



Water Quality

State of Water Quality of Quamichan Lake 1988-1995

Canada - British Columbia Water Quality Monitoring Agreement

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

April, 1996

Executive Summary

Quamichan Lake is located on southern Vancouver Island 3 km east of Duncan, B.C. ([Figure 1](#)). The watershed for this large, shallow lake is 16.3 km².

This report assesses 5 years of water quality data, 21 years (1973-1995) of fecal coliform data, and makes the following conclusions:

- Spring overturn sampling indicates that in recent years there were less nutrients (e.g., total phosphorus, total dissolved phosphorus, dissolved ammonia) in the water column. These changes in nutrient values may be attributed to a change in the amount of nutrients entering the lake or to a change in lake processes.
- Total phosphorus values from Quamichan Lake:
 - outside the limits (0.005-0.015 mg/L) for aquatic life in 1992 and 1993, but within them in 1994 and 1995; and
 - exceeded the criteria for drinking water and protecting recreational use (0.010 mg/L) in 1992, 1993, and 1995.
- Total phosphorus is the limiting nutrient for algal growth in Quamichan Lake.
- The Central Vancouver Island Health Unit has posted Art Mann Park Beach as being unfit for recreational bathing since 1986, warning of the potential for increased risk to bathers' health. Fecal coliform values increased between 1973 and 1995. This increase may be due to an increasing resident waterfowl population.
- True colour values were constant (5 colour units) since 1993. One value exceeded the criteria for drinking water and for recreation.
- Three water quality indicators (total aluminum, total copper, and total zinc) exceeded the criterion for protecting aquatic life. This increase may be due to the level of uncertainty near their minimum detectable limits.

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

We recommend monitoring:

**Ministry of Environment
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- to determine if aluminum, copper, manganese, and zinc exceed the criteria for protecting aquatic life in Quamichan Lake.
- to identify changes in water quality attributed to activities within the watershed such as urbanization, changes in nonpoint discharge, and biological activity.

Both monitoring programs could be implemented by the Ministry of Environment, Lands and Parks with assistance from a Quamichan Lake stewardship group.

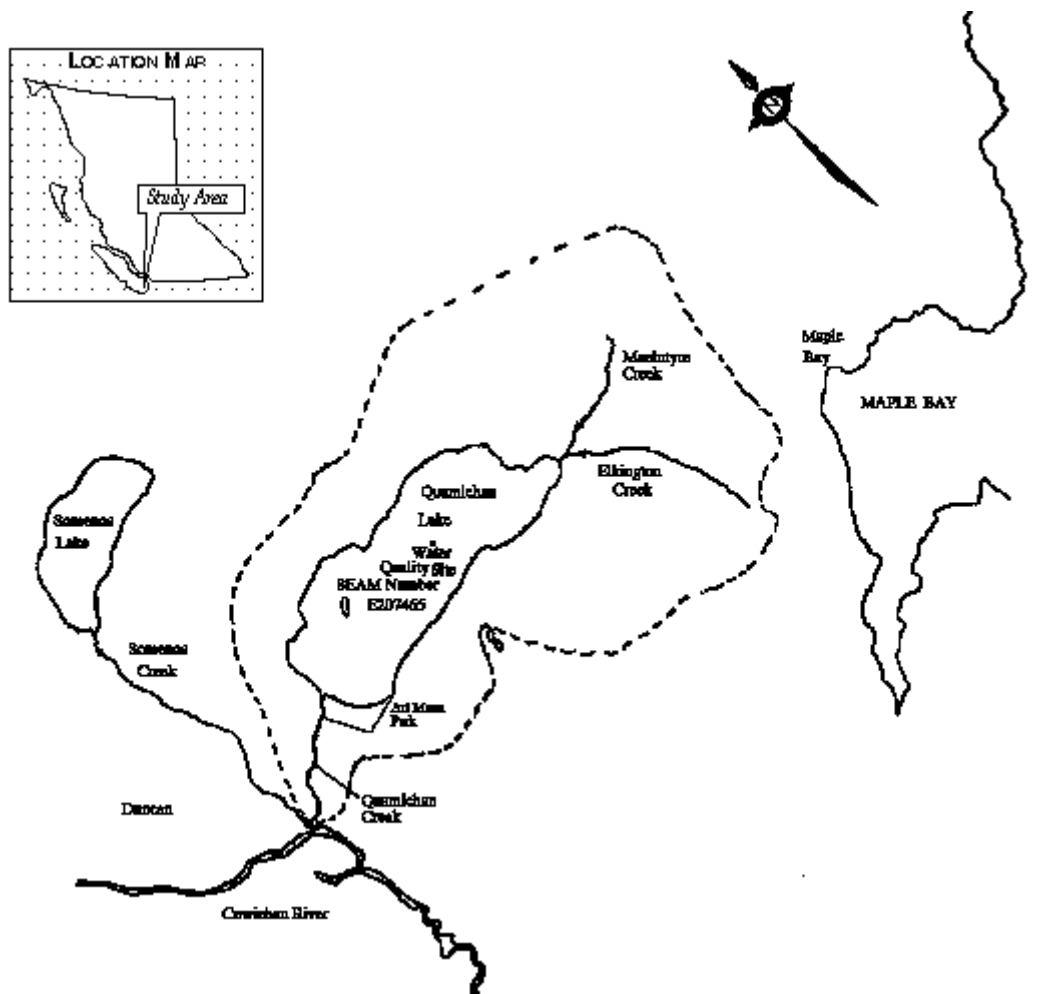
- to determine whether public beaches are suitable for bathing.

