a 30-day period are used to establish a geometric mean at the beginning of the season. A beach advisory notice, warning of the potential for increased risk to bathers' health, is considered for posting if the geometric mean exceeds 200 fecal coliforms/100 mL over a 30-day period. More intense sampling may occur if the results of a single sample exceeds 400 fecal coliforms/100 mL.

This report assesses 20 years of water quality data. These data are from a 20-year (1975-1995) spring overturn and summer water quality sampling program and from an 11-year (1980-1986, 1988, 1990-1995) fecal coliform sampling program. The water quality data are plotted in Figures 3 to 18 and summarized in Tables 1 and 2.

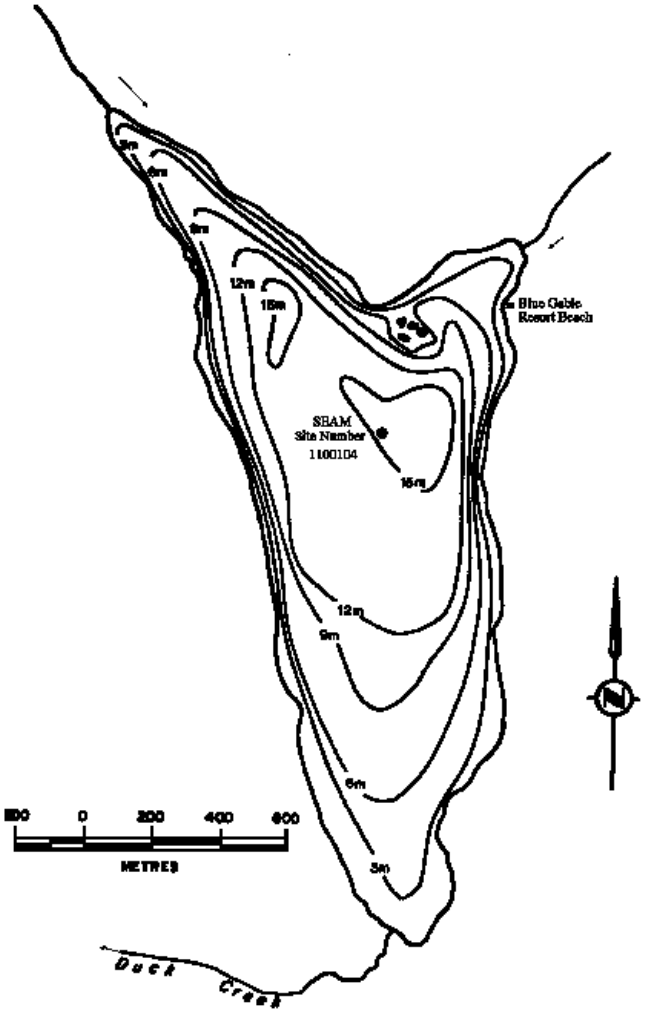
The box plots in Figures 3 to 18 represent the variability of water quality indicators collected at the surface, mid depth, and near the bottom of the lake. The plot is comprised of a rectangle with the top portraying the upper quartile (75th percentile of the data series, Q(0.75)), the bottom portraying the lower portion (25th percentile of the data series, Q(0.25)), and a horizontal line within the rectangle portraying the median. Vertical lines extend from the ends of the rectangle to the adjacent values, also known as "whiskers", and are defined by:

- computing the interquartile range, IQR=Q(0.75)- Q(0.25);
- defining the upper adjacent value as the largest observed value between the upper quartile and the upper quartile plus 1.5 X IQR; and
- defining the lower adjacent value as the smallest observed value between the lower quartile and the lower quartile minus 1.5 X IQR.

Values that fall outside the range of the adjacent values are defined as "outside values" and are plotted as asterisks (*). Values are defined as "far outside values" if they are located outside the outer range which is defined as the upper quartile plus 3 X IQR or the lower quartile minus 3 X IQR. These values are plotted as empty circles (O).

Trends in water quality data collected at different depths and at different frequencies over time are assessed by comparing yearly changes in median values in conjunction with the size of sample variability. The size of sample variability is represented in the box plots by the rectangle, whiskers, and the two types of outliers. A change is observed when the median values and sample variability do not overlap.

Figure 2 Bathymetric map of St. Mary Lake



Quality Assurance

The water quality plots were reviewed. No questionable values or values that were known to be in error were found.

State of the Water Quality

The state of the water quality is assessed by comparing the values to any site-specific water quality objectives or to Ministry of Environment, Lands and Parks' Approved and Working Criteria for Water Quality (Nagpal *et al.*, 1995) if objectives have not been set. Any levels or trends in water quality that are deleterious to sensitive water uses are noted.

Nordin, McKean, and Wiens (1983) identified two water uses (drinking and fisheries) for St. Mary Lake. Also, St. Mary Lake is used for recreation. These uses were threatened by excessive internal phosphorus loading from the lake sediments. Other sources of phosphorus loadings to the lake include residential and resort development activities (e.g., road building, septic tanks), and forestry (e.g. land clearing). A free-floating full-lift hypolimnetic aerator was installed in 1985 to reduce the amount of phosphorus released by the lake sediments and provide oxygen to the deep waters of the lake (Nordin, McKean, and Wiens, 1983). Initially, the aerator was only partially successful in increasing dissolved oxygen values and destratifying St. Mary Lake. The aerator was modified in 1988 and operated until the end of 1993. Deep water oxygen values were maintained at 5 mg/L during this period (Nordin. personal comm. 1995).

