Water Quality

State of Water Quality of Shawnigan Lake 1976-1995

Canada - British Columbia Water Quality Monitoring Agreement

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

April, 1996

Executive Summary

Shawnigan Lake is located on southern Vancouver Island near Victoria, B.C. (Figure 1). The watershed for this medium-sized lake is 69.4 km².

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

- The turbidity objectives for Shawnigan Lake have been met at the deepest point (50 m) of the lake. Turbidity decreased between 1977 and 1995.
- Total phosphorus values exceeded the objective to limit algal growth only in 1980. These values have decreased since 1985. This may be attributed to a decrease in nutrients entering the lake or to an increase in biological production.
- Phosphorus is the limiting nutrient for algal growth in Shawnigan Lake.
- Total organic carbon values exceeded the criterion for drinking water in 1980. Chlorinated drinking water may produce trihalomethanes which exceed the drinking water criterion (0.1 mg/L) when total organic carbon values are greater than 4 mg/L.
- Central Vancouver Island Health Unit determined that all public beaches were fit for bathing between 1988 and 1995.
- There were insufficient data to assess the suitability of the lake water as a drinking source.

We recommend monitoring:

- to determine whether water quality objectives are being met.
- to identify changes in water quality attributed to biological activity in the lake, to activities within the watershed such as urbanization, and to changes in nonpoint discharge.

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

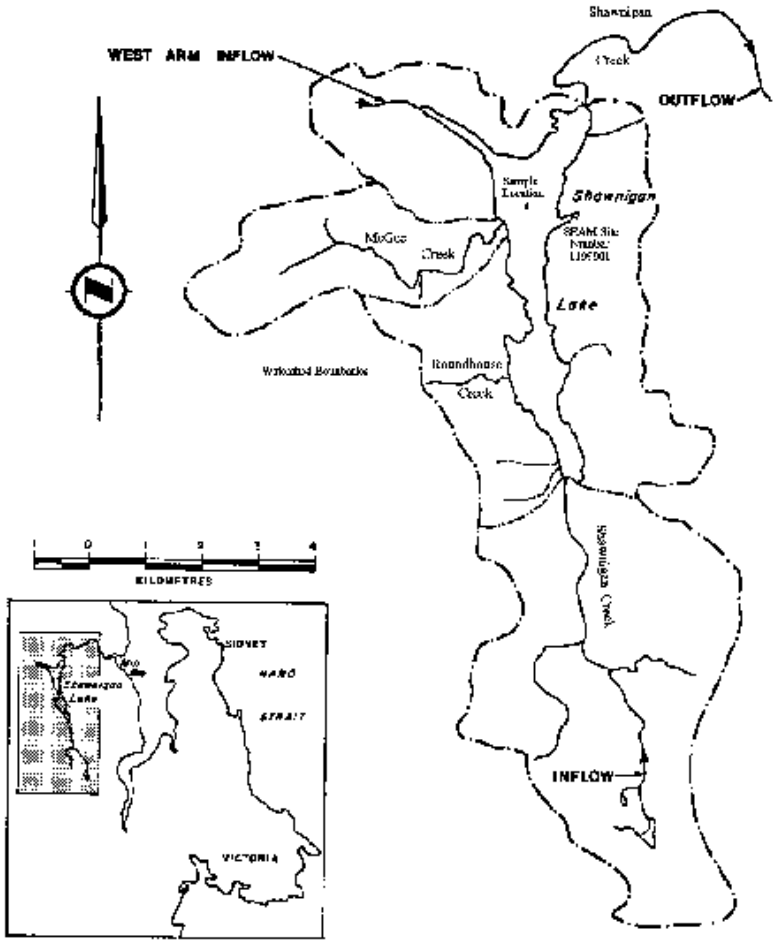
- to determine whether public beaches were suitable for bathing.

This monitoring will continue to be implemented at the four bathing beaches by the Central Vancouver Island Health Unit.

- to determine whether trihalomethanes values in chlorinated drinking water from Shawnigan Lake meet the drinking water criterion.

This monitoring should be implemented by the two water works licencees (Sherwood Water Works and Lidtech Holdings Ltd.). The results of this monitoring should be reported, on a quarterly basis, to the Central Vancouver Island Health Unit.

Figure 1 Shawnigan Lake Watershed



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Introduction

Shawnigan Lake is located on southern Vancouver Island near Victoria, B.C. (Figure 1). The watershed for this medium-sized lake is 69.4 km². The surface area of the lake is 537 ha and is comprised of one main basin with several smaller basins on the south part of the lake (Nordin and McKean, 1984). The lake has a maximum depth of 50 m and a mean depth of 12 m (Figure 2). There are ten inflow streams, including Shawnigan Creek. This creek flows out of the lake and drains into Saanich Inlet.

The Ministry of Environment, Lands and Parks monitored the water quality at the deepest point (50 m) of the main basin between 1976 and 1995. The data are stored on the provincial data base, SEAM, under station number 1199901 (Figure 1). The two purposes for monitoring the water quality of Shawnigan 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 four public beaches (Mason's Beach, West Shawnigan Lake Provincial Park, Shawnigan Lake Recreation Association Beach, Easter Seals Camp) on Shawnigan 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 consist of:

- 2 years (1976-1978) of intensive water quality sampling,
- 8 years (1988-1995) of fecal coliform sampling, and
- 15 years (1979-1995) of spring overturn water quality sampling.