The monitoring program will continue to be implemented at Art Mann Beach by the Central Vancouver Island Health Unit.

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

The monitoring program should be implemented by the Central Vancouver Island Health Unit, or by a Quamichan Lake stewardship group.

Figure 1 Quamichan Lake Watershed
Scale 1:50,000



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Introduction

Quamichan Lake is located on southern Vancouver Island 3 km east of Duncan, B.C. ([Figure 1](#)). The watershed for this large, shallow lake is 16.3 km² (Willis, Cunliffe, and Tait, 1979). The surface area of Quamichan Lake is 313.4 ha ([Figure 2](#)) with a maximum depth of 8.2 m and a mean depth of 4.7 m (Klein and Heathman, 1972).

Quamichan Lake has two seasonal inlet streams (MacIntyre and Elkington Creeks). These creeks enter the east end of the lake (Yaworski, 1986). Quamichan Creek flows west and drains into the Cowichan River.

The Ministry of Environment, Lands and Parks monitored the water quality at the deepest point (8 m) of the lake between 1988 and 1995. The data are stored on the provincial data base, SEAM, under station number E207465 ([Figure 1](#)). The two purposes for monitoring the water quality of Quamichan Lake are to identify:

- 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 Central Vancouver Island Health Unit collected fecal coliform samples from a bathing beach (Art Mann Park) on Quamichan 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 5 years (1988-1995) of spring overturn water quality sampling, and 21 years (1973-1995) of fecal coliform sampling. The water quality data are plotted in Figures 3 to 19 and summarized in [Table 1](#) and [Table 2](#).

The box plots, used in Figures 3 to 19, represent the variability of water quality indicators collected at the surface, mid-depth, and near the bottom of the lake. Each 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;

- 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.

Quality Assurance

The water quality plots were reviewed. Samples collected on May 14, 1992 at the surface and at a depth of 3 m from Quamichan Lake contained:

- elevated values of aluminum, copper, manganese, iron, chromium, potassium, barium, total dissolved phosphorus, and Kjeldahl nitrogen; and
- lower values for dissolved sulphate, sodium, and strontium.