There are 26 domestic water licences, that may be used as a drinking water source, and 11 local authority water works licenses on Duck Creek and St. Mary Lake. The water works licenses are held by the Capital Regional District and North Saltspring Waterworks District.

Spring Overturn

The water in St. Mary Lake is vertically mixed (no thermal stratification) between November and the end of April. A key time for sampling is late during this period of mixing. The objective of this monitoring is to assess water quality from year to year and to estimate the potential algal growth during the summer months in St. Mary Lake.

Total phosphorus (Figure 3) values before thermal stratification, average of samples taken at different depths within the water column, were outside limits (0.005-0.015 mg/L) for protecting aquatic life in 1975, 1982-1984, 1988-1991, and 1993. All of these values exceeded the criterion (0.01 mg/L) for drinking water and recreational use.

Total phosphorus (Figures 3 and 4) and **total dissolved phosphorus** (Figure 5) values decreased over time. This decrease of phosphorus in the water column may be attributed to several factors including:

- an increase in Ultra Violet light (UVb) absorption in the water column,
- an increase in phosphorus uptake by aquatic plants,
- an increase in phosphorus fixing by lake sediments,
- a result of the free-floating full-lift hypolimnetic aerator,
- a reduction in phosphorus loadings to the lake, or
- an increase in the flushing rate of St. Mary Lake.

Nitrogen, dissolved ammonia (Figure 6) were below all criteria (30-day average 1.88 mg/L) designated to protect aquatic life from toxicity. These values decreased between 1981 and 1984 and have remained low since then. **Nitrate/nitrite** (Figure 7) values ranged from the minimum detectable limit (0.02 mg/L) to 0.29 mg/L and all were below the drinking water criterion (10 mg/L). 78% of the nitrate/nitrite values were less than the minimum detectable limit (0.02 mg/L). **Kjeldahl nitrogen** (Figure 9) and nitrate/nitrite concentrations are added together to represent total nitrogen in the lake. These concentrations are used to calculate the N:P ratio (Figure 10). This ratio indicates (N:P > 15) that phosphorus was the limiting factor for algal growth in all samples collected after 1987 from St. Mary Lake. Both the dissolved ammonia:nitrate ratio (Figure 8) and the N:P ratio were highly variable over time. The variability in the ratios indicate that there are changes occurring in the lake systems (e.g., land use, biological activity) which affect water quality.

Carbon, total organic (Figure 11): 53% of the values exceeded the criterion (4 mg/L) for protecting drinking water between 1975 and 1981. Chlorinated drinking water from North Saltspring Water Works may produce trihalomethanes which exceed the drinking water criterion (0.10 mg/L) when total organic carbon values are greater than 4 mg/L. **Total inorganic carbon** values increased between 1976 and 1988 (Figure 12). The ratio of total organic carbon and total organic nitrogen is used to classify sources of organic material in lakes (Hutchinson, 1957). The C:N for St. Mary Lake (Figure 13) indicates that the source of organic material is through the decomposition of plankton within St. Mary Lake (i.e., C:N ratio values were less than or equal to 12:1).

Colour, true (5-10 TC Units) and **total absorbance colour** values were constant (3-7 TAC units) and were below all criteria.

Fecal Coliform values ranged between L 3 MPN/ 100 mL and 93 MPN/100 mL at a bathing beach (Blue Gables Resort) on the east side of St. Mary Lake (Table 2). Fecal coliform values from the beach site may not be similar to values collected elsewhere in the lake. Resident waterfowl populations make this area unique and may cause fecal coliform values to be higher than at other sites in St. Mary Lake.

The Capital Regional District's Health Protection and Environmental Division determined that the public beach, at Blue Gables Resort, on St. Mary Lake was suitable for bathing between 1988 and 1995 (Table 2).

There are 26 active domestic water licenses and 11 local authority water works licenses on Duck Creek and St. Mary Lake. The Ministry of Health recommends that all surface waters in the province must undergo some form of treatment (e.g., disinfection, filtration) before being used as a drinking source. Raw water fecal coliform values should not exceed the 90th percentile criteria for partially treated drinking water of 100/100 mL, and 10/100 mL for disinfected drinking water. Fecal coliform monitoring was not done near water intakes nor at a sufficient frequency to permit comparison to drinking water criteria.

Total calcium (Figure 14) shows that St. Mary lake has a low sensitivity to acid inputs (the lake is well buffered).

Chlorophyll a (Figure 15) All mean summer chlorophyll a values collected between 1979 and 1989 exceeded the upper limits for protecting drinking water (2.5 µg/L) and aquatic life (3.5 µg/L).