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. 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.

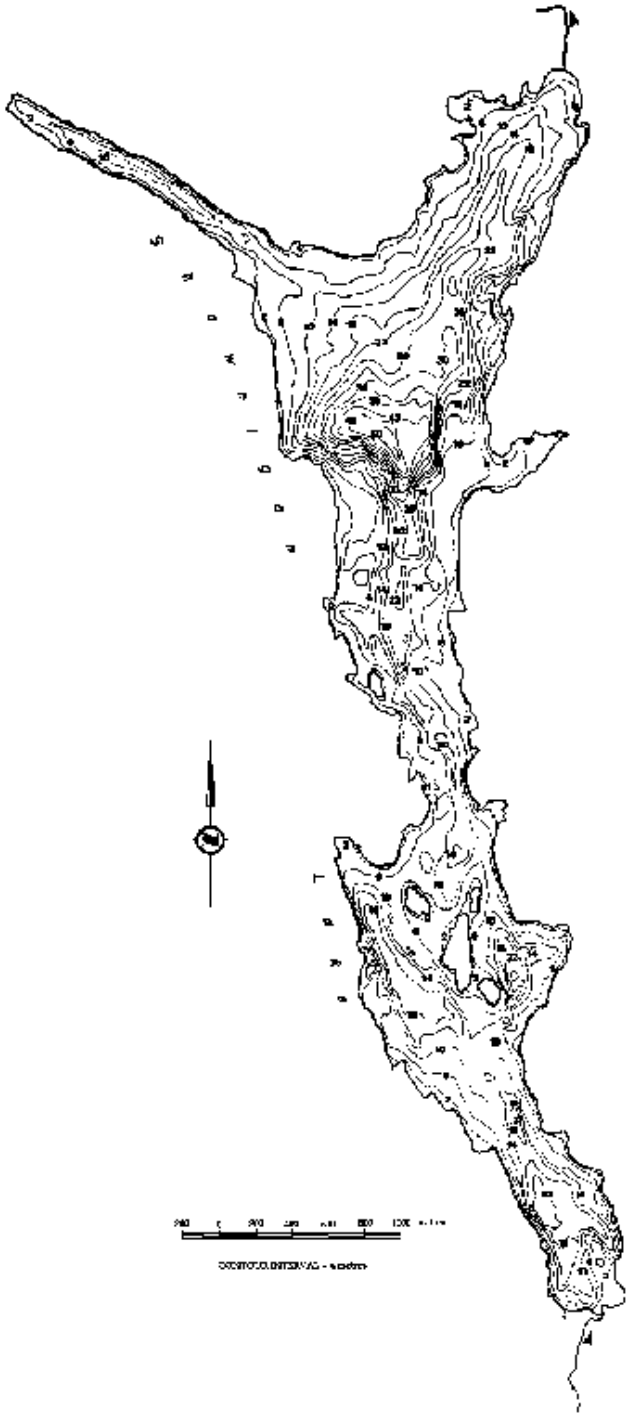
Quality Assurance

The water quality plots were reviewed. 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, including drinking water, aquatic life and wildlife, recreation, irrigation, and livestock watering are noted.

Figure 2 Bathymetric map of Shawnigan Lake



Water Quality Objectives

Nordin and McKean (1984) identified objectives for bulk water supply, water-based recreation, fisheries and the prevention of eutrophication for Shawnigan Lake. There are 106 domestic water licences that may be used as a drinking water source.

The objectives are:

- Total Phosphorus concentrations at spring overturn shall not exceed 8 µg/L. This objective applies to the average of at least 3 samples taken 1 m below the surface, at mid depth and 1 m above the bottom.
- Turbidity shall not exceed 5 NTU in any grab sample taken within 10 m of a domestic intake, nor shall the means from at least 10 such samples taken throughout the year exceed 1 NTU.
- Fecal coliform density shall not exceed 10 MPN per 100 mL in 90% of the lake samples, taken in any consecutive 30-day period, within 10 m of a domestic intake.

Spring Overturn

The water in Shawnigan Lake is vertically mixed (no thermal stratification) between November and the end of April. A key time for sampling is in the spring 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 Shawnigan Lake.

Total phosphorus (Figure 3) values before thermal stratification (average of samples taken at different depths within the water column) exceeded the objective to limit algal growth in 1980. These values have decreased between 1976 and 1992 (Figures 3 and 5) and were less than the minimum detectable limit (0.003 mg/L) 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 Shawnigan Lake.

Turbidity (Figure 4): Water quality data were not collected within 10 m of a domestic intake nor at a frequency outlined in the objective (at least 10 samples taken throughout the year). All turbidity values collected at SEAM site 1199901 met the drinking water objectives (average turbidity value of 1 NTU, maximum turbidity value of 5 NTU). Average turbidity values have decreased between 1977 and 1995.