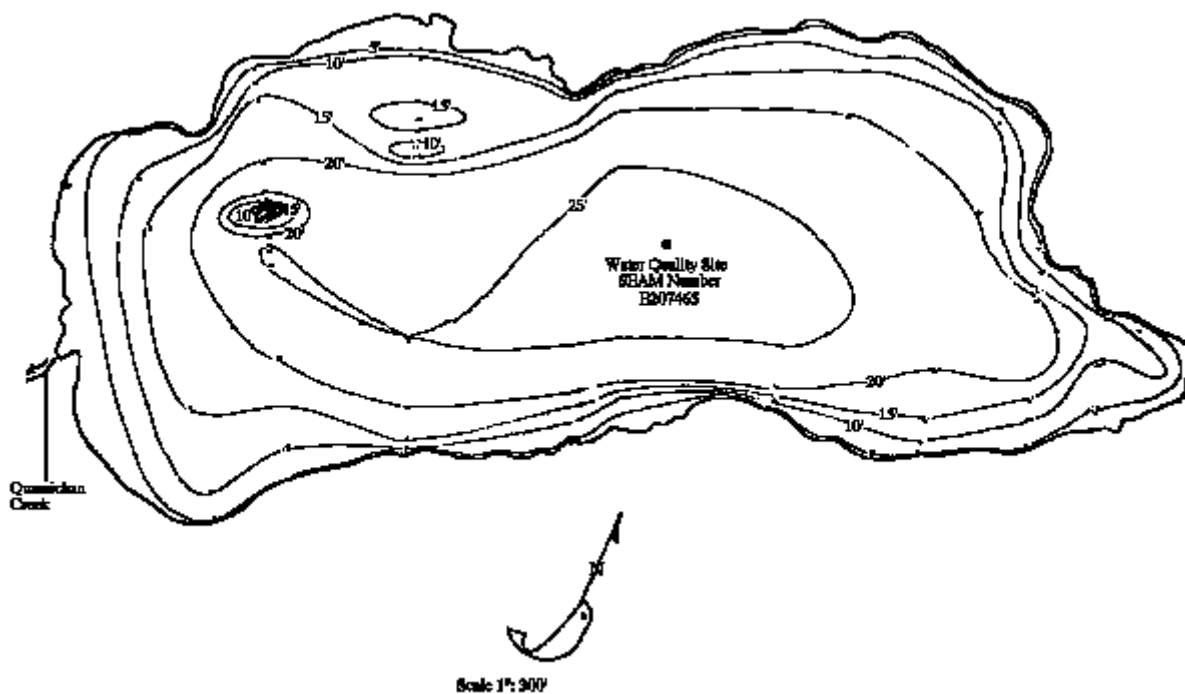
The total phosphorus value collected on October 7, 1992 and the total dissolved phosphorus value collected on May 14, 1992 were "far outside values" ([Figures 4 and 5](#)), and are considered as questionable values.

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, including drinking water, aquatic life and wildlife, recreation, irrigation, and livestock watering are noted.

Water from Quamichan Lake is used for irrigation, water-based recreation, and to sustain aquatic life. There are 24 domestic water licences that may be used as a drinking water source.

Figure 2 Bathymetric Map of Quamichan Lake



Spring Overturn

The water in Quamichan 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 Quamichan Lake.

Total Phosphorus (Figure 3) values before thermal stratification, average of samples taken at different depths within the water column, were outside the limits (0.005-0.015 mg/L) for aquatic life in 1992 and 1993. These values were within the limits for aquatic life after 1993. Total phosphorus values before thermal stratification exceeded the criteria for drinking water and protecting recreational use (0.010 mg/L) in 1992, 1993, and 1995.

Total phosphorus (Figures 3 and 4) and **total dissolved phosphorus** values (Figure 5) generally decreased between 1992 and 1995. This decrease of phosphorus in the water column may be attributed to several factors including:

- an increase in Ultra Violet light (UVb) penetration in the water column,
- an increase in phosphorus uptake by aquatic plants,

- an increase in phosphorus fixing by lake sediments,
- a reduction in phosphorus loadings to the lake, or
- an increase in the flushing rate of Quamichan Lake.

Nitrogen, Dissolved ammonia (Figure 6) values were below the criterion (30-day average of 1.83 mg/L) to protect aquatic life from toxicity. 75% of the values collected between 1993 and 1995 were less than the minimum detectable limit (0.005 mg/L). Dissolved ammonia values have decreased between 1988 and 1995. 94% of the **Nitrate/nitrite** values equalled or were less than the minimum detectable limit (0.02 mg/L). **Kjeldahl nitrogen** (Figure 7) and nitrite/nitrate concentrations are added together to represent total nitrogen in the lake. These concentrations are used to calculate the N:P ratio (Figure 8). The N:P ratios were highly variable between 1988 and 1995, and increased after 1993. Phosphorus is the limiting nutrient for algal growth (N:P > 15:1) in Quamichan Lake (Figure 8). The trends in the ratios indicate that there are changes occurring in the lake systems (e.g., land use, flushing rate, biological activity) which affect water quality.

Total calcium (Figure 9) values of total calcium increased over time, and the lake has a low sensitivity to acid inputs (the lake is well buffered).

Fecal coliform values were collected for 21 years (between 1973 and 1991, and between 1994 and 1995) from a beach site at Art Mann Park on Quamichan Lake (Table 2). These values ranged from less than 3 MPN/100 mL to > 7000 MPN/100 mL. Fecal coliform values from this beach site may not be similar to values collected elsewhere in the lake. Factors such as resident waterfowl populations make this area unique and may cause fecal coliform values to be higher than at other sites in the lake.