Extinction depth values were reported for the 5-year period between 1975 and 1981. These values ranged between 0.46 m and 4.03 m. These values indicate that the lake is eutrophic (Nordin, 1985). 65% of the extinction depth values from St. Mary met the criterion (> 1.2 m) for recreational use.

Total magnesium values ranged from 1.61 mg/L to 3.51 mg/L and were below all criteria.

Dissolved silica (Figure 16) values were highly variable between 1975 and 1988, ranging from 0.5 mg/L to 10 mg/L. These values indicate that dissolved silica is not a limiting factor (i.e., values were greater than 0.5 mg/L) for diatom growth in St. Mary Lake (Wetzel, 1975). The variability in dissolved silica values may be attributed to the variability in diatom activity in the lake.

Total residue (i.e. dissolved plus suspended solids) values ranged from 92 mg/L to 140 mg/L between 1979 and 1994. There are no criteria for total residues. **Suspended solids** (non-filterable residues) values ranged between less than the minimum detectable limit (1 mg/L) and 9 mg/L. These values were below all criteria for suspended solids. **Dissolved solids** (filterable residues) values, collected between 1979 and 1986, ranged from 62 mg/L to 98 mg/L. Also, **Specific conductivity (µS/cm)** can be used to indicate dissolved solid concentrations. These values were ranged from 97 µS/cm to 119 µS/cm between 1975 and 1995, and were below all criteria for specific conductivity.

Turbidity (Figure 17) values ranged between 1 NTU and 7.5 NTU between 1975 and 1995. 15% of the turbidity values from St. Mary were greater than the upper limit (5 NTU) for drinking water, and 39% of the values exceeded the lower limit (1 NTU) for drinking water. All of the turbidity values that exceeded the upper limit were collected in 1980 and 1994. North Saltspring Water Works uses a sand filter and chlorination to treat St. Mary Lake water before distribution (Nordin, McKean, and Wiens, 1983). The sand filters will reduce the turbidity of the water to meet the lower drinking water criterion (1 NTU).

pH (Figure 18) values met all criteria. These values ranged between 6.7 and 8.2.

Dissolved oxygen and water temperature were reported by Nordin, McKean, and Wiens (1983) for the period 1975 to 1981. Minimum dissolved oxygen values ranged from 4.9 mg/L in the epilimnion to 0 mg/L in the hypolimnion, which do not meet criteria for aquatic life (30-day average criterion (8 mg/L), minimum criterion (5 mg/L)). Minimum dissolved oxygen values in deep water have been maintained at 5 mg/L between 1988 and the end of 1993 (Nordin. personal comm. 1995). Maximum temperature values ranged from 25° C in the epilimnion to 14° C in the hypolimnion.

Conclusions - State of Water Quality

- Total phosphorus values in the water column have decreased since 1980. However, phosphorus values exceeded the criteria for recreation and aquatic life.

- Phosphorus has been the limiting nutrient for algal growth in St. Mary Lake since 1986.
- Total organic carbon values exceeded the criterion for drinking water. Chlorinated drinking water may produce trihalomethanes which exceed the drinking water criterion (0.10 mg/L) when total organic carbon values are greater than 4 mg/L.
- The Capital Regional District's Health Protection and Environmental Division determined that the public beach, at Blue Gables Resort, on St. Mary Lake was suitable for bathing between 1988 and 1995.
- All mean summer chlorophyll a values collected between 1979 and 1989 exceeded the upper limits for protecting drinking water (2.5 µg/L) and aquatic life (3.5 µg/L).
- Extinction depth values from St. Mary met the criterion (> 1.2 m) for recreational use in 65% of the measurements.
- Turbidity values from St. Mary were outside the limits for drinking water (15% exceeded the upper limit and 39% exceeded the lower limit for drinking water). Capital Regional District and North Saltspring Waterworks District uses a sand filter to reduce the turbidity of the water to meet the drinking water criterion (1 NTU).

Recommendations for Water Quality Management

Remediation

Five water quality indicators (total phosphorus, chlorophyll a, extinction depth, dissolved oxygen, and turbidity) did not met the criteria for aquatic life and/or drinking water. We recommend that a remediation plan be developed and implemented to improve water quality in St. Mary Lake.

Monitoring

We recommend that sampling at the surface and at depth during spring overturn and in the mid-summer at SEAM site 1100104. The focus of this monitoring will be to identify changes in water quality attributed to activities within the watershed such as urbanization, changes in nonpoint discharge, and lake aeration. This monitoring program would include the following water quality indicators:

- water temperature and dissolved oxygen profiles,
- total phosphorus, dissolved ammonia, nitrate/nitrite, kjeldahl nitrogen, total and dissolved organic carbon, true color, turbidity, dissolved silica from 3 samples taken 1 m below the surface, at mid depth and 1 m above the bottom;
- chlorophyll a, taken near the surface; and
- extinction depth (i.e., Secchi depth) and UVb absorption.

This monitoring program could be implemented by a St. Mary Lake stewardship group with assistance from the Ministry of Environment, Lands and Parks.