Fecal coliform: values were collected between 1988 and 1995 at four beach sites around Shawnigan Lake (Table 2). These values ranged between less than 1 MPN/100 mL and 4500 MPN/ 100 mL. Fecal coliform values from these beach sites may not be similar to values collected elsewhere in the lake. Resident waterfowl populations make these areas unique and may cause fecal coliform values to be higher than at other sites in the lake.

The Central Valley Health Unit determined that all public beaches on Shawnigan Lake were suitable for bathing between 1988 and 1995 (Table 2).

The Ministry of Environment, Lands and Parks collected fecal coliform samples at the deepest point (50 m) of the lake between 1976 to 1978 (Table 1). These values ranged between 2 MPN/100 mL and 8 MPN/100 mL. These data indicate that the recreation criterion (geometric mean of 200/100 mL) was met at this site. A sampling frequency of 5 samples in 30 days would provide more accurate data for comparison to the recreation criterion.

There are 106 active domestic water licenses on Shawnigan Lake. The Ministry of Health recommends that all surface waters in the province 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.

Nitrogen, dissolved ammonia (Figure 6): values were below the criterion (30-day average of 1.31 mg/L) designated to protect aquatic life from toxicity. **Nitrate/nitrite** (Figure 7) values were ranged between < 0.02 mg/L and 0.12 mg/L and were below the criterion (10 mg/L) for protecting drinking water. **Kjeldahl nitrogen** (Figure 8) 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 9). This ratio indicates (N:P > 15) that phosphorus was the limiting factor for algal growth in Shawnigan Lake. There was an increase in the N:P ratio over time due to the decline in total phosphorus in the lake. The dissolved ammonia:nitrate ratio (Figure 10) decreased over time due to the decline in ammonia in the lake. The trends in the ratios indicate that there are changes occurring in the lake systems (e.g., land use, biological activity) which affect water quality.

Extinction depth (Figure 11), which is measure of the amount of light penetrating the water column, were highly variable (1.2 m to 7.45 m) between 1976 and 1994. However, the average annual extinction depth was approximately 6 m between 1976 and 1994. All extinction depth values from Shawnigan Lake met the criterion (> 1.2 m) for recreational use.

Chlorophyll a : A summer average chlorophyll a value in 1978 (3.2 µg/ L) exceeded the criteria (2-2.5 µg/ L) for drinking water and recreational use. There were insufficient data collected in subsequent years to compare to these criteria.

Total calcium (Figure 12): values show that the lake has a moderate sensitivity to acid inputs (the lake is moderately buffered).

Total absorbance colour (Figure 13): values and **true colour** (Table 1) values met the true colour criteria for drinking water and recreation. Total absorbance colour values ranged from 4 TAC to 11 TAC, and total colour values ranged from 5 TCU to 10 TCU.

Total organic carbon (Figure 14): values exceeded the drinking water criterion (4 mg/L) in 1980. Trihalomethane values in chlorinated waters from Sherwood Water Works or Lidtech Holdings Ltd. may exceed the drinking water criterion for trihalomethanes (0.1 mg/L) when total organic carbon values exceed the criterion. Total organic carbon values have not been collected since 1980. Trihalomethane values in chlorinated waters should be collected and compared to the drinking water criterion.

Dissolved oxygen: 2% of dissolved oxygen values were less than the criterion (5 mg/L) for protecting aquatic life. These values occurred at depths greater than 20 m in October and November.

Dissolved silica (Figure 15): values ranged from 2 mg/L to 2.57 mg/L. These values indicate that dissolved silica is not a limiting factor (i.e., values were > 0.5 mg/L) for diatom growth in Shawnigan Lake (Wetzel, 1975). The increase in dissolved silica, between 1993 and 1995, may be attributed to a decrease in diatom activity in the lake.

Chloride (Figure 16): values were below all criteria for dissolved chloride.

Total residue: (i.e., dissolved plus suspended solids) values were relatively constant between 1978 and 1993 (30-50 mg/L). 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 4 mg/L. These values were below all criteria for suspended solids. **Dissolved solids** (filterable residues) values ranged from 3 mg/L to 50 mg/L. **Specific conductivity (µS/cm)** (Figure 17) can be used to indicate dissolved solid concentrations. These values were relatively constant (50-65 µS/cm) and were below all criteria for specific conductivity.

pH (Figure 18): values met all criteria. These values ranged between 6.5 and 8.

Conclusions - State of Water Quality

- The turbidity objectives for Shawnigan Lake have been met at the deepest point (50 m) of the lake. Turbidity decreased between 1977 and 1995.
- Total phosphorus values before thermal stratification (average of samples taken at different depths within the water column) exceeded the objective to limit algal growth only in 1980. These values have decreased since 1985. This may be attributed to a decrease in nutrients entering the lake or to an increase in biological production.
- Phosphorus is the limiting nutrient for algal growth in Shawnigan Lake.
- Total organic carbon values exceeded the criterion for drinking water in 1980. Chlorinated drinking water from Sherwood Water Works or Lidtech Holdings Ltd. may produce trihalomethanes which exceed the drinking water criterion (0.1 mg/L) when total organic carbon values are greater than 4 mg/L.
- The Central Valley Health Unit determined that all public beaches on Shawnigan Lake were suitable for bathing between 1988 and 1995.
- There were insufficient fecal coliform data to assess the suitability of the lake water as a drinking source.