The Central Vancouver Island Health Unit has posted advisory notices at Art Mann Park Beach on several occasions since 1986 (Table 2), warning of the potential for increased risk to bathers' health. These notices were posted when the geometric mean exceeded 200 fecal coliforms/100 mL over a 30-day period. Fecal coliform values increased between 1973 and 1995.

There are 24 active domestic water licenses on Quamichan 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. Fecal coliform values must not exceed the 90th percentile criterion for partially treated drinking water of 100 MPN/100 mL, and 10 MPN/100 mL for disinfected drinking water. There are insufficient data to assess the suitability of the lake to be used as a drinking water source.

True colour: 7 % (one value) of the true colour values from Quamichan Lake (Figure 10) exceeded the criteria (15 colour units) for drinking water and recreation. Total colour values were constant (5 colour units) between 1993 and 1995.

Total aluminum (Figure 11): 14 % of the values exceeded the 30-day average criterion (0.05 mg/L) for protecting aquatic life. One value exceeded the maximum criterion for protecting drinking water (0.2 mg/L). This value occurred on May 14, 1992 when the values for several water quality indicators were high. All aluminum values were below the minimum detectable limit (0.06 mg/L) between March, 1993 and 1995. Analysis of samples from Quamichan Lake for aluminum should use a minimum detectable limit 10 times lower than the lowest criterion (e.g., 0.005 mg/L). This would provide more accurate data for comparison to the 30-day average criterion (0.05 mg/L) for protecting aquatic life.

Total copper (Figure 12) 21% of the values exceeded the 30-day average criteria (0.002 mg/L) for protecting aquatic life in water with hardness less than or equal to 50 mg/L of CaCO₃. All copper values reported in 1994 and 1995 were at the minimum detectable limit of 0.002 mg/L. Analysis of samples from Quamichan Lake for copper should use a minimum detectable limit 10 times lower than the lowest criterion (e.g., 0.0002 mg/L). This would provide more accurate data for comparison to the 30-day average criterion (0.002 mg/L) for protecting aquatic life.

Total iron (Figure 13): One value (0.451 mg/L), on May 14, 1992, exceeded the maximum criterion (0.3 mg/L) for protecting aquatic life, and drinking water.

Total manganese (Figure 14): 21% of the values exceeded the criterion (0.05 mg/L) for protecting drinking water. One value (0.133 mg/L), on May 14, 1992, exceeded the criterion for protecting aquatic life. Total manganese values did not been exceeded the criteria after 1992.

Total residue (i.e., dissolved plus suspended solids) ranged from 86 mg/L to 212 mg/L (Figure 15). The criterion for suspended solids could not be used because there were insufficient suspended solids (non-filterable residues) data. There are no criteria for total residues. **Specific conductivity (µS/cm)** can be used to indicate dissolved solid concentrations. These values (Figure 16) were below all criteria for specific conductivity.

Dissolved silica (Figure 17): These values indicate that dissolved silica was a not limiting factor (i.e., values were greater than 0.5 mg/L) for diatom growth in Quamichan Lake in 1994 (Wetzel, 1975).

Total zinc (Figure 18): 2 of 14 values exceeded the criterion for protecting phytoplankton (0.014 mg/L). Analysis of samples from Quamichan Lake for zinc should use a minimum detectable limit 10 times lower than the lowest criterion (e.g., 0.001 mg/L). This would provide more accurate data for comparison to the criterion (0.014 mg/L) for protecting phytoplankton.

pH (Figure 19) values ranged between 7.1 and 7.4 and met all criteria. The values were relatively constant between 1988 and 1995.

Conclusions - State of Water Quality

- Spring overturn sampling indicates that in recent years there were less nutrients (e.g., total phosphorus, total dissolved phosphorus, dissolved ammonia) in the water column. These changes in nutrient values may be attributed to a change in the amount of nutrients entering the lake or to a change in lake processes.
- Total phosphorus values from Quamichan Lake:
 - outside the limits (0.005-0.015 mg/L) for aquatic life in 1992 and 1993, but within them in 1994 and 1995; and
 - exceeded the criteria for drinking water and protecting recreational use (0.010 mg/L) in 1992, 1993, and 1995.
- Total phosphorus is the limiting nutrient for algal growth in Quamichan Lake.
- The Central Vancouver Island Health Unit has posted Art Mann Park Beach as being unfit for recreational bathing since 1986, warning of the potential for increased risk to bathers' health.

