Shawnigan Lake Water Quality Assessment 1976 – 2004

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Executive Summary

Shawnigan Lake is the second largest lake on southern Vancouver Island. The lake provides a number of uses including drinking water, fisheries and recreation. Development within the watershed has increased steadily over the years and the population continues to grow as more people make Shawnigan Lake their permanent residence. Concern over the sustainability of the water resources of Shawnigan Lake at the local level prompted the Ministry of Water, Land and Air Protection (WLAP) in Nanaimo to make assessing the water quality a regional priority.

This study examined the physical, chemical and biological aspects of water quality in Shawnigan Lake from February 2003 to February 2004. Samples were collected from the lake basin, perimeter, inflows and the outflow. These results were compared to historical data collected by WLAP (formerly Environment, Lands and Parks) staff since the 1970's. Specific comparisons were made to the work of Nordin and McKean (1984), which proposed provisional water quality objectives for Shawnigan Lake, to determine if any trends in water quality were apparent.

Water temperature, stratification patterns and water clarity were consistent with previous reports. Dissolved oxygen concentrations were similar as well, however a greater period of oxygen supersaturation was noted in the two deep sites sampled.

Spring overturn phosphorus levels were below guideline levels (10 μg/L) as well as the proposed water quality objective (8 μg/L) over the period of record and showed a general decreasing trend since the mid-1980's. The spring overturn phosphorus concentration was very low in 2004 at 2 μg/L. There was no obvious reason for this decrease in phosphorus. Nitrogen and total organic carbon concentrations were also below guideline levels and showed no trend over the period of record. The nutrient results indicate that Shawnigan Lake continues to be oligotrophic, which is desirable from a recreational and drinking water supply water quality perspective.

The monitoring results of other water chemistry parameters showed that the water quality of Shawnigan Lake has been consistently good over the period of study, despite significant changes within the watershed. No parameters measured showed levels or trends which would cause concern for aquatic life and recreational water uses at this time. The surface microlayer was also sampled and again, the results indicated good water quality.

The results of the biological monitoring support this interpretation of the water chemistry data. Chlorophyll *a* concentrations have decreased over time suggesting a reduction in the primary productivity of the lake. The phytoplankton and zooplankton communities are typical of oligotrophic conditions; however, dominance by some blue-green algae species in the summer months of 2003 was noted. This appears to be the result of a decrease in nitrogen concentrations in the epilimnion rather than an increase in phosphorus concentrations.

The results for the microbiological indicators (*E. coli*, enterococci and fecal coliforms) showed values which exceeded drinking water guidelines at all sites sampled during the fall freshet period and on all inflows sampled during the summer low flow period. Only one lake site exceeded the drinking water guidelines during the summer low flow period. The recreational primary contact guidelines were met most of the time, but the enterococci guideline was exceeded at all the inflow sites during the summer low flow period. Overall, these results suggest a risk to drinking water quality and further monitoring should be considered.

Based on the results reported here, it is recommended that:

- Ministry of Water, Land and Air Protection (WLAP) staff should continue spring overturn sampling, including water chemistry at multiple depths and biological parameters (chlorophyll a, phytoplankton, zooplankton).
- WLAP staff should conduct additional bacteriological sampling in 2004 to confirm results noted in this study. Efforts should be concentrated to areas in the lake within 10 m from domestic intakes as well as McGee Creek and the Shawnigan Creek inflow. Samples should be collected a minimum of five times in a 30-day period.
- WLAP should review and formalize the water quality objectives for Shawnigan Lake proposed by Nordin and McKean (1984).
- Support should be provided to organized lake stewards to continue with basic water quality sampling through the BC Lake Stewardship Society. Other activities for lake stewards could include monitoring of aquatic macrophyte growth and distribution, and tracking sportfishing catches to monitor fish populations, especially bass and trout.
- The Cowichan Valley Regional District should ensure residential and commercial land development within the watershed take into account the potential impacts on the water quality of any such activities. Appropriate best management practices and planning techniques should be applied to protect Shawnigan Lake for domestic purposes and other current and future water uses.

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1 Introduction

Shawnigan Lake has long been a popular recreational destination on southern Vancouver Island. Since the early 1970's, the land-use has gradually changed from seasonal to permanent residential. The lake provides the primary source of domestic drinking water in this watershed and therefore protection of the water quality is a primary concern for residents, purveyors and resource managers.

A comprehensive water quality assessment for Shawnigan Lake was prepared by Nordin and McKean in 1984 and provides the baseline for this work. That assessment noted that the general water quality was good and recommended that controls be implemented to minimize sediment, phosphorus and bacteria inputs from land development and on-site sewage disposal systems. Based on concerns from residents around the lake, Regional Operations staff of the Ministry of Water, Land and Air Protection (WLAP) in Nanaimo made this waterbody a priority for the Vancouver Island region. The lake was sampled throughout 2003 and in the spring of 2004; these data were combined with historical data collected by WLAP to provide an overview of water quality from the late 1970's to 2004.

The objectives of the study were to determine if there have been any changes in the water quality in Shawnigan Lake and to promote long-term stewardship of Shawnigan Lake and its watershed. Chemical, biological and bacteriological parameters were measured at a number of sites within and around the lake and at key inflow and outflow locations. In addition, the surface microlayer was sampled to assess potential impacts from boating activities. The results are compared to draft provisional water quality objectives proposed by Nordin and McKean (1984) and the information generated will be provided to local government, local environmental stewards and the water purveyors.

2 Previous Reports

There have been several reports produced in the past with relevance to the water quality of Shawnigan Lake. Carl (1940) described aspects of the lake biota at that time providing a baseline for comparison to current conditions. Stonehouse (1969) examined water quality with respect to sewage disposal and coliform concentrations. The most extensive investigation was done by Nordin and McKean (1984) in response to concerns expressed by the Cowichan Valley Regional District about deteriorating water quality in the lake. They investigated all aspects of water quality in Shawnigan Lake and proposed water quality objectives to protect water uses and prevent eutrophication. Since that time, Holms (1996) conducted a review of all monitoring data collected by Ministry of Water, Land and Air Protection staff (formerly Environment, Land and Parks) and Webber (1996) investigated fecal coliform concentrations during August 1995. *Cryptosporidium* and *Giardia* concentrations and the effect of public access on drinking water supplies, including Shawnigan Lake, were reported by the Westland Resource Group in 2000.

Research projects at the University of Victoria dealing specifically with the water quality of Shawnigan Lake include Black *et al.* (1977) which looked at general water chemistry and coliforms, McKinnel (1978) which examined the deposition of diatoms in bottom sediments, and Lucey and Jackson (1983) which compared the limnology of an oligotrophic lake (Shawnigan) to the eutrophic Langford Lake. All this work was reported in Nordin and McKean (1984). Since that time, several aspects of the water quality and biology of Shawnigan Lake have been investigated by graduate students including Furey (2003), Nowlin (2003) and Davies (2004). The University of Victoria continues to be very active with respect to water quality research in Shawnigan Lake.

Wiens and Nagpal (1983) dealt extensively with the geology, soils and land use surrounding Shawnigan Lake in a report that complimented Nordin and McKean's work (1984).

A good overview of the fisheries aspect of Shawnigan Lake is provided in Best (2001) that concentrates on potential of Shawnigan Creek to support coho salmon. Gibson (1967) provided a historical narrative of Shawnigan Lake that included a review of settlement and human activities which may have influenced water quality.

3 Site Description

3.1 Watershed Description and Hydrology

Shawnigan Lake is located on southern Vancouver Island in the Shawnigan Community Watershed with a watershed size of approximately 69 km^2 (Figure 1). The Shawnigan Community Watershed is larger at 110 km^2 and includes the land draining to Shawnigan Creek below the lake outlet to Mill Bay. The watershed has a maximum elevation of 610 m GSC (Geodetic Survey of Canada) and a minimum elevation of approximately 116 m GSC at the lake level (Bryden and Barr, 2002).

Shawnigan Lake empties from south to north. There are three main inflows to the lake: Shawnigan Creek at the south end of the lake, McGee Creek on the west shore and the West Arm inflow in the northwest corner of the lake. Shawnigan Lake has a relatively short water residence time of just under one year (Nordin and McKean, 1984).

Water levels are controlled on Shawnigan Lake by a dam (consisting of flashboards and stop logs) on Shawnigan Creek located 450 m downstream from the lake outlet. In 1983, there was general agreement that the lake level should be maintained at elevations between 116.3 m GSC and 115.75 GSC between March 15 and October 1 to provide storage and prevent flooding (Bryden and Barr, 2002).