Recommendations for Water Quality Management

Remediation

There are no apparent water quality remediation measures needed at this time.

Monitoring

We recommend that monitoring be done to determine whether water quality objectives are being met. This monitoring program would require that at least:

- 5 fecal coliform samples, taken in any consecutive 30-day period, within 10 m of domestic intakes.
- 3 total phosphorus samples taken 1 m below the surface, at mid depth and 1 m above the bottom during spring overturn at the deepest point in the lake (SEAM site 1199901); and
- 10 turbidity grab sample taken within 10 m of domestic intakes taken throughout the year.

We recommend that sampling at the surface and at depth during spring overturn and in the mid-summer at SEAM site 1199901. The focus of this monitoring would be to identify changes in water quality due to activities within the watershed such as urbanization, and changes in nonpoint discharge. 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, and 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 could be implemented by a local interest group (e.g., Shawnigan Lake stewardship group, Cowichan Valley Regional Regional District) with assistance from the Ministry of Environment, Lands and Parks.

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

We recommend that the two water works licencees (Sherwood Water Works and Lidtech Holdings Ltd.) monitor the chlorinated water for trihalomethanes. The results of this monitoring should be reported, on a quarterly basis, to the Central Vancouver Island Health Unit.

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

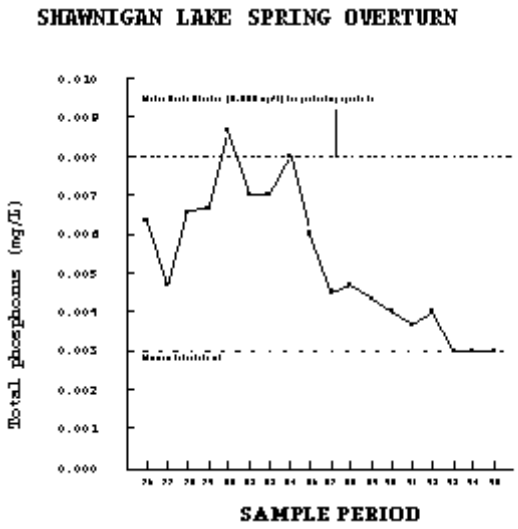


Figure 4 Turbidity (annual average) from Shawnigan Lake

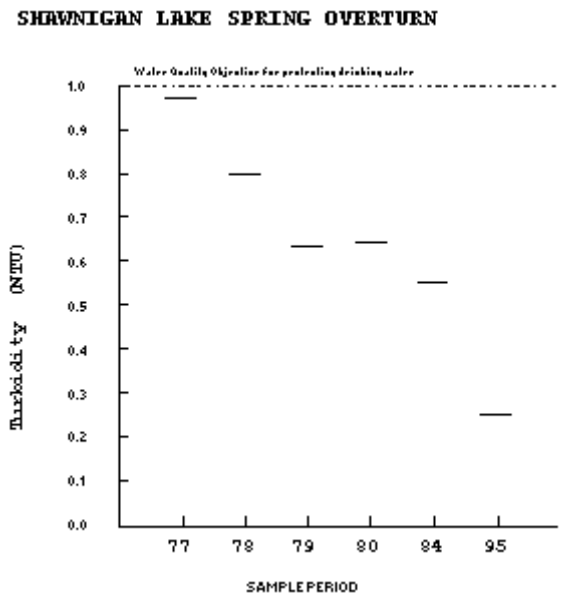


Figure 5 Total Phosphorus from Shawnigan Lake

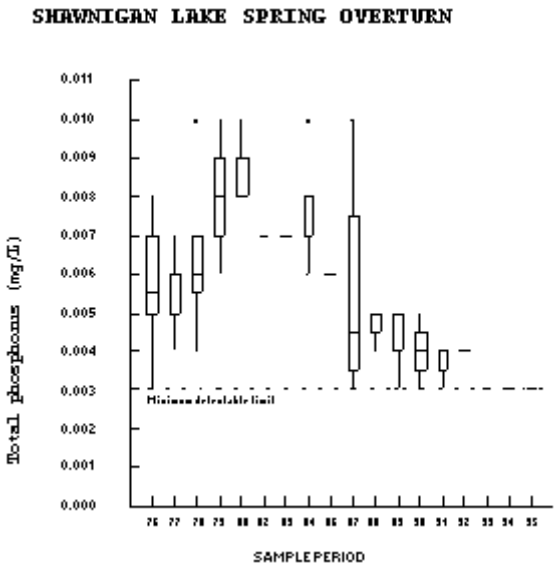


Figure 6 Dissolved ammonia from Shawnigan Lake

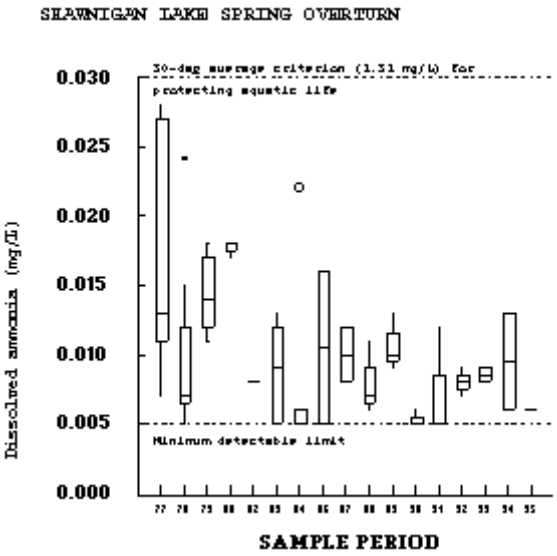


Figure 7 Nitrate/nitrite from Shawnigan Lake

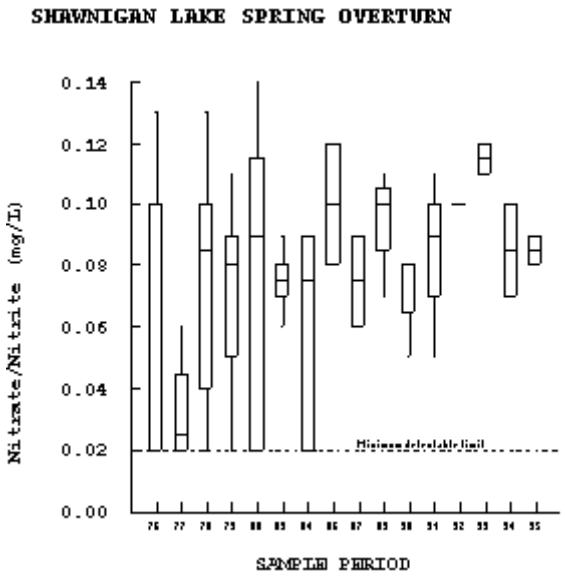


Figure 8 Kjeldahl nitrogen from Shawnigan Lake

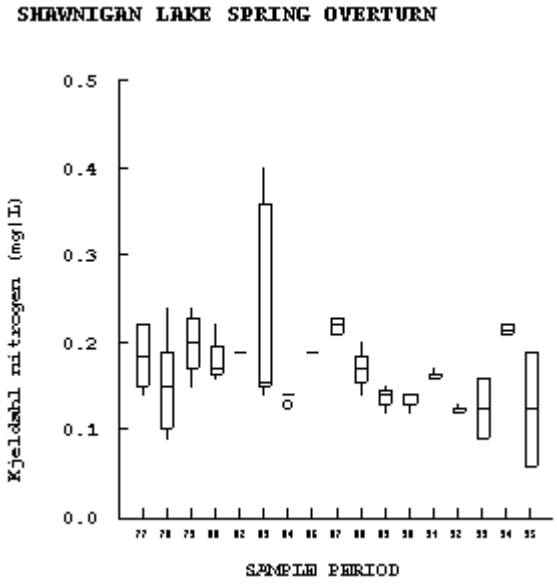


Figure 9 N:P ratio from Shawnigan Lake

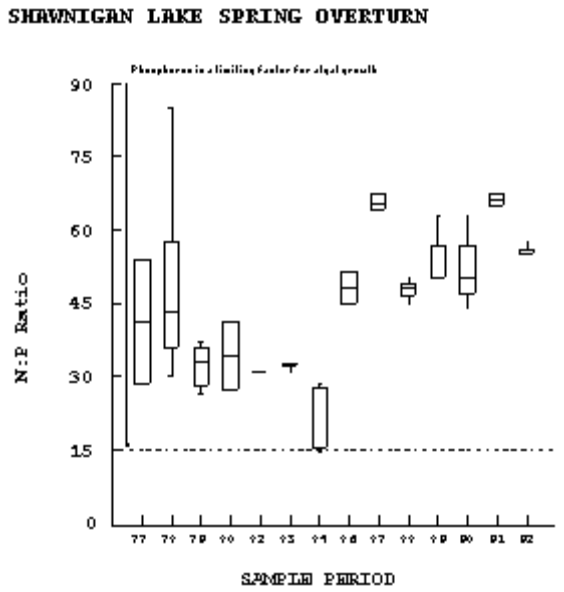


Figure 10 Ammonia:nitrate ratio from Shawnigan Lake

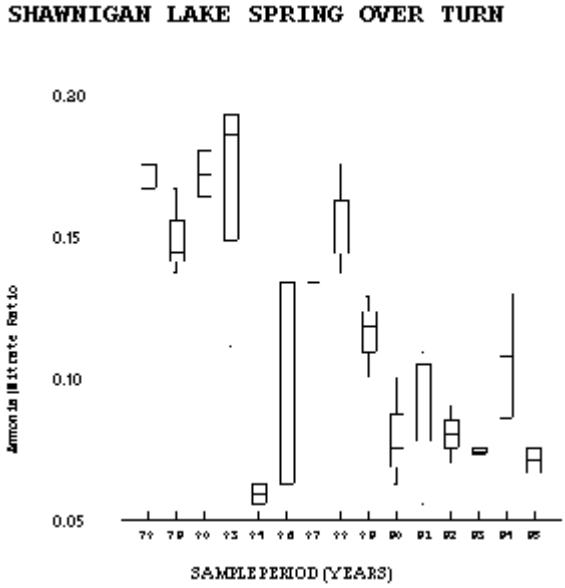