Fecal coliform values increased between 1973 and 1995. This increase may be due to an increasing resident waterfowl population.

- True colour values were constant (5 colour units) since 1993. One value exceeded the criteria for drinking water and for recreation.
 - Three water quality indicators (total aluminum, total copper, and total zinc) exceeded the criterion for protecting aquatic life. This increase may be due to the level of uncertainty near their minimum detectable limits.
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Recommendations for Water Quality Management

Remediation

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

Monitoring

We recommend that minimum detectable limits for analytical procedures used to measure total aluminum, total copper, and total zinc in Quamichan Lake water must be at least 10 times lower than the criterion level. Monitoring for these water quality indicators and total manganese should be done in conjunction with the spring overturn and mid-summer sampling program.

We recommend that sampling at the surface and at depth during spring overturn and mid-summer be conducted at SEAM site E207465. 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, changes in biological activity in the lake. 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 colour, 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 Quamichan Lake stewardship group with assistance from the Ministry of Environment, Lands and Parks.

We recommend that fecal coliform sampling continue at Art Mann Park beach on Quamichan Lake. The monitoring program is being implemented by the Central Vancouver Island Health Unit. In future, local interest groups (e.g., Quamichan Lake stewardship group, North Cowichan Valley Regional District) could assist with this ongoing monitoring.

We recommend that fecal coliform sampling be started at the intakes of all domestic licences used for drinking water on Quamichan Lake. The monitoring program would require that 5 samples be collected in

30 days at the intakes of these domestic licences. The fecal coliform values from these samples would be compared to the drinking water criteria. The monitoring program could be implemented by the Central Vancouver Island Health Unit, or by a Quamichan Lake stewardship group.

Figure 3 Total phosphorus (average in the water column before stratification) from Quamichan Lake