We recommend that bacteriological sampling continue at the public beach on St. Mary Lake. The monitoring program is currently being conducted by the Capital Regional District's Health Protection and Environmental Division. In future, local interest groups (e.g., St. Mary Lake stewardship group, Island Trust) could assist with this ongoing monitoring.

We recommend that the two water works licencees (Capital Regional District and North Saltspring Waterworks District) monitor the chlorinated water for trihalomethanes. The results of this monitoring should be reported, on a quarterly basis, to the Capital Regional District's Health Protection and Environmental Division.

Figure 3 Total phosphorus (average in the water column before stratification) from St. Mary Lake

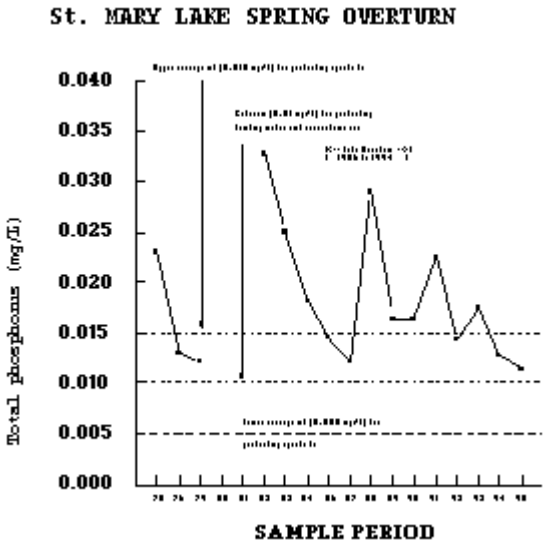


Figure 4 Total phosphorus from St. Mary Lake

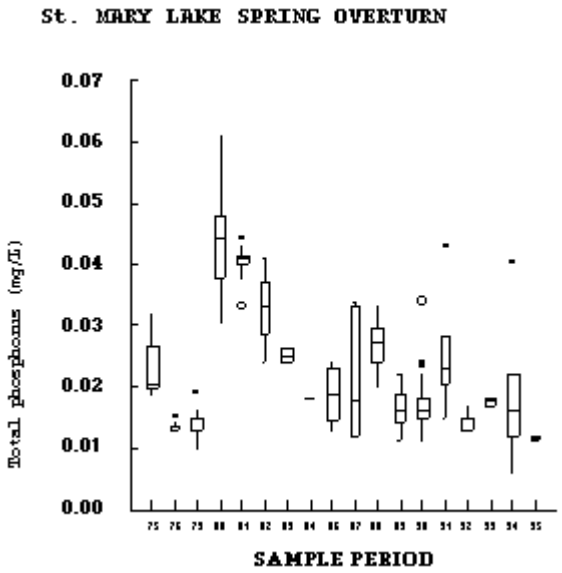