Figure 11 Extinction depth from Shawnigan Lake

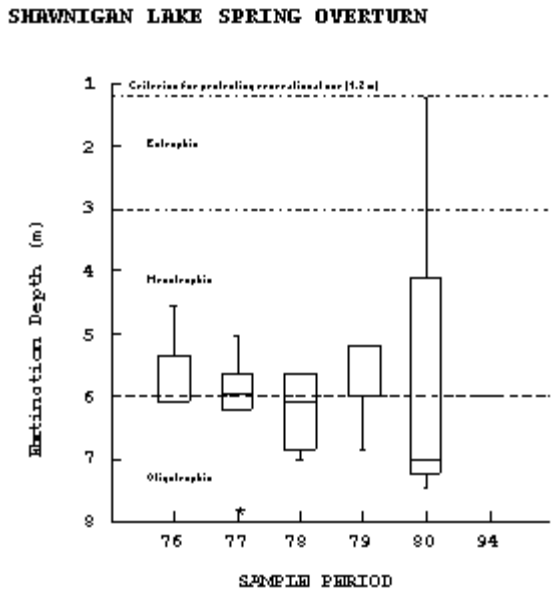


Figure 12 Total calcium from Shawnigan Lake

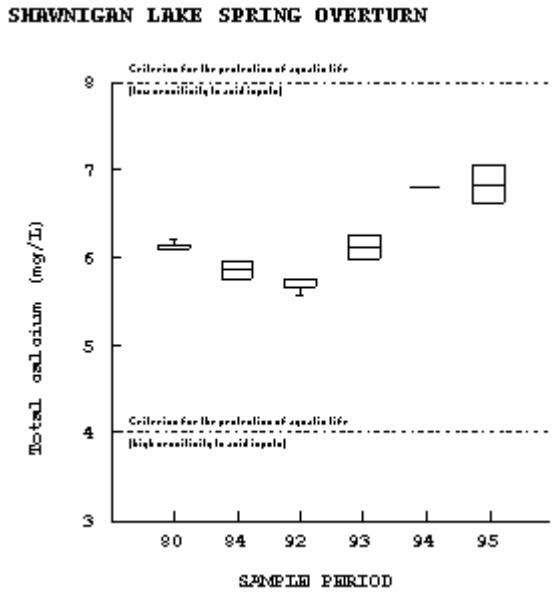


Figure 13 Total absorbance colour from Shawnigan Lake

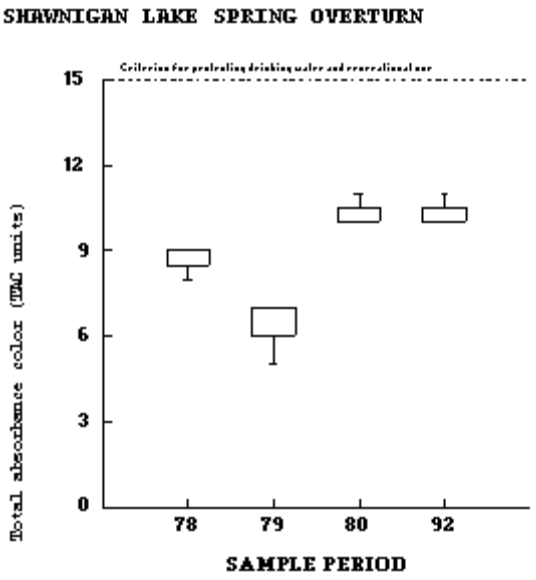


Figure 14 Total organic carbon from Shawnigan Lake

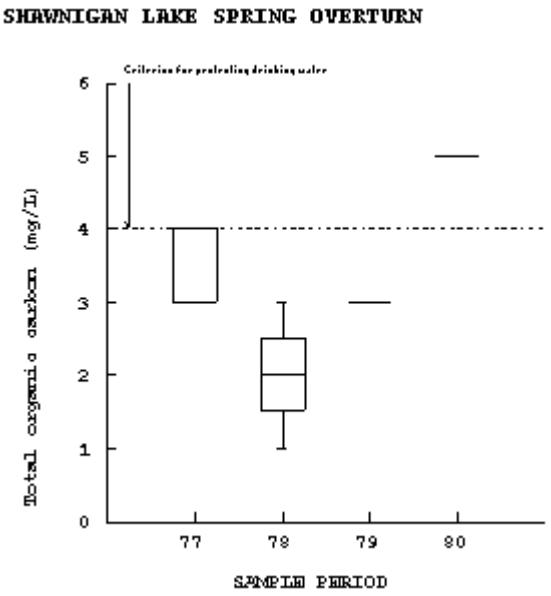


Figure 15 Total silica from Shawnigan Lake

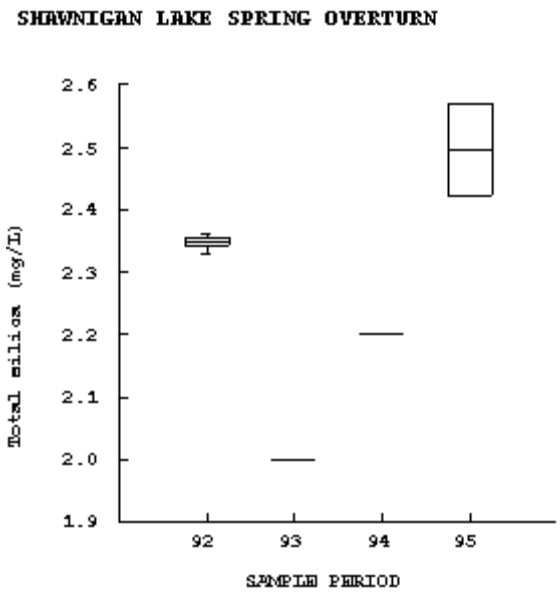


Figure 16 Dissolved chloride from Shawnigan Lake

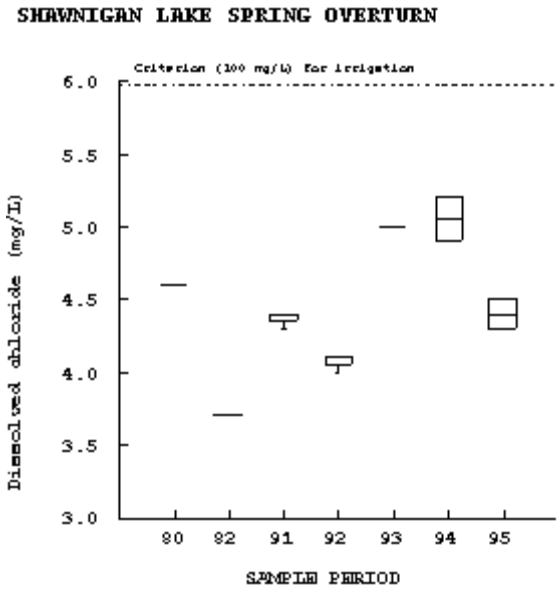


Figure 17 Specific conductivity from Shawnigan Lake

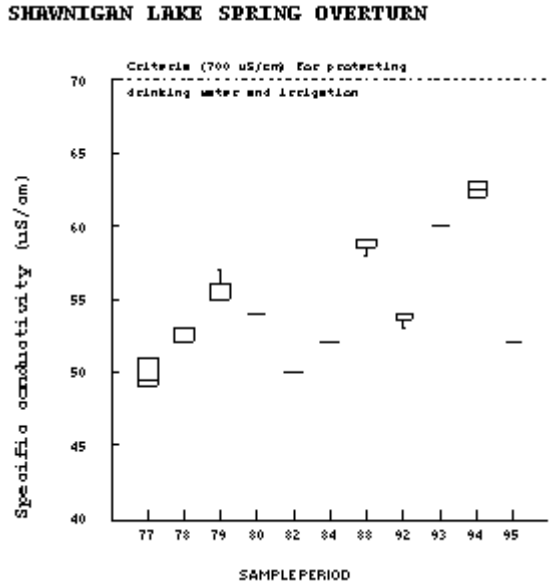


Figure 18 pH from Shawnigan Lake

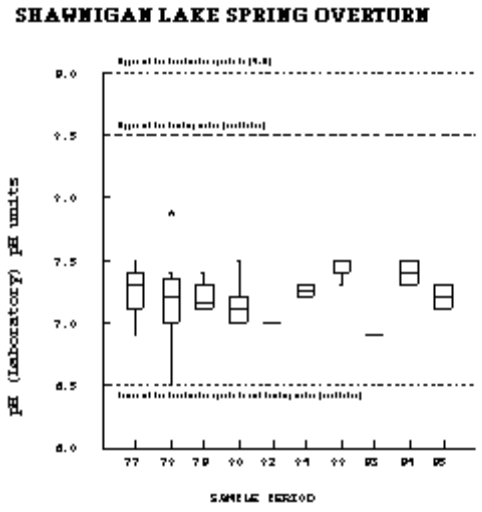


Table 1 Summary of water quality data from Shawnigan Lake (SEAM site 1199901)