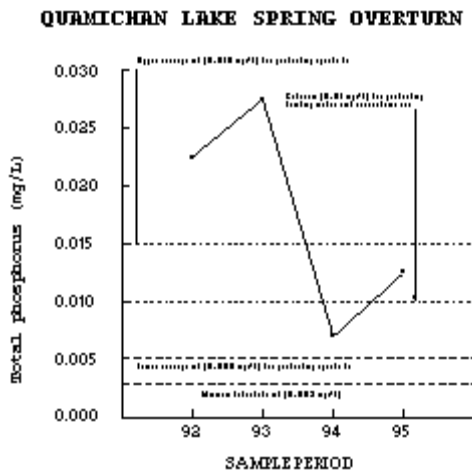


Figure 4 Total phosphorus from Quamichan Lake

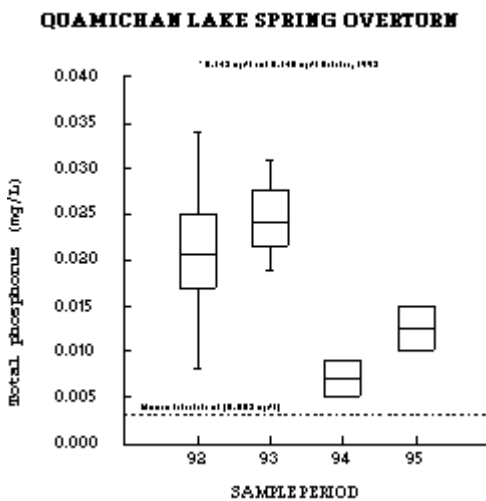


Figure 5 Total dissolved phosphorus from Quamichan Lake

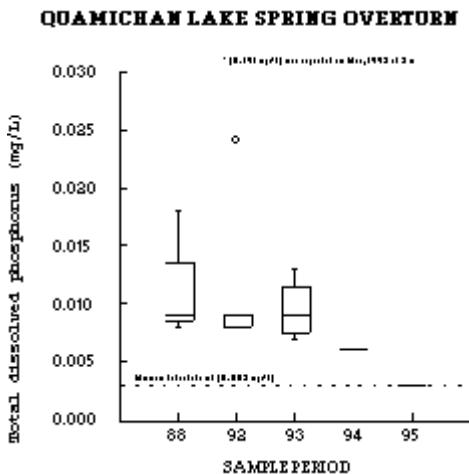


Figure 6 Dissolved ammonia from Quamichan Lake

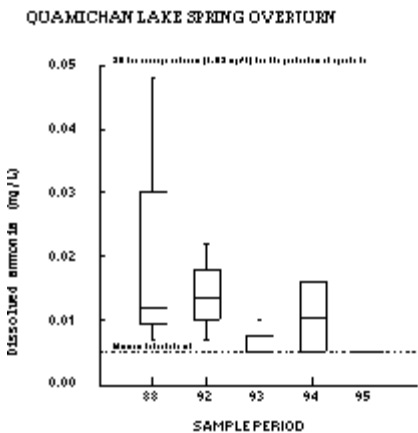


Figure 7 Kjeldahl nitrogen from Quamichan Lake

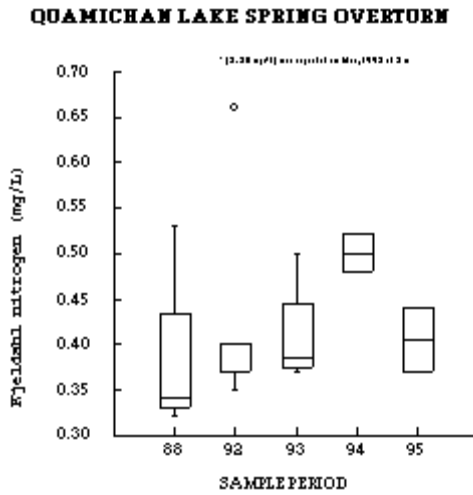


Figure 8 N:P Ratio from Quamichan Lake

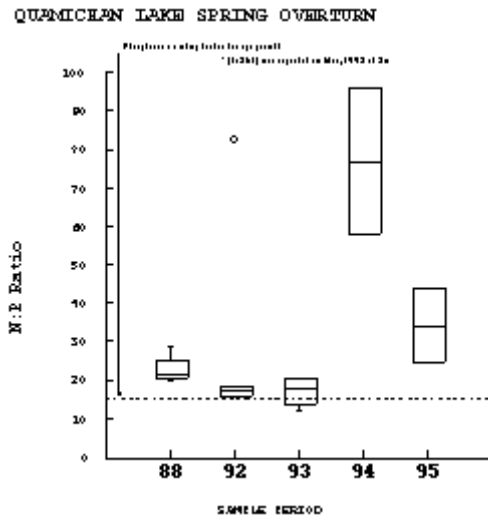


Figure 9 Total calcium from Quamichan Lake

QUAMICHAN LAKE SPRING OVERTURN

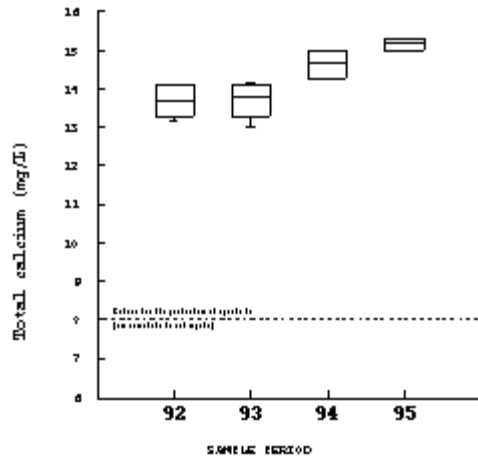


Figure 10 True colour from Quamichan Lake

QUAMICHAN LAKE SPRING OVERTURN

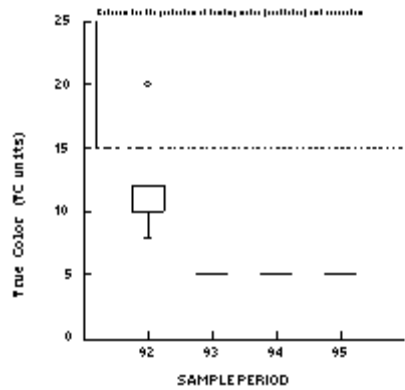