Figure 5 Total dissolved phosphorus from St. Mary Lake

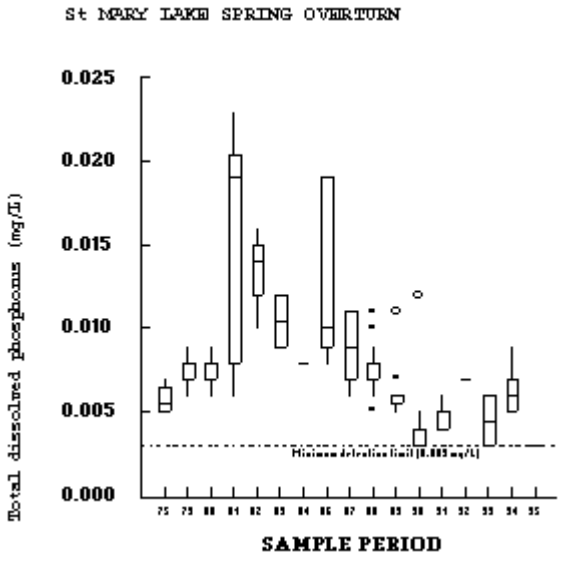


Figure 6 Dissolved ammonia from St. Mary Lake

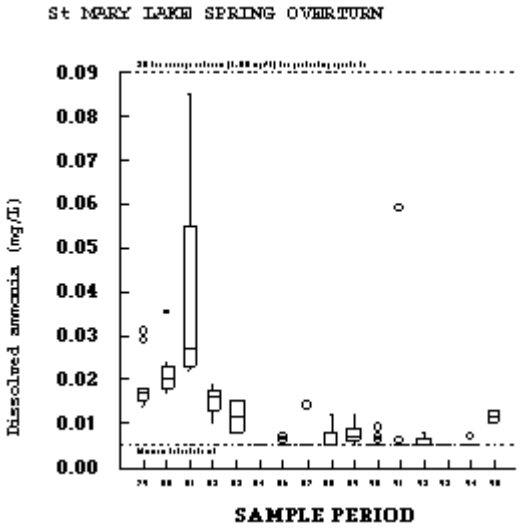


Figure 7 Nitrate/Nitrite from St. Mary Lake

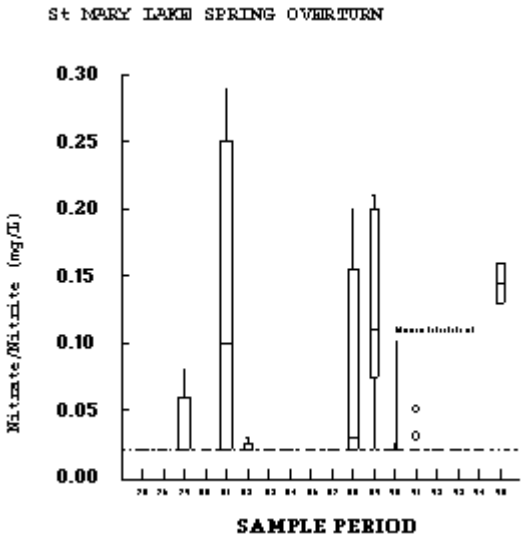


Figure 8 Dissolved ammonia:nitrate from St. Mary Lake

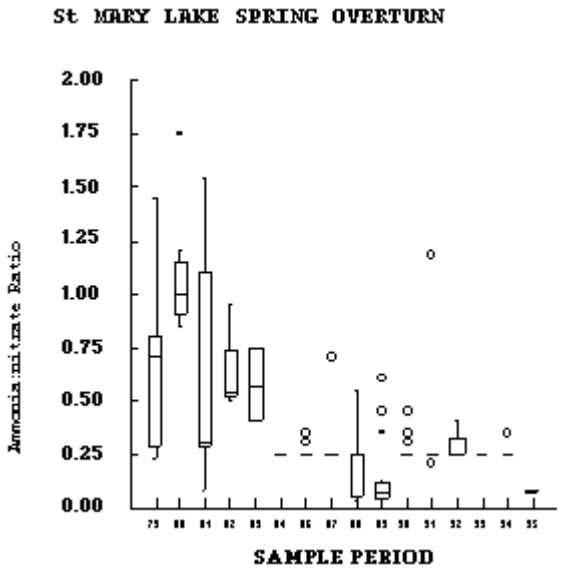


Figure 9 Kjeldahl nitrogen from St. Mary Lake

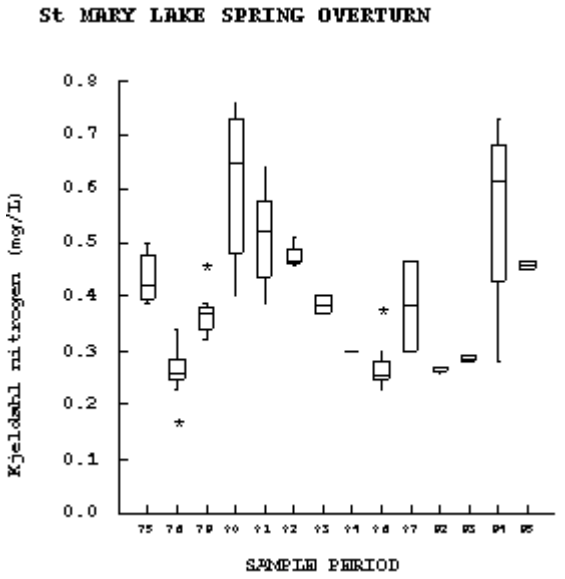


Figure 10 N:P ratio from St. Mary Lake

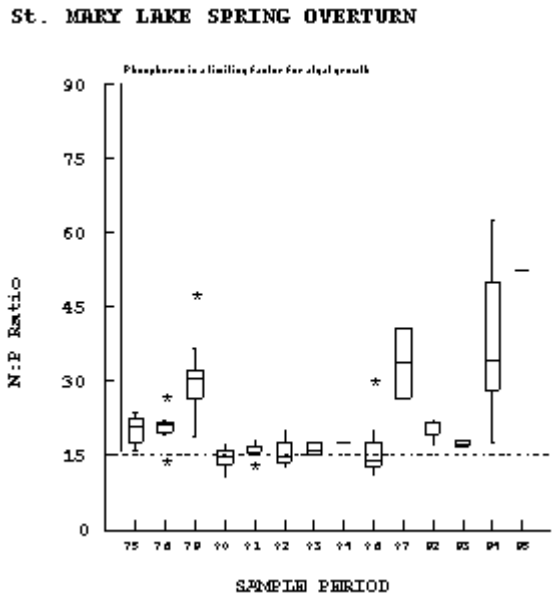


Figure 11 Total organic carbon from St. Mary Lake

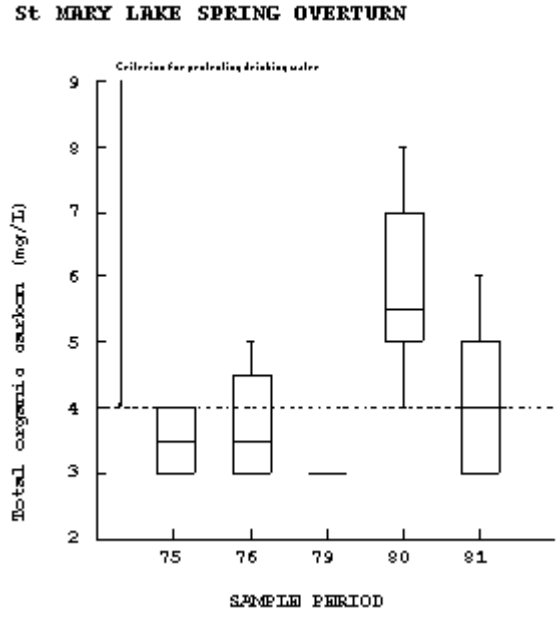


Figure 12 Total inorganic carbon from St. Mary Lake

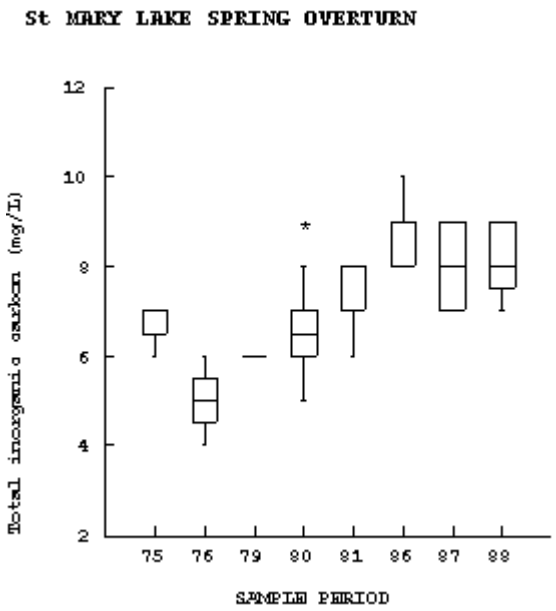


Figure 13 C:N ratio from St. Mary Lake

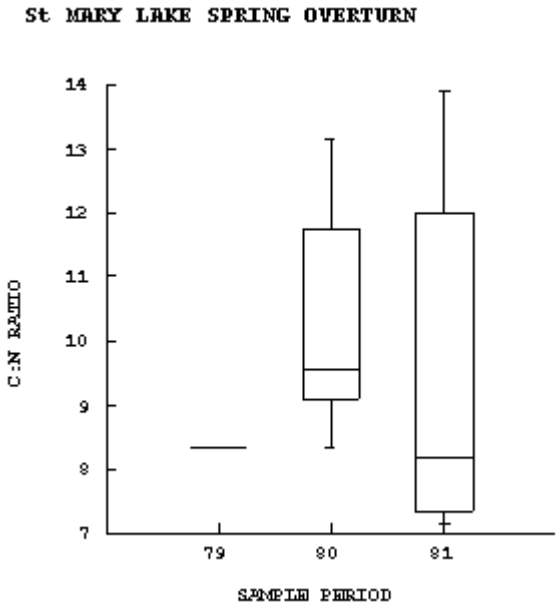


Figure 14 Total calcium from St. Mary Lake

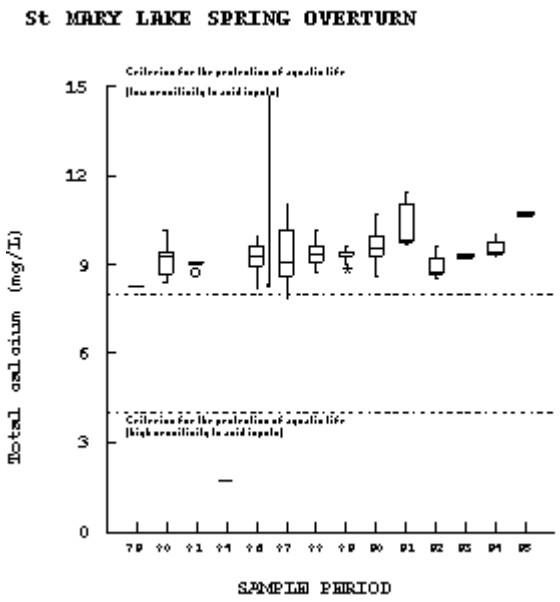