3.2 Lake Morphometry

Shawnigan Lake is a medium-sized lake with a surface area of 537 ha, a volume of over 64 Mm^3, a mean depth of 12 m and a maximum depth of 52 m. It is approximately 7.2 km long and 1.4 km across at its widest point. The narrowest point is approximately 150 m wide in the West Arm; this part of the lake is quite distinct in that it is a long, narrow, shallow arm isolated from the main body of the lake. The lake has one main deep basin in the northern half of the lake and several smaller basins to 28 m in the southern half. A bathymetric map of Shawnigan Lake is provided in Appendix 1.

3.3 Sampling Sites

The sites used in this assessment are listed in Table 1 and illustrated in Figure 1.

Table 1: Shawnigan Lake water quality sampling sites.

Site Location	Site No.	EMS No.	Site Description
Lake	1	1199901	Deepest point of main (north) basin, approximate depth is 45 m
Lake	2	1199902	Deepest point in south basin midway between Memory Island and the west shore of the lake, approximate depth is 20 m
Lake	3	1199903	West Arm, halfway up the arm and mid-channel, approximate depth is 9 m
Lake	4	1199904	North end of the lake near Mason's Beach, approximate depth is 15 m
Inflow	5	1199906	Shawnigan Creek inflow at south end of lake
Inflow	6	1199909	McGee Creek inflow on west side of lake
Inflow	7	1199911	West Arm inflow
Inflow	8	1199916	Shawnigan Lake inflow at East Shawnigan Road
Outflow	9	1199912	Shawnigan Creek outflow at north end of lake
Perimeter	10	E222045	Galley Restaurant, marina dock on east side of lake
Perimeter	11	E222048	Easter Seal Camp beach, camp float on east side of lake
Perimeter	12	E222055	West Shawnigan Lake Park, beach on west side of lake
Perimeter	13	E246900	Shawnigan Lake Resort, resort dock on northwest end of lake

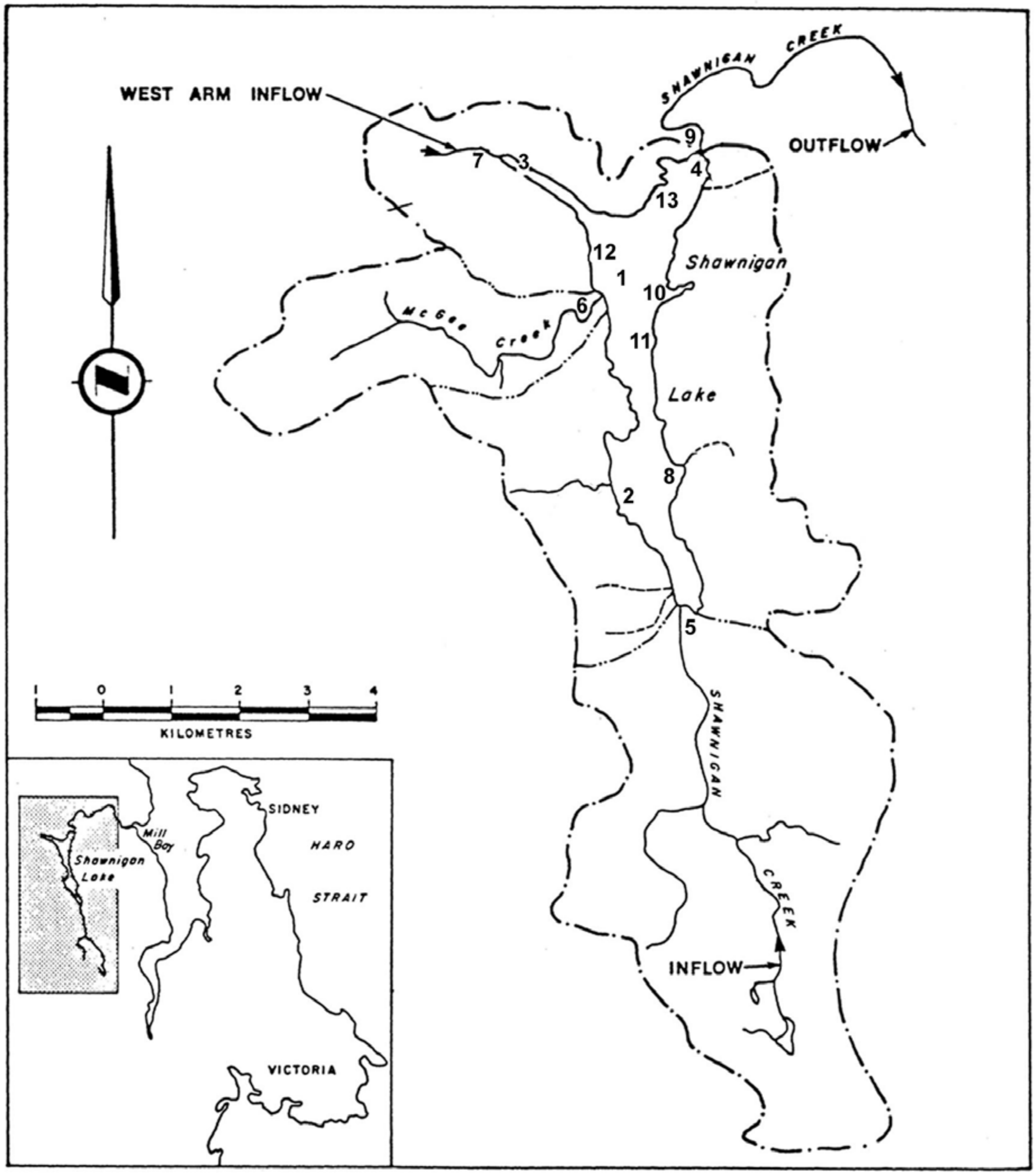

Figure 1: Location of Shawnigan Lake with watershed boundaries (adapted from Nordin and McKean, 1984). Sites are identified with site numbers corresponding to the EMS numbers and descriptions provided in Table 1.

4 Water Uses

4.1 Recreational

Shawnigan Lake provides a number of recreational opportunities including swimming, water skiing, boating, and fishing. Although the majority of the residences are now occupied year round, there are number of campgrounds and resorts that receive the heaviest use in the summer months.

4.2 Fisheries

Shawnigan Lake provides a good recreational fishery that has been supported by rainbow (*Onchorhynchus mykiss*) and cutthroat trout (*O. clarki*) stockings since 1903. In 2004, Shawnigan Lake was stocked with 7,500 rainbows and 15,000 cutthroat. There is also a native population of kokanee salmon (*O. nerka*) present in Shawnigan Lake.

Shawnigan Lake has also received several unauthorized introductions of non-native species including brown bullhead (*Ictalurus nebulosus*), pumpkinseed sunfish (*Lepomis gibbosus*), yellow perch (*Perca flavescens*) and smallmouth bass (*Micropteus dolomieui*). Although these species provide anglers with additional opportunities, there is concern of the impact these introductions have had on populations of juvenile salmonids and non-fish species like crayfish (Best, 2001).

4.3 Domestic

There are three major waterbodies licensed for water withdrawal in the Shawnigan Lake watershed: Shawnigan Lake, Shawnigan Creek and McGee Creek. In total, these areas have 225 active water withdrawal licenses that are permitted to extract over 7,000 m^3/day (Table 2) (Land and Water BC, 2001). In addition, there is approximately 5,500 m^3/day of water licensed for storage in Shawnigan Lake.

Table 2: Total licenced water withdrawals and storage volumes for Shawnigan Lake.

Site	Number of Licenses	Quantity of Withdrawal (m^3/day)	Quantity of Storage (m^3/day)
McGee	2	38	
Shawnigan Creek	26	1,354	2,002
Shawnigan Lake	197	5,646	3,489
Sum	225	7,038	5,491

The largest withdrawals for Shawnigan Lake are located near the northeastern portion of the lake, servicing the Village and Shawnigan Lake Estates (Table 3). These are treated water supplies with chlorine disinfection. They account for about 3.5% of all licences for Shawnigan Lake and approximately 38% of all water withdrawn from the lake itself.

The number of licenses issued for the Shawnigan Lake watershed increased steadily during the 1940's to 1970's (Table 4). Since the 1970's, this trend has decreased considerably.

There are also withdrawals from Shawnigan Creek downstream of the lake, including the Mill Bay Waterworks District, and changes in water quality in Shawnigan Lake could potentially impact these users.

Table 3: Major water purveyors licenced to withdraw water from Shawnigan Lake.

Licensee	Licence No.	Quantity
Cowichan Valley Regional District	C057107	209,115 m^3/year
Lidstech Holdings Ltd.	C116151	165,932 m^3/year
Cowichan Valley Regional District	C106569	141,884 m^3/year
Shawnigan Lake School	C117969	273 m^3/day
Cowichan Valley Regional District	C040373	61,395 m^3/year
Lidstech Holdings Ltd.	C045744	58,076 m^3/year
Cowichan Valley Regional District	C041661	53,928 m^3/year

Table 4: Licensed water withdrawals, by decade, for Shawnigan Lake.