Figure 11 Total aluminum from Quamichan Lake

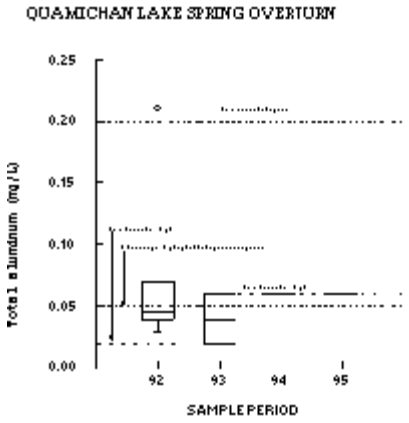


Figure 12 Total copper from Quamichan Lake

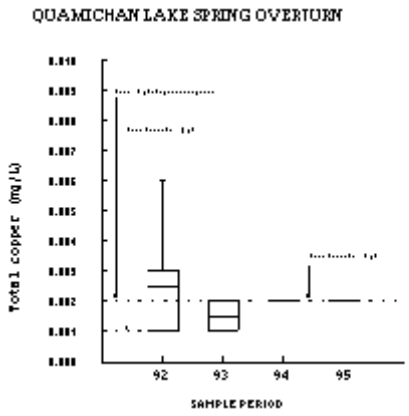


Figure 15 Total residues from Quamichan Lake

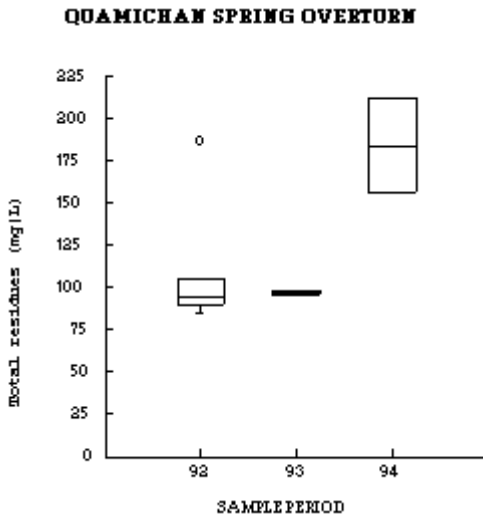


Figure 16 Specific conductivity from Quamichan Lake

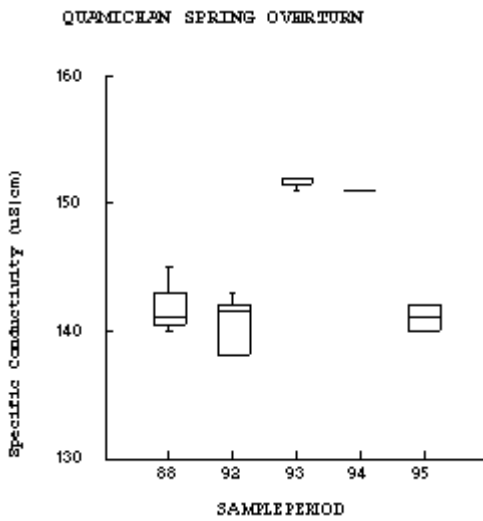


Figure 17 Dissolved silica from Quamichan Lake

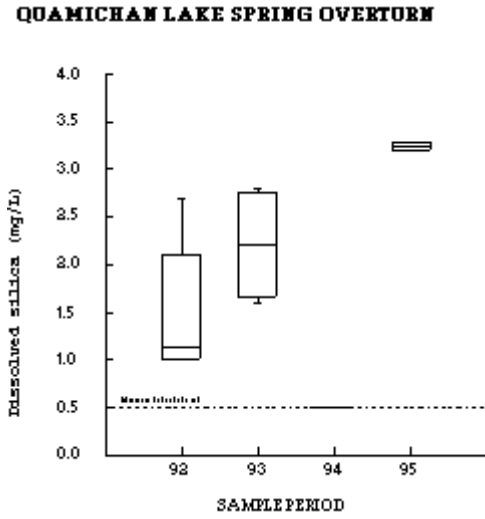


Figure 18 Total zinc from Quamichan Lake

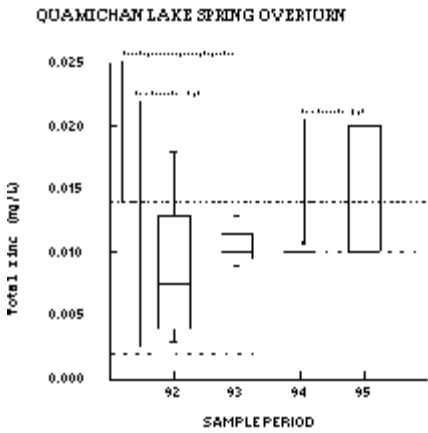


Figure 19 pH from Quamichan Lake

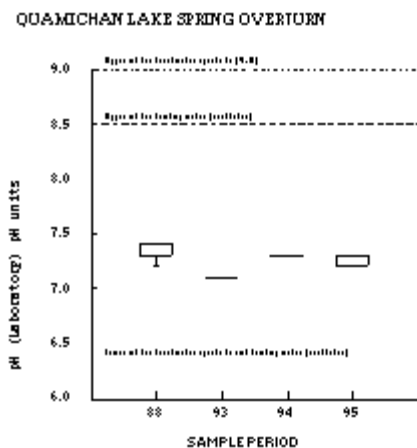


Table 1 Summary of water quality data from Quamichan Lake (SEAM site E207465)