Figure 15 Mean summer chlorophyll a from St. Mary Lake

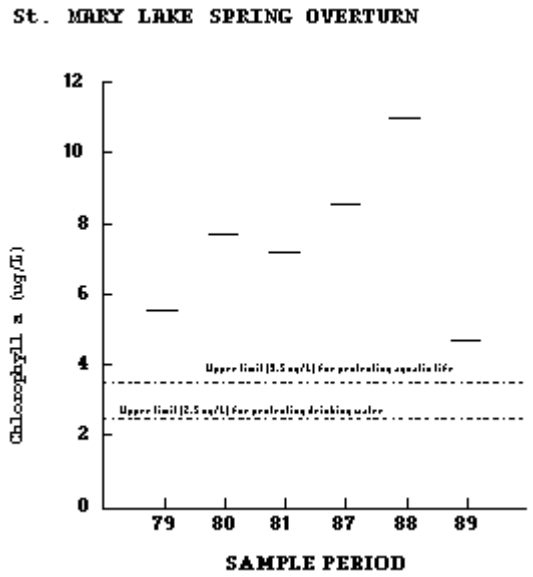


Figure 16 Dissolved silica from St. Mary Lake

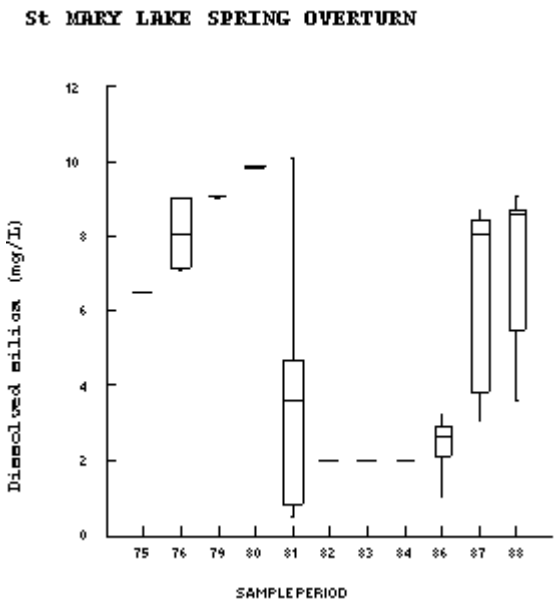


Figure 17 Turbidity from St. Mary Lake

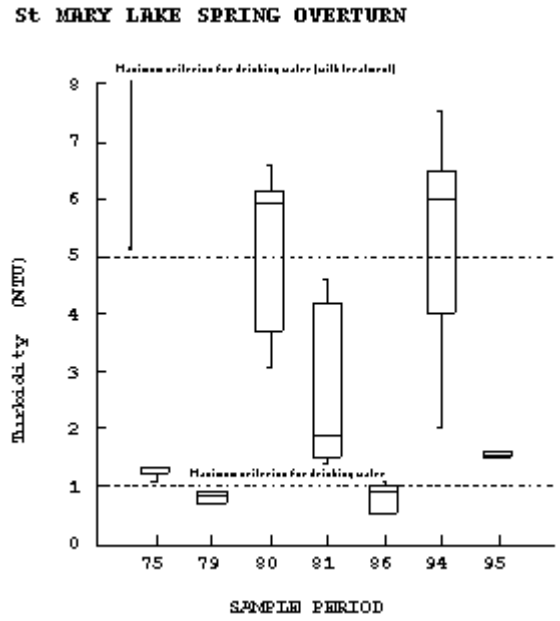


Figure 18 pH from St. Mary Lake

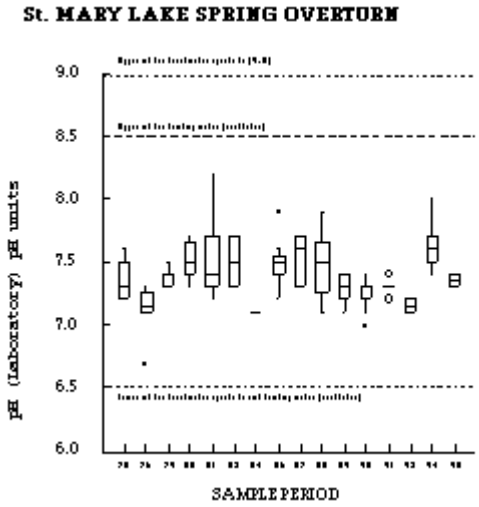


Table 1 Summary of water quality data from St. Mary Lake (SEAM 1100104)

Water Quality Indicator	Average	Std Dev.	Number of samples	Maximum	Minimum
SPRING OVERTURN MONITORING	.	.	.	.	.
Water Clarity and Colour	.	.	.	.	.
Turbidity (NTU)	2.3	2.10	65	7.5	0.5
Colour, true (TCU)	6.1	1.95	118	10	5
Colour, Absorbance (TAC)	5.07	1.21	27	7	3
Residues, suspended (mg/L)	3	2.6	62	9	1
Extinction depth (m)	2.0	1.10	20	4.039	0.46
General Ions	.	.	.	.	.
pH (pH units)	7.40	0.211	162	8.2	6.7
Residues, dissolved (mg/L)	75	8.7	52	98	62
Residues, total (mg/L)	105	9.9	60	140	92