Water Quality Indicator	Average	Std Dev	Number of samples	Maximum	Minimum
OBJECTIVE MONITORING	.	.	.	.	.
Total Phosphorus (mg/L)	0.006	0.0020	135	0.014	0.003
Turbidity (NTU)	0.69	0.331	28	1.6	0.2
Fecal coliform (MPN/100 mL)	2	1.31	21	8	2
SPRING OVERTURN MONITORING	.	.	.	.	.
Water Clarity and Colour	.	.	.	.	.
Colour, true (TCU)	6.0	2.11	10	10	5
Colour, total absorbance (TAC)	6.3	2.41	39	11	L 1
Residues, Non-filterable (mg/L)	2	0.94	21	4	1
Extinction depth (m)	6.02	0.84	15	7.47	4.54
General Ions	.	.	.	.	.
pH (pH units)	7.00	0.35	66	7.5	5.99
Residues, filterable (mg/L)	38.8	3.77	24	44	30
Residues, total (mg/L)	40.4	5.94	39	60	28
Specific conductivity (µS/cm)	49.4	6.54	88	63	35
Calcium, total (mg/L)	6.198	0.460	14	7.06	5.57
Chloride, dissolved (mg/L)	4.48	0.407	16	5.2	3.7
Magnesium, total (mg/L)	1.11	0.093	14	1.27	1
Silica, dissolved (mg/L)	5.0	0.35	23	5.7	4.6
Sulphate, dissolved (mg/L)	4.3	1.20	8	5	2.3
Temperature, water (° C)	8.4	3.91	306	16.5	0.75
Nutrients	.	.	.	.	.
Carbon, total organic (mg/L)	3.3	1.02	30	5	1
Carbon, total inorganic (mg/L)	3.68	1.33	19	6	2
Nitrogen, ammonia (mg/L)	0.011	0.0061	66	0.029	L 0.005
Nitrogen, Kjeldahl (mg/L)	0.16	0.06	86	0.4	0.04
Nitrogen, organic (mg/L)	0.16	0.070	51	0.39	L 0.02
Nitrogen, Nitrate+Nitrite (mg/L)	0.07	0.031	66	0.12	L 0.02
Nitrogen, Nitrate (mg/L)	0.05	0.030	24	0.13	L 0.02
Nitrogen, Nitrite (mg/L)	.	.	62	L 0.005	L 0.005
Phosphorus, ortho (mg/L)	0.003	0.0006	51	0.007	L 0.003
Phosphorus, total dissolved (mg/L)	0.004	0.0016	64	0.009	L 0.003
Oxygen, dissolved (mg/L)	9.26	2.77	299	13.5	L 1
Chlorophyll a (mg/L)	0.0025	0.0008	6	0.0035	0.0019
Metals	.	.	.	.	.
Aluminum, total (mg/L)	.	.	11	L 0.06	L 0.02
Antimony, total (mg/L)	.	.	9	L 0.02	L 0.015
Arsenic, total (mg/L)	.	.	11	L 0.25	L 0.04
Boron, total (mg/L)	.	.	9	L 0.04	0.008
Barium, total (mg/L)	0.005	0.001	9	0.007	0.004
Beryllium, total (mg/L)	.	.	9	L 0.002	L 0.001
Bismuth, total (mg/L)	.	.	9	L 0.02	L 0.02

Cadmium, total (mg/L)	.	.	14	L 0.01	L 0.0005
Cobalt, total (mg/L)	0.03	0.049	11	0.13	L 0.003
Chromium, total (mg/L)	.	.	11	L 0.01	L 0.002
Copper, total (mg/L)	.	.	14	L 0.01	L 0.001
Iron, total (mg/L)	0.06	0.033	11	0.15	L 0.02
Lead, total (mg/L)	.	.	14	L 0.1	L 0.001
Manganese, total (mg/L)	.	.	11	L 0.01	L 0.002
Molybdenum, total (mg/L)	.	.	11	L 0.01	0.004
Nickel, total (mg/L)	.	.	14	L 0.05	L 0.008
Selenium, total (mg/L)	.	.	9	L 0.03	L 0.03
Sodium, dissolved (mg/L)	2.9	0.19	12	3.3	2.7
Silicon, total (mg/L)	2.27	0.189	9	2.57	2
Silver, total (mg/L)	.	.	9	L 0.03	L 0.01
Strontium, total (mg/L)	0.024	0.0021	9	0.026	0.021
Tin, total (mg/L)	.	.	9	L 0.02	L 0.02
Zinc, total (mg/L)	0.010	0.0065	12	0.03	0.004

Note: L = less than

Table 2 Summary of Ministry of Health's Bacteriological data (fecal coliform/100 mL) from Shawnigan Lake

Year	Mason's Beach	West Shawnigan Lake Prov. Park	Shawnigan Lake Recreation Assoc.	Easter Seals Camp
1988	.	.	.	.
Max	93	1100	.	43
Min	< 1	< 3	.	< 3
Geo. Mean	24.13	26.61	.	19.48
Number	Number=10	Number=10	.	Number=10
1989	.	.	.	.
Max	55	35	5	< 5
Min	< 5	5	< 5	< 5
Geo. Mean	13.52	9.67	< 5	< 5
Number	Number=8	Number=4	Number=5	Number=3
1990	.	.	.	.
Max	60	.	.	.
Min	< 5	.	.	.
Median	16.23	.	.	.
Number	Number=8	.	.	.
1991	.	.	.	.
Max	40	60	1100	< 5
Min	< 5	< 5	< 5	< 5
Geo. Mean	13.85	13.39	38.51	< 5
Number	Number=11	Number=10	Number=8	Number=6
1992	.	.	.	.

Max	1150	35	< 5	< 5
Min	< 5	< 5	< 5	< 5
Geo. Mean	172.97	23.45	< 5	< 5
Number	Number=10	Number=6	Number=1	Number=5
1993	.	.	.	.
Max	40	170	4500	5
Min	< 5	< 5	< 5	< 5
Geo. Mean	8.39	30	24.34	5
Number	Number=11	Number=7	Number=12	Number=9
1994	.	.	.	.
Max	25	400	100	80
Min	< 5	< 5	< 5	< 5
Geo. Mean	9.83	30.55	13.05	10.32
Number	Number=11	Number=9	Number=9	Number=12
1995	.	.	.	.
Max	5	75	5	5
Min	< 5	< 5	< 5	< 5
Geo. Mean	.	.	.	.
Number	Number=2	Number=2	Number=2	Number=2

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