Water Quality Indicator	Average	Std Dev	Number of samples	Maximum	Minimum
SPRING OVERTURN MONITORING					
Water Clarity and Colour					
Colour, true (TCU)	7.9	4.3	14	20	5
Colour, total absorbance (TAC)	8.4	2.1	8	12	6
Residues, non-filterable (mg/L)	4.5	0.71	2	5	4
Extinction depth (m)	.	.	1	2.4	2.4
General Ions					
pH (pH units)	7.26	0.11	9	7.4	7.1
Residues, filterable (mg/L)	101	1.4	2	102	100
Residues, total (mg/L)	117.5	42.5	12	212	86
Specific conductivity (µS/cm)	144.8	5.4	17	152	138
Calcium, total (mg/L)	14.03	0.7	14	15.3	13
Magnesium, total (mg/L)	3.917	0.269	14	4.404	3.6
Silica, dissolved (mg/L)	1.81	0.98	14	3.3	L 0.5
Sulphate, dissolved (mg/L)	17.25	2.24	6	19.1	14.3
Temperature, water (° C)	11	0	3	11	11
Nutrients					
Nitrogen, total (mg/L)	0.385	0.021	2	0.4	0.37
Nitrogen, ammonia (mg/L)	0.0119	0.0112	15	0.048	L 0.005
Nitrogen, Kjeldahl (mg/L)	0.538	0.475	17	2.35	0.32
Nitrogen, Nitrate+Nitrite (mg/L)	0.0206	0.002	17	0.03	L 0.02
Nitrogen, Nitrate (mg/L)	.	.	2	0.02	L 0.02
Nitrogen, Nitrite (mg/L)	.	.	4	0.006	L 0.005
Phosphorus, total (mg/L)	0.017	0.0076	17	0.031	0.005

Phosphorus, ortho (mg/L)			3	0.01	L 0.003
Phosphorus, total dissolved (mg/L)	0.02	0.044	17	0.191	L 0.003
Oxygen, dissolved (mg/L)	9.27	0.12	3	9.4	9.2
Metals					
Aluminum, total (mg/L)	0.06	0.046	14	0.21	L 0.02
Boron, total (mg/L)	0.043	0.021	14	0.092	0.008
Barium, total (mg/L)	0.008	0.0008	14	0.01	0.007
Chromium, total (mg/L)	L 0.002	0	14	0.003	L 0.002
Copper, total (mg/L)	0.002	0.001	14	0.006	L 0.001
Iron, total (mg/L)	0.088	0.107	14	0.451	0.019
Manganese, total (mg/L)	0.04	0.041	14	0.133	0.007
Potassium, total (mg/L)	1.217	0.133	6	1.3	1
Sodium, total (mg/L)	7.232	0.641	6	8.05	6.43
Sodium, dissolved (mg/L)	7.64	0.521	10	8.5	7.2
Silicon, total (mg/L)	1.004	0.427	14	1.74	0.53
Strontium, total (mg/L)	0.097	0.005	14	0.106	0.09
Sulfur, total (mg/L)	4.973	0.219	6	5.18	4.68
Zinc, total (mg/L)	0.01	0.005	14	0.02	0.003

Note: L = less than

Table 2 Summary of Central Vancouver Island Health Unit's Bacteriological data (fecal coliform/100 mL) from Quamichan Lake (Art Mann Park)

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Maximum	L 3	4	L 3	240	240	240	4	43	240	2400	460	460
Minimum	L 3	L 3	L 3	L 3	L 3	L 3	L 3	L 3	L 3	23	L 3	L 3
Geometric Mean	L 3	28	.	7.98	11.73	6.43	3.3	9.67	19.89	216.23	18.86	20.66
Number of Samples	4	19	1	10	6	6	3	6	9	8	11	11

Year	1985	1986	1987	1988	1989	1990	1991	1994	1995
Maximum	240	G 2400	2400	G 2400	6700	3250	785	G 6400	G 6400
Minimum	4	L 3	4	93	80	500	35	225	25
Geometric Mean	25.54	70.06	177	887.34	931.94	1377.56	162.55	13697.0	1454.19
Number of Samples	11	13	12	12	8	9	3	5	4

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