Specific conductivity (µS/cm)	169	27.3	193	219	90
Calcium, total (mg/L)	9.4	0.94	124	11.4	1.7
Magnesium, total (mg/L)	3.08	0.277	123	3.51	1.611
Silica, dissolved (mg/L)	5.1	2.93	87	10.1	0.5
Tannin & Lignin (mg/L)	0.269	0.048	13	0.3	L 0.2
Temperature, water (° C)	8	3.0	164	16	1
Nutrients	.	.	.	.	.
Carbon, total organic (mg/L)	5	1.5	34	8	3
Carbon, total inorganic (mg/L)	8	1.2	66	10	4
Nitrogen, total (mg/L)	1.41	6.228	51	45	0.133
Nitrogen, ammonia (mg/L)	0.012	0.014	162	0.085	L 0.005
Nitrogen, Kjeldahl (mg/L)	0.40	0.150	93	0.76	0.17
Nitrogen, organic (mg/L)	0.47	0.130	42	0.74	L 0.3
Nitrogen, Nitrate+Nitrite (mg/L)	0.05	0.062	174	0.29	L 0.02
Total Phosphorus (mg/L)	0.023	0.0105	175	0.061	0.006
Phosphorus, ortho (mg/L)	0.004	0.0030	161	0.016	L 0.003
Phosphorus, total dissolved (mg/L)	0.008	0.0047	163	0.023	L 0.003
Oxygen, dissolved (mg/L)	9.9	2.15	133	13.7	2
Chlorophyll a (µg/L)	8.11	5.15	70	31.1	L 0.5