	Decade						
	1940	1950	1960	1970	1980	1990	2000
Cumulative number of licenses	5	24	40	142	184	216	225
Cumulative total quanitity (m^3/day)	61	210	3,886	6,003	6,104	6,177	7,038

4.4 Ground Water

Groundwater is a valuable drinking water resource in Shawnigan Lake and there are eight aquifers located within the watershed (Table 5). The aquifers are classified to provide information of their level of development, vulnerability to contaminants and water quality, but do not consider the existing type of land use, nature of potential contaminants or other risks (Bernardinucci and Ronneseth, 2002). Vulnerability is defined as the potential for an aquifer to be degraded by contaminants, based on the aquifer's hydrogeological characteristics.

Two aquifers within the Shawnigan Lake watershed, one immediately surrounding Shawnigan Lake and one in Mill Bay, have a classification of II A indicating moderate development and high vulnerability. Aquifers with this classification usually require particular care and attention regarding land use activities that could affect water quality (Bernardinucci and Ronneseth, 2002).

The remaining six aquifers are classified II B (moderate development, moderate aquifer vulnerability) or II C (moderate development, low aquifer vulnerability). All may be able to support additional withdrawals; however, until site specific studies are undertaken, aquifers with either classification require care and attention for development activities that could affect water quality of quantity (Bernardinucci and Ronneseth, 2002).

The number of wells constructed in the Shawnigan Lake watershed has risen dramatically since 1970 to accommodate population growth; currently there are approximately 860 wells within the watershed. The bulk of the wells constructed are in the north-east quadrant of the watershed, where the village area is located. The number of new wells constructed will likely continue to rise since there are no immediate plans to implement central water and sewer services in these areas.

Table 5: Aquifers and their classifications within the Shawnigan Lake watershed.

Aquifer Number	Descriptive Location	Classification	Size (km2)	Productivity	Vulnerability	Domestic Well Density (wells/km2)	Use
197	Cobble Hill, Cowichan Bay	IIC	39	Moderate	Low	16.6	Multiple
201	Cobble Hill	IIC	1.7	Moderatel to high	Low	8.2	Domestic
202	Shawnigan Lake, Cowichan Bay	IIB	20	Low	Moderate	5.5	Multiple
203	Shawnigan Lake, Cobble Hill	IIA	30.5	Low	High	8	Multiple
204	Cobble Hill, Mill Bay	IIB	16.2	Moderate	Moderate	16.6	Multiple
205	Shawnigan Lake, Cobble Hill	IIC	2.6	Moderate	Low	17.7	Multiple
206	Mill Bay	IIA	2.7	Moderate	High	11	Multiple
207	Shawnigan Lake, Mill Bay	IIB	27	Low to moderate	Moderate	7.3	Multiple

5 Land Use

Shawnigan Lake is located within the Cowichan Valley Regional District (CVRD) Electoral Area B. Shawnigan Lake's current population is over 7,000 people (BC Statistics, 2003) and has experienced considerable growth over the past 15 years. From 1986 to 2001, the population of Shawnigan Lake increased by 190%, compared to 136% for the rest of BC during this time (Statistics Canada, 2004). The majority of development has been concentrated around the north end of the lake around the Shawnigan Lake Village and Shawnigan Lake Estates communities.

Forestry is the dominant land use in this watershed with urban development and agriculture using the majority of the remaining land base. Approximately 9.5% of the land base is under the Agricultural Land Reserve (ALR).

Historically, Shawnigan Lake was a rural community with predominately seasonal residences but its close proximity to Victoria makes it ideal for commuting workers and permanent residences have become more prevalent. At one time, Shawnigan Lake was considered to be the most reliable source of water for future development (CVRD, 1976). However, as of 1979, it was determined that any further water withdrawals, except for individual residential water use, would require storage (Bryden and Barr, 2002). This has created an increasing reliance on groundwater as a domestic water source.

The majority of Shawnigan Lake waterfront is developed and zoned as either Suburban Residential or Urban Residential. The only waterfront area that is not zoned this way is approximately one kilometre of the Lake's most southern shoreline, which is included in the ALR. As of 1996, there were approximately 616 subdivision lots bordering directly on Shawnigan Lake with a further 2,000+ lots bordering these, but not directly adjacent to the lake. A "flood construction level" was established at 119.2 m GSC (Bryden and Barr, 2002).

Within the Shawnigan Lake watershed there are five waste management discharge permits for point discharges to ground, all of which are adequately set back from the lake based on distance of the discharges to the lake (400 m – 4,100 m). The total maximum discharge volume from these permits is approximately 800 m^3/d.

There are also numerous smaller residential septic and onsite disposal systems which are regulated by the Ministry of Health (discharges less than 22.7 m^3/d). Septic systems are the dominant means of disposing of domestic effluent in the Shawnigan Lake watershed and are effective at treating household sewage if designed properly and maintained regularly. In typical onsite sewage systems, the wastewaters from toilets and other drains flow from the home to a tank where the solids and liquids are separated. Bacteria in the tank help break down the solids into sludge and the liquid flows from the tank to a network of pipes in the drainfield. From here, the liquid is released to the ground where naturally occurring bacteria cleanse the wastewater. If the system is improperly located, constructed, serviced or maintained, it can fail, discharging untreated wastewater to nearby waterbodies. This can impact the suitability of the water for drinking, recreational activities and aquatic life.

The CVRD Stage Three South Sector Liquid Waste Management Plan has outlined an initiative to sewer the densest areas of Shawnigan Lake. Shawnigan Lake Beach Estates, near the Village is the only area serviced by a centralized sewage collection system. Presently, there are approximately 275 sewer connections in this area which receive secondary wastewater treatment and in-ground disposal by the CVRD.

6 Results and Interpretation

The Ministry of Water, Land and Air Protection uses water quality guidelines and site-specific objectives to protect water quality in British Columbia. Guidelines apply to all waterbodies unless site-specific objectives have been developed through a process which includes a detailed assessment of the waterbody and its watershed. The most sensitive uses of the waterbody will be protected if the guidelines or objectives are met. Water quality objectives were proposed for Shawnigan Lake (Nordin and McKean, 1984) but never formally adopted by the Ministry. These included:

- Total phosphorus: 8 μg/L at spring overturn;
- Turbidity: 5 NTU (maximum) and 1 NTU (average of at least 10 samples);
- Suspended solids: 25 mg/L (maximum from any inflow stream grab sample);
- Fecal coliform bacteria: 10 MPN/100 mL (90^{th} percentile in any 30-day period within 10 m of a domestic intake).

This section presents and interprets the results of water quality sampling in Shawnigan Lake from 1976 to the present and compares these to the general guidelines and site-specific objectives proposed by Nordin and McKean in 1984.

6.1 Limnological Characteristics

6.1.1 Lake Temperature Stratification

Water temperature was measured at each lake site throughout the sampling period and time/depth temperature profiles for each site are illustrated in Figures 2 through 5. The water temperature ranged from a minimum of 4°C - 6°C in the winter months to a maximum surface water temperature of 20°C - 22°C in July and August for all sites. The north basin (1199901) and the south basin (1199902) showed similar patterns of thermal stratification with a strong thermocline forming by June. Deterioration of the thermocline and vertical mixing for both sites took place in mid-November which is consistent with earlier assessments (Nordin and McKean, 1984). The water in the north basin was warmer than the south basin and corresponding isotherms were generally deeper at 1199901.

The west arm (1199903) was interesting in that it did not show a strong pattern of stratification and vertical mixing of the water column occurred relatively early compared to the other sites. This is likely related to the morphometry of the west arm; it is a long, slender and relatively shallow body of water and may be easily mixed by the increased inflow at the head of the arm, which increases with the fall freshet.

The north beach site (1199904) showed an earlier pattern of stratification and breakdown of the thermocline. This is likely due to the location of the sampling site in shallower waters which are more easily cooled and mixed in the fall.

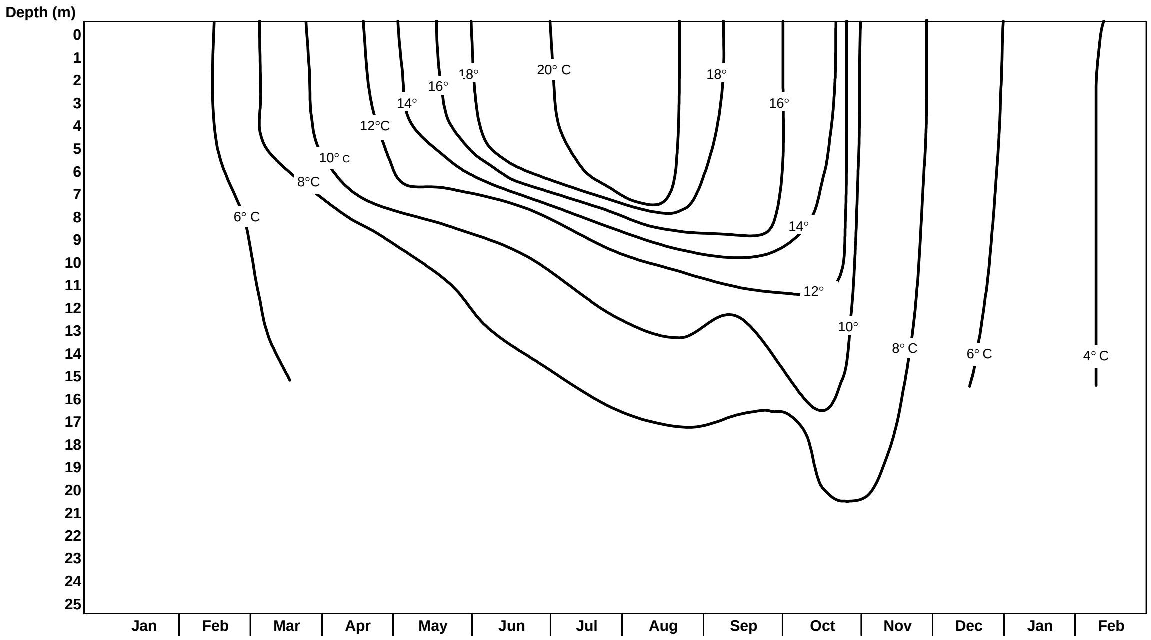

Figure 2: Time/depth temperature profile for Shawnigan Lake north basin site (1199901), February 2003 – February 2004.

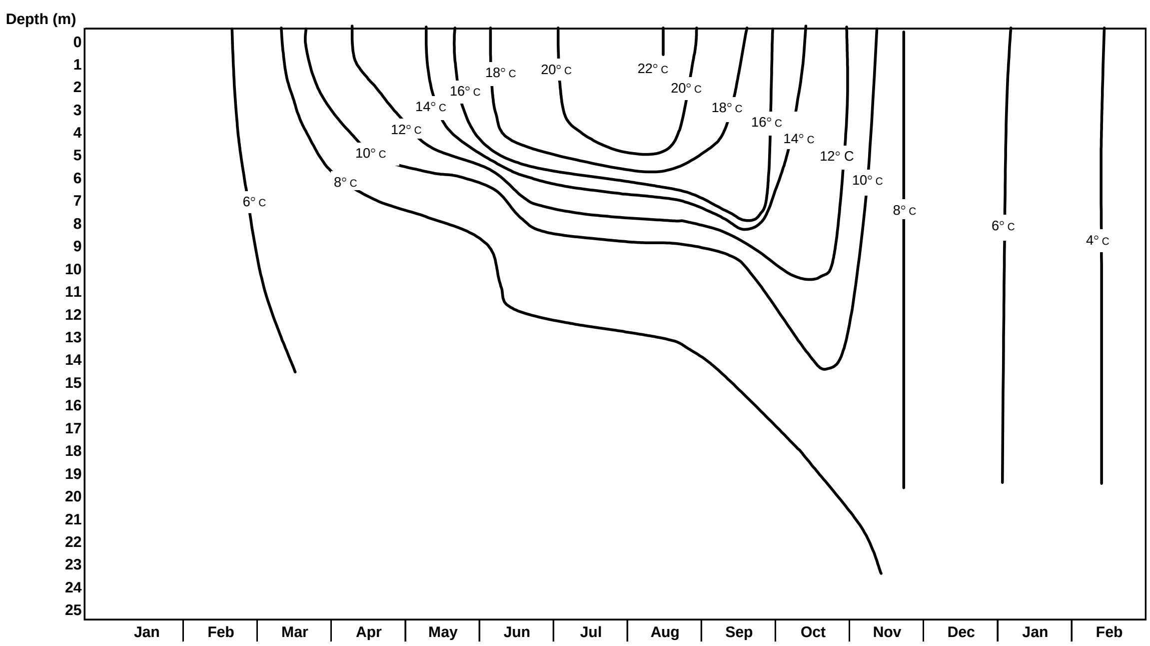

Figure 3: Time/depth temperature profile for Shawnigan Lake south basin site (1199902), February 2003 – February 2004.

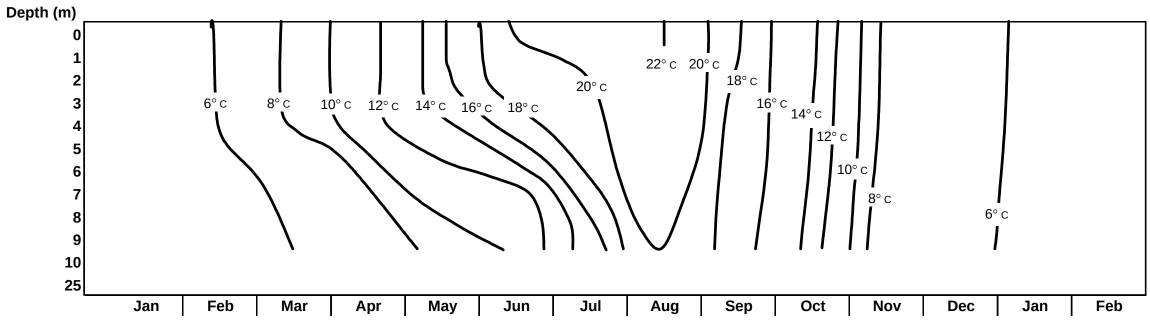

Figure 4: Time/depth temperature profile for Shawnigan Lake west arm site (1199903), February 2003 – February 2004.

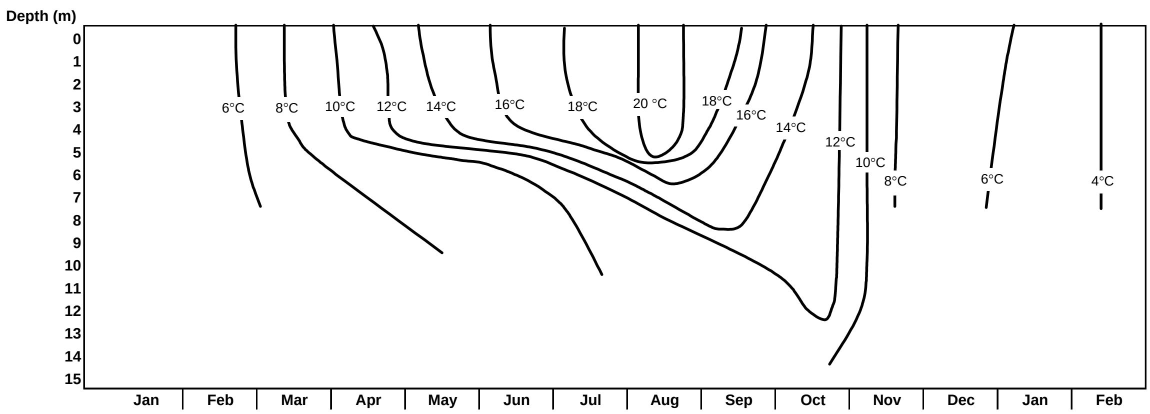

Figure 5: Time/depth temperature profile for Shawnigan Lake north beach site (1199904), February 2003 – February 2004.

6.1.2 Dissolved Oxygen

Dissolved oxygen (DO) concentrations were measured throughout the water column at each lake site on each sampling date. Percent DO saturation was calculated and time/depth DO profiles were drawn for each site (Figures 6 to 9).

The north basin (1199901) site showed a similar pattern of DO saturation to those reported by Nordin and McKean (1984) from 1977 and 1978. The 2003 data did show a more extensive period of DO supersaturation (>100%) in the epilimnion and higher DO concentrations in the hypolimnion.

The south basin (1199902) also showed a similar pattern to that previously reported (Nordin and McKean, 1984) with greater DO levels in both the epilimnion and the hypolimnion. The 2003 results showed a much greater hypolimnetic oxygen depression in the south basin, compared to the north basin, as was previously reported. Nordin and McKean (1984) attributed this difference between the two main basins to the relatively small hypolimnion of the south basin and to the morphometry of the main basin.

The DO profiles for the west arm (1199903) and north beach site (1199904) showed fairly well oxygenated waters throughout the year.

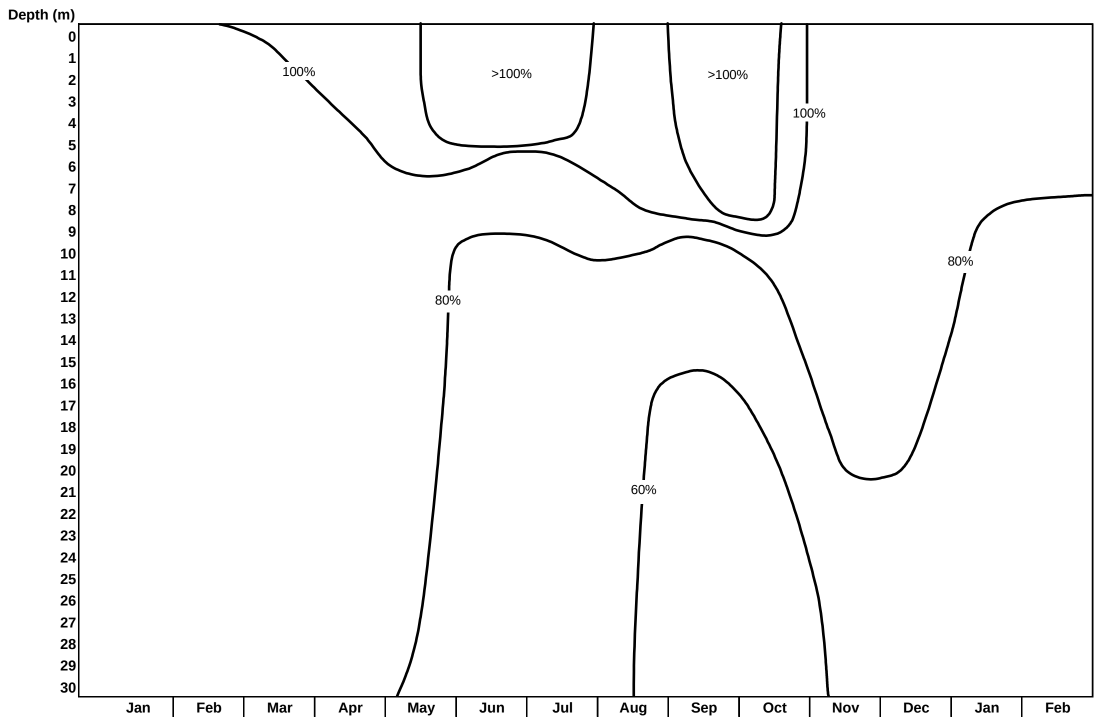

Figure 6: Time/depth dissolved oxygen profile for Shawnigan Lake north basin site (1199901), February 2003 – February 2004.

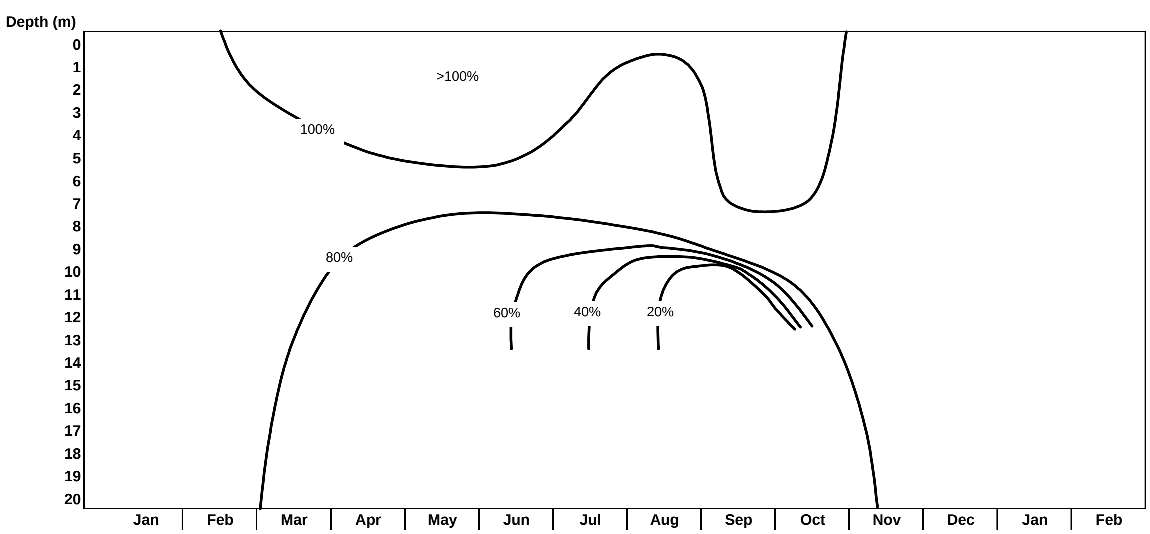

Figure 7: Time/depth dissolved oxygen profile for Shawnigan Lake south basin site (1199902), February 2003 – February 2004.

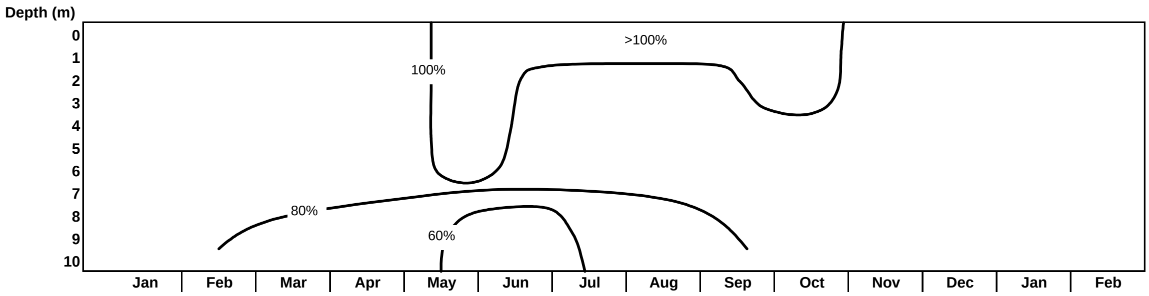

Figure 8: Time/depth dissolved oxygen profile for Shawnigan Lake west arm site (1199903), February 2003 – February 2004.

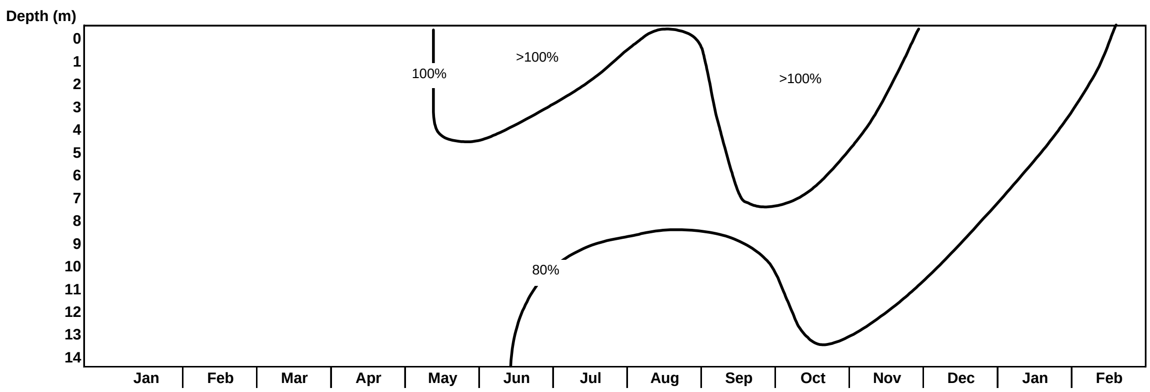

Figure 9: Time/depth dissolved oxygen profile for Shawnigan Lake north beach site (1199904), February 2003 – February 2004.

The water quality guideline for dissolved oxygen in the water column is 5 mg/L (instantaneous minimum). This guideline was met throughout the water column at all lake sites in 2003 except 1199902. At the south basin site, the DO guideline was met throughout the water column up until June. A DO profile was not taken in July and in August the guideline was not met at 15 m (2.7 mg/L). In September, the guideline was not met at nine metres (4.8 mg/L) and in October it was not met at 14 m (2.9 mg/L). In November, the guideline was again met throughout the water column at 1199902 indicating that vertical mixing of the water column had begun to take place. It is not uncommon to have depressed hypolimnetic DO levels in lakes and the fact that Shawnigan Lake meets the guideline level throughout the water column most of the time indicates the lake has a well oxygenated hypolimnion.

6.1.3 Water Clarity

Water clarity was measured using a standard 20 cm Secchi disc, lowered in the water column until it was no longer visible from the surface. This is a standard, yet simple, measure of water clarity or transparency and can be used to indicate changes in water quality, as transparency decreases with increasing colour, suspended sediments or algal abundance.

The average Secchi depths for the four Shawnigan Lake basin sites are listed in Table 6. Overall, the average was approximately 6 m which is consistent with what was reported by Nordin and McKean (1984) (6.2 m at 1199901 and 5.8 m at 1199902).

Table 6: Mean Secchi depths (metres) for Shawnigan Lake basin sites.

Site	1199901			1199902			1199903			1199904		
Year	Mean	std. dev	n	Mean	std. dev	n	Mean	std. dev	n	Mean	std. dev	n
1976-1979	6.1	1.0	26	5.8	1.15	23						
1980-1987	5.4	2.6	5	7.0		1						
1994	6.0		1									
2003-2004	5.7	2.1	8	6.1	2.2	7	6.0	1.0	8	6.7	1.3	6

Secchi depth readings over time for the north and south basins are illustrated in Figures 10 and 11, respectively. These diagrams show that, although there is some seasonal variance, the overall water clarity has remained fairly consistent since 1976. Some of the highest transparencies measured over the period of record were in the summer of 2003 at both the north and south basins.

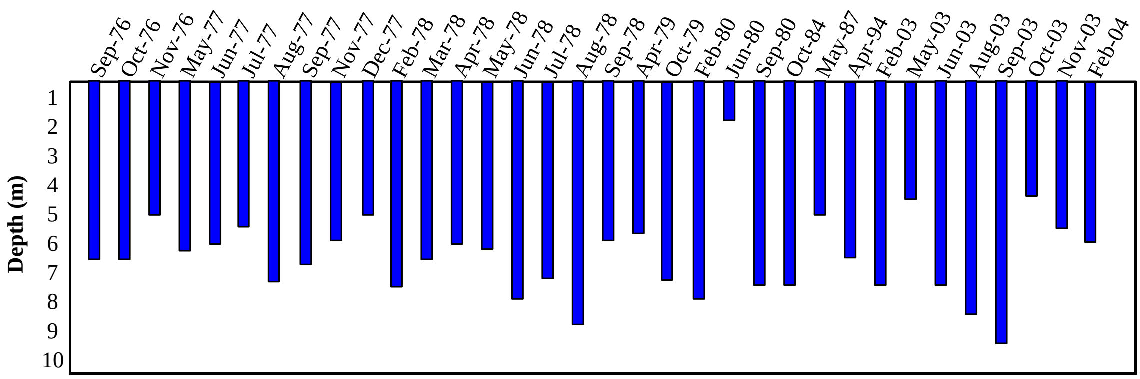

Figure 10: Secchi depths for the Shawnigan Lake north basin (1199901), September 1976 to February 2004.

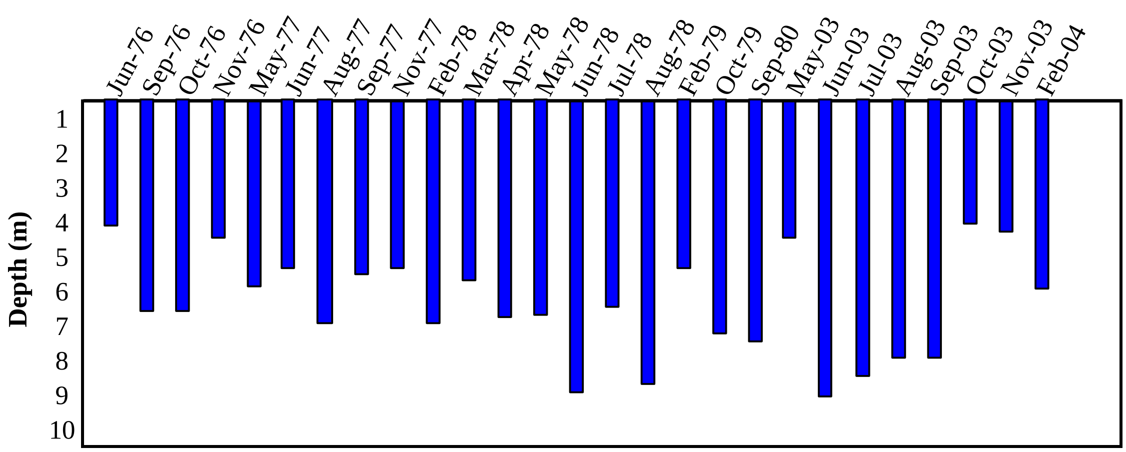

Figure 11: Secchi depths for the Shawnigan Lake south basin (1199902), September 1976 to February 2004.

6.1.4 Interpretation

Water temperature, thermal stratification patterns and water clarity were similar with previous reports (Nordin and McKean, 1984). The deepest Secchi depth measurements were generally seen during summer months and may have partially resulted from brighter, sunnier conditions when the disc would have been more visible in the water. Dissolved oxygen concentrations appear to be higher than those previously reported with greater periods of epilimnetic oxygen supersaturation in the summer months and greater hypolimnetic oxygen concentrations. Nordin and McKean (1984) reported an oxygen depletion rate of 276 mg/m^2/d for the years 1976-1980 suggesting mesotrophic conditions. They indicated that the high oxygen deficit seen in Shawnigan Lake was likely due to the long-term decomposition of wood waste material in the lake. We were unable to calculate oxygen depletion rates because of incomplete oxygen profiles for the entire water column; however, a comparison of the time/depth DO profiles with those from Nordin and McKean's work suggests that the oxygen depletion rate may not be as extreme as previously measured. This observation is supported by a decrease in chlorophyll *a* concentrations (Section 6.4.2.2), which would result in a lower oxygen demand in bottom waters from decomposing organic material.

6.2 Water Chemistry

6.2.1 Methods

Water chemistry was sampled at four lake basin sites, four lake perimeter sites, four inflow sites and one outflow site (Figure 1 and Table 1). All samples were collected according to ministry approved sampling procedures.

Samples were collected from the basin sites in February 2003 (while the water column was mixed), and then monthly from May to November 2003. The final sampling took place in February 2004 to collect data while the water column was well mixed.

Field measurements were taken using a Hydrolab Surveyor 4 at one metre intervals up to 15 m, and at five metre intervals beyond that. The parameters measured included temperature, dissolved oxygen, pH, specific conductance and oxidation-reduction potential. Results were entered into the Ministry of Water, Land and Air Protection's Environmental Monitoring System (EMS) database. Grab samples were taken throughout at three depths in the water column (surface, 5 m and 20 m) for the deep stations (1199901 and 1199902) and at the surface and bottom of the water column for the other basin sites (1199903 and 1199904). Water column samples were collected using a Van Dorn bottle and analyzed for the following parameters:

- Physical: pH, colour true, turbidity, hardness
- General inorganics: alkalinity
- Nitrogen: total Kjeldahl N, total N, total organic N, ammonia N, nitrate + nitrite
- Phosphorus: ortho-P, total P

Total and dissolved metals were also analyzed once at the beginning of the monitoring program for each lake basin site.

The lake perimeter, inflow and outflow sites were sampled four times over the period of study: February, May, August and November, 2003. Surface grab samples were analyzed for the following parameters:

- Physical: pH, colour true, specific conductance, turbidity
- Carbon: total inorganic carbon, total organic carbon
- Nitrogen: total Kjeldahl N, total N, total organic N, ammonia N, nitrate + nitrite
- Phosphorus: total P

Total metals were also analyzed once in the period of study for each perimeter, inflow and outflow site.

6.2.2 Water Chemistry Results

6.2.2.1 Lake basin sites

The results of all water chemistry monitoring are summarized in Appendix 2. The data are organized by decade to illustrate any changes in water quality over time. The north basin site (1199901) had the most data over the period of record and provides the best representation of water quality in Shawnigan Lake.

General Parmeters

All general parameters showed low levels and no significant trends were identified over the period of record. The water quality can be described as neutral (mean pH = 7.1 – 7.2) and clear for all sites with low dissolved solids (mean specific conductivity = 46 μS/cm – 63 μS/cm) and turbidity values well below the guidelines for the protection of aquatic life (5 NTU). Current average values for alkalinity ranged between 15.3 mg/L (1199902) and 19.6 mg/L (1199903) indicating a moderate sensitivity to acidic inputs.

Nutrients

Phosphorus

Total phosphorus (TP) results were summarized temporally and spatially and are presented in Table 7. Site 1199901 has the most extensive data set and provides the best indication of water quality. Overall, average total phosphorus levels are low for this site and present values ($\bar{x}$ = 6 μg/L) are not noticeably different from the 1970's data. The 2004 spring overturn results for 1199901 showed a very low average TP concentration of about 2 μg/L.

Table 7: Average total phosphorus concentrations (μg/L) for Shawnigan Lake basin sites.

Site	1976-79			1980-89			1990-99			2000-present		
	Mean	Std. Dev.	n	Mean	Std. Dev.	n	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =
1199901	6	2	81	7	2	39	4	1	20	6	3	89
1199902	6	2	67	9	3	7				7	4	45
1199903	5	2	24							5	5	16
1199904	5	2	14							4	2	17

Total phosphorus results for the south basin (1199902) showed a higher average value for results collected in 1980 – 1989 ($\bar{x}$ = 9 μg/L). This higher result is due to a smaller sample size with the majority of samples taken during periods of water column stratification when higher concentrations are more prevalent deeper in the water column due to internal loading processes and reduced flushing. The spring overturn total P concentration for 1199902 in 2004 was low at 3.5 μg/L.

Average TP concentrations were low for the other two lake sites and have not changed significantly since the 1970's. The West Arm site (1199903) had an average concentration of 5 μg/L in the 1970's and 5 μg/L in 2000 – present. The spring overturn average TP concentration in 2004 was 3.5 μg/L. The north end site (1199904) had an average concentration of 5 μg/L in the 1970's and 4 μg/L in 2000 – present. The spring overturn average TP concentration in 2003 was also 3.5 μg/L.

Average total phosphorus concentrations at the north basin were calculated for all spring overturn data and these results are illustrated in Figure 12. Spring overturn phosphorus concentrations correlate with summer algal biomass and water clarity, and therefore provide a good indicator of nutrient status of the lake. Spring overturn phosphorus values for coastal lakes should be obtained in February before the biological uptake of P begins (Nordin and McKean, 1984). The proposed objective value for TP at overturn (8 μg/L) has been exceeded only once in the past 28 years (9 μg/L in 1980). In 1979, 1984 and 2001 the spring overturn concentrations equalled the objective level; for all other years the overturn TP concentration was low with most values being less than 6 μg/L.

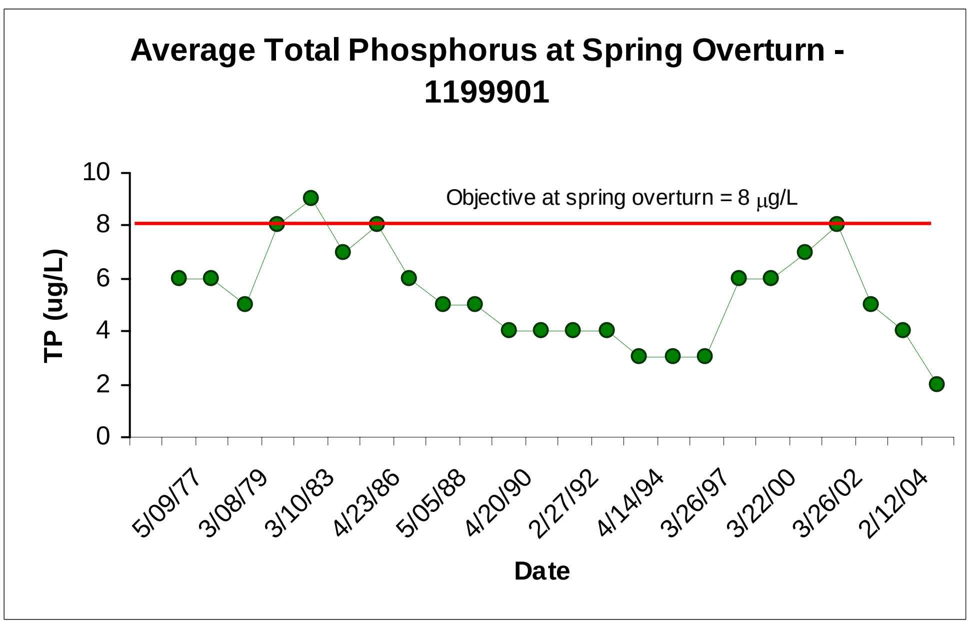

Figure 12: Average spring overturn total phosphorus concentrations for the Shawnigan Lake deep station (1199901), 1976 – 2004.

Average total dissolved phosphorus and average dissolved ortho-phosphate values (a measure of the biologically available form of P) were also low for all lake sites (Appendix 2).

Nitrogen
The forms of nitrogen monitored in the lake sites include total nitrogen (TN), ammonia (dissolved) and nitrate + nitrite (dissolved). Kjeldahl nitrogen (total), total organic nitrogen and total nitrate were not consistently measured and are not discussed here. All data are summarized in Appendix 2.

The deep station (1199901) provided the most complete data set, while there were less data from the south basin (1199902) and minimal results available from the West Arm (1199903) and the north end site (1199904).

Nitrogen levels were low in all forms at all sites throughout the period covered. At 1199901, average TN values increased from the 1970's (182 μg/L) to the 1980's (240 μg/L) but have decreased since that time to 212 μg/L in (2000 – present). A similar pattern was seen in the 1199902 data. The West Arm and north end sites showed increases from 182 μg/L and 165 μg/L to 260 μg/L and 220 μg/L, respectively.

The average ammonia concentrations showed overall decreases for all sites, while nitrite + nitrate concentrations have shown overall increases since the 1970's.

Although the measured values are low, changes in average concentrations were noted over time for all forms of N. To determine if these represented a significant change over time, the data were plotted and fitted with least-squares regression lines. These results are listed in Table 8 and showed no significant trends of parameter concentration over time.

Table 8: Results of least squares regression on nitrogen parameters versus time on Shawnigan Lake.

	Total Nitrogen		Ammonia		Nitrate + Nitrite	
	R^2	Slope	R^2	Slope	R^2	Slope
1199901	0.0919	+	0.3036	-	0.3479	+
1199902	0.0371	+	0.0466	-	0.3625	+
1199903	0.1693	+	0.0007	0	0.1537	+
1199904	0.1509	+	0.1351	-	0.0414	+

Nitrogen:Phosphorus Ratio
Nitrogen:phosphorus (N:P) ratios are useful indicators of a lake's trophic status and whether primary production is limited by phosphorus or nitrogen concentrations. Algae normally require a N:P ratio of 5-10:1, by mass (Nording and McKean, 1984). Values above this range indicate a phosphorus-limited system while values below indicate a nitrogen-limited system. Most lakes, including Shawnigan, are P-limited and N:P ratios tend to decrease with increasing eutrophication, which is often the result of increasing anthropogenic P inputs. Therefore, decreasing N:P ratios would indicate deteriorating water quality.

Nitrogen:phosphorus ratios were calculated by dividing the average spring overturn total N concentration by the average spring overturn total P concentration. Where total N data were not available, it was calculated by summing the Kjeldahl nitrogen and nitrate + nitrite values. The N:P ratios over time for 1199901 are illustrated in Figure 13. The N:P ratio for this site has increased over the period of study, from 26:1 in 1976 to 120:1 in 2004. This corresponds with a low in total phosphorus concentrations at spring overturn of 2 μg/L, as illustrated in Figure 13.

N:P ratios were also calculated by site using the average values by decade and these are listed in Table 9. These are all comparable to the N:P ratio reported by Nordin and McKean (1984) of 35:1 which was based on all of the lake data available at that time.

Table 9: N:P ratios by site for Shawnigan Lake.

Year	1199901 N:P	1199902 N:P	1199903 N:P	1199904 N:P
1976 – 1979	30:1	34:1	36:1	33:1
1980 – 1989	34:1	26:1		
1990 – 1999	58:1			
2000 - present	35:1	32:1	52:1	55:1

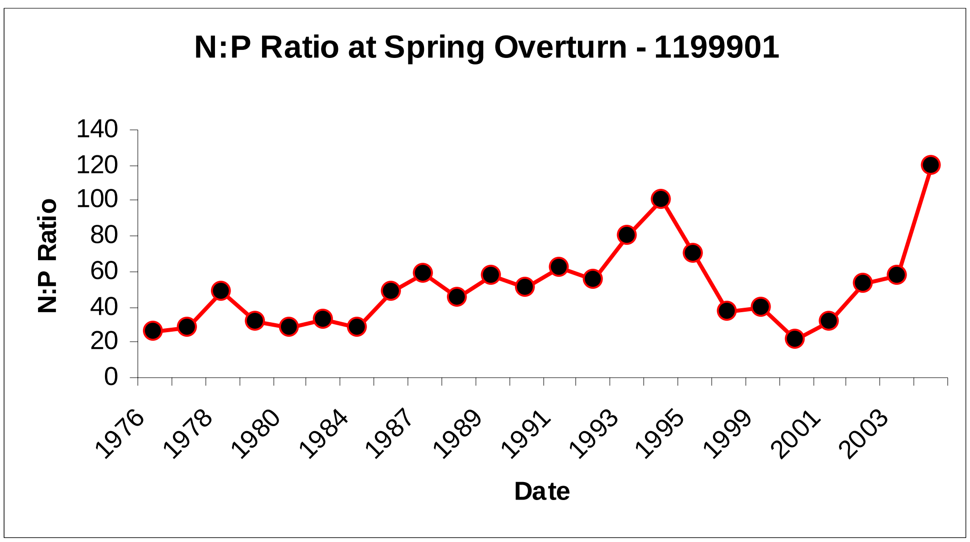

Figure 13: N:P ratios (total N: total P) at spring overturn, over time, for the Shawnigan Lake deep station (1199901).

Total Organic Carbon

Organic carbon is an important water quality parameter to consider with respect to drinking water sources. The guideline for total organic carbon (TOC) in raw drinking water or source water with disinfection is 4 mg/L to prevent the production of disinfection by-products (e.g., trihalomethanes) during treatment with chlorine (BC Ministry of Environment, Lands and Parks, 1998). Although there have been exceedences of the TOC guideline in past, it was met during the most recent sampling efforts and the overall average concentrations were below the guideline level.

Halides
Dissolved bromide, chloride and fluoride were measured at sites 1199901 and 1199902. Average concentrations for dissolved bromide were below analytical detection limits. Dissolved chloride concentrations were well below the guidelines for raw drinking water and aquatic life (250 mg/L and 600 mg/L, respectively) (BC Ministry of Water, Land and Air Protection, 2003) as were the dissolved fluoride concentrations (1.5 mg/L and 0.2 mg/L, respectively) (BC Ministry of Environment, Lands and Parks, 1990) for both sites.

Metals
The majority of the total metals results were collected from the north basin (1199901) and the south basin (1199902) and most of these results were below analytical detection limits. For those parameters where concentrations were above detection, the average values were below BC's approved or working guidelines, or there were no guidelines available. For parameters without approved or working guidelines, levels measured were low and likely do not present any cause for concern at this time.

6.2.2.2 Lake perimeter sites
Data from the four lake perimeter sites were limited to what had been collected since 2001 and are presented in Appendix 2. The results were low for all parameters and consistent with concentrations from the basin sites.

6.2.2.3 Inflow Sites
The West Arm inflow (1199911) showed the highest average concentrations of the inflow sites for hardness ($\bar{x} = 51.8$ mg/L), conductivity ($\bar{x} = 111$ μS/cm) and turbidity ($\bar{x} = 0.97$ NTU). All forms of nitrogen were low at this site but were highest among the inflow sites (average TN = 341 μg/L). Average TP among inflows was also highest at this site (10 μg/L); however, recent average total and dissolved phosphorus concentrations were similar to those measured in the 1970's. The concentrations measured at 1199911 were also higher than those for the nearest basin site in the West Arm (1199903) (see Appendix 2).

The Shawnigan Creek inflow site (1199906) showed average colour, hardness, conductivity and turbidity values that were consistent with those measured for the South Basin site (1199902). Nitrogen and phosphorus concentrations were also comparable to concentrations for 1199902 and were similar to values measured in the 1970's. Total metals concentrations were low and were below guideline levels or analytical detection limits.

McGee Creek (1199909) showed higher average colour, hardness and conductivity values than those measured at the north basin site (1199901). However, turbidity, nitrogen and phosphorus concentrations were comparable to those at 1199901 and historical data. Total metals results were below guideline levels or analytical detection limits.

Data for site 1199916 (Inflow at East Shawnigan Road) are limited, although available results show low levels for all parameters measured.

6.2.2.4 Outflow

Monitoring results for the Shawnigan Creek outflow (1199912) were consistent with those from the lake basin sites. A higher average concentration was noted for turbidity ($\bar{x}$ = 1.33 NTU) but this was influenced by one high measurement of 12 NTU taken in October, 2003 after a period of extremely high rainfall.

6.2.3 Water Chemistry Interpretation

The monitoring results for Shawnigan Lake show that water quality has been consistently good over the period of study, despite significant changes within the watershed. No parameters measured showed levels or trends which would cause concern at this time.

Phosphorus is probably the most influential parameter with respect to water quality and aquatic ecosystems. The productivity of most lakes is limited by phosphorus and very small increases in P can have significant effects to both the chemical and biological aspects of water quality. Nordin and McKean (1984) proposed an objective of 8 μg/L at spring overturn to control an uncharacteristically high dissolved oxygen depletion rate and protect the level of water quality for domestic purposes. Even though the population within the watershed has doubled since 1986 and significant development and logging has taken place, the total phosphorus concentration remains low at all sites. This is probably the result of the lake's short residence time (approximately one year) that was estimated to flush out half the phosphorus inputs for a given year (Nordin and McKean, 1984). The extremely low total P concentrations measured in 2004 could be partly due to an elevated flushing rate caused by extremely high precipitation events which occurred in the fall of 2003.

The decreasing P levels in Shawnigan Lake are also reflected in the ratio of total nitrogen to total phosphorus (N:P). The N:P ratio is useful for confirming the limiting nutrient for a given lake and its trophic status, as well as tracking changes in nutrient inputs into the system (Chiaudani and Vighi, 1974). N:P ratios greater than 27:1 (by mass) indicate oligotrophic conditions (Kalff, 2002) and, from a eutrophication perspective, very good water quality. A decreasing trend in N:P ratios would indicate an increasing input of nutrients, especially P, and values less than 10:1 generally indicate nitrogen limiting conditions. The shift towards N limitation favours the phytoplanktonic cyanobacteria (blue-green algae), which are capable of fixing atmospheric nitrogen, but are also associated with water quality concerns (generally taste and odour problems, but in extreme cases, hepatotoxins and neurotoxins can be produced). Spring overturn N:P ratios for Shawnigan Lake are showing an overall increasing trend which appears to be the result of decreasing phosphorus concentrations rather than increasing nitrogen levels. The N:P ratios indicate that Shawnigan Lake is oligotrophic and very phosphorus-limited.

Although total organic carbon concentrations were below guideline levels, this parameter is still of concern because of the potential health concerns associated with it. The reasons for reducing organic carbon in drinking water are not related to the toxicity of the organic carbon compounds, but the desire to reduce the formation of disinfection by-products following chlorination (BC MELP, 1998). The major purveyors of domestic water on

Shawnigan Lake all provide disinfection with chlorine and because of anthropogenic activities within the watershed (e.g., forestry, urban runoff) there is the potential for increases in TOC concentrations over time and consequently, increases in disinfection by-product formation.

The one area of concern would be the West Arm which has always had the highest inputs of nutrients and sediments. Because this area is relatively shallow and isolated from the main basins of the lake it could be more susceptible to increasing nutrient inputs in the future.

6.3 Surface Microlayer

The surface microlayer consists of the uppermost 50 microns of the water column where primary productivity is 10 to 100 times greater per unit volume than in the deeper bulk-water phytoplankton zone (Hardy and Wood, 1986; Hardy *et al*., 1987). Because toxins tend to concentrate in the surface microlayer, there can be significant impacts to the eggs and larvae of organisms that utilize this area (Moore and Freyman, 2001). The surface microlayer of Shawnigan Lake was sampled to examine the potential impacts of boating (i.e. fuel spills and leaks) on water quality by comparing the ambient concentrations of polycyclic aromatic hydrocarbons (PAH's) and metal contaminants to the underlying water column.

PAH's are non-essential organic compounds that are ubiquitous in the environment. In sufficient quantities, they have been found to be acutely toxic to aquatic life and carcinogenic (BC Ministry of Environment, Lands and Parks, 1997). Incomplete combustion of organic matter at high temperatures and creosote-treated wood are major sources of PAHs (Nagpal, 1993, Warrington, 1999).

Metals were sampled because they have been shown to be mutagenic, carcinogenic, and bioaccumulative (Nagpal, 1993).

6.3.1 Methods

The methods described here are based on the earlier work of Moore and Freyman (2001). A custom-made rotating drum was used to collect water from the surface microlayer. The drum is scraped with a plastic blade that directs the water into a collection bottle. Sampling was conducted in the morning, when wave action was minimal, to ensure that the microlayer was intact. Samples were analyzed for PAH's (acenaphthylene, fluoranthene, naphthalene, pyrene, total PAH's, total low molecular weight PAH's and total high molecular weight PAH's) and dissolved and total metals (aluminium, copper, manganese, lead and zinc). Samples were also collected from directly below the water surface and subjected to the same analyses as the surface microlayer to provide comparison. Samples were collected near a marina with a fueling dock (Galley Restaurant – E222045) and at three sites in the south basin.

The Microtox® Bioassay Testing System was used as a primary screening tool for abnormal levels of toxicants in the surface microlayer of Shawnigan Lake. The Microtox® assay uses freeze-dried luminescent bacterial (*Photobacterium phosphoreum*) as the test organism. The bacteria's light-producing abilities are linked to the overall health of the cell and if the health is compromised by a toxicant, the amount of light produced is decreased. After the bacteria are exposed to the test water, the light outputs are measured and used to calculate the median effective concentration (EC50) of the sample. The EC50 represents the sample concentration (%) estimated to cause a 50% reduction in light production and is compared against a control sample to determine relative toxicity. The lower the EC50 value, the greater the toxicity of the sample.

Provincial quality assurance/quality control (QA/QC) programs evaluate the quality and validity of water quality monitoring data. For this portion of the study, QA/QC concerns were addressed using surrogate recoveries, which assessed the precision and accuracy of the analytical organic extractions.

6.3.2 Surface Microlayer Results

Analytical results from the surface microlayer and the underlying water column are summarized in Appendix 3 and discussed in the following sections.

PAH's

The majority of the surface microlayer PAH concentrations were below the analytical detection limits for all sites. Overall, PAH