Note: L = less than

Table 2 Summary of Capital Regional District's Health Protection and Environmental Division's Bacteriological data (fecal coliforms/100 mL) from St. Mary Lake

Year	St. Mary Lake Blue Gables	St. Mary Lake at Tripp	St. Mary Lake at Cottages	St. Mary Lake 32	St. Mary Lake 33	St. Mary Lake 34	St. Mary Lake 35
1980	.	.	.	.	.	.	.
Max.	.	.	.	3	4	4	4

Min.	.	.	.	3	3	3	3	
Geo. Mean	.	.	.	3	3.5	3.6	3.5	
Number	.	.	.	Number=8	Number=8	Number=8	Number=8	
1981	.	.	.	.	.	.	.	
Max.	3	3	3	.	.	.	.	
Min.	3	3	3	.	.	.	.	
Geo. Mean	3	3	3	.	.	.	.	
Number	Number=4	Number=4	Number=4	.	.	.	.	
1982	.	.	.	.	.	.	.	
Max.	< 3	.	.	.	.	.	.	
Min.	< 3	.	.	.	.	.	.	
Geo. Mean	< 3	.	.	.	.	.	.	
Number	Number=12	.	.	.	.	.	.	
1983	.	.	.	.	.	.	.	
Max.	5	.	.	.	.	.	.	
Min.	5	.	.	.	.	.	.	
Geo. Mean	5	.	.	.	.	.	.	
Number	Number=10	.	.	.	.	.	.	
1984	.	.	.	.	.	.	.	
Max.	5	.	.	.	.	.	.	
Min.	3	.	.	.	.	.	.	
Geo. Mean	3.5	.	.	.	.	.	.	
Number	Number=11	.	.	.	.	.	.	
1985	.	.	.	.	.	.	.	
Max.	7	.	.	.	.	.	.	
Min.	4	.	.	.	.	.	.	
Geo. Mean	6	.	.	.	.	.	.	
Number	Number=14	.	.	.	.	.	.	
1986	.	.	.	.	.	.	.	
Max.	39	.	.	.	.	.	.	
Min.	3	.	.	.	.	.	.	
Geo. Mean	5.7	.	.	.	.	.	.	
Number	Number=8	.	.	.	.	.	.	
1988	.	.	.	.	.	.	.	
Max.	93	.	.	.	.	.	.	
Min.	3	.	.	.	.	.	.	
Geo. Mean	6.9	.	.	.	.	.	.	
Number	Number=12	.	.	.	.	.	.	
1990	.	.	.	.	.	.	.	
Max.	6	.	.	.	.	.	.	
Min.	5	.	.	.	.	.	.	
Geo. Mean	5.8	.	.	.	.	.	.	
Number	Number=5	.	.	.	.	.	.	
1991	.	.	.	.	.	.	.	
Max.	4	.	.	.	.	.	.	
Min.	4	.	.	.	.	.	.	
Geo. Mean	4	.	.	.	.	.	.	

Number	Number=12
1992	
Max.	11
Min.	4
Geo. Mean	7.8
Number	Number=13
1993	
Max.	2
Min.	1
Geo. Mean	1.4
Number	Number=12
1994	
Max.	1
Min.	1
Geo. Mean	1
Number	Number=13
1995 *	
Max.	1
Min.	1
Geo. Mean	1
Number	Number=10

* Samples for June to August are summarized for 1995

References

Hutchinson, G.E. (1957) A Treatise on Limnology. I Geography, Physics, and Chemistry. New York, John Wiley & Sons, Inc. 1015p.

Nagpal, N.K. L.W. Pommen and L.G. Swain. (1995) Approved and Working Criteria for Water Quality Ministry of Environment, Land, and Parks, Environmental Protection Department, Water Quality Branch, Victoria B.C.

Nordin, Richard N, C.J.P. McKean, and J.H. Wiens. (1983) St. Mary Lake water quality: 1979-1981 Ministry of Environment, Land, and Parks. Water Management Branch and Surveys and Resources Branch, Victoria B.C.

Nordin, Richard N. (1985) Water Quality Criteria for Nutrients and Algae. Ministry of Environment, and Parks. Water Management Branch, Resource Quality Section, Victoria, B.C.

Nordin, Richard N. (1995) Personal Communication. Ministry of Environment, Land, and Parks, Environmental Protection Department, Water Quality Branch, Victoria B.C.

Wetzel, R.G. (1975) Limnology. Philadelphia, W.B. Saunders Co. 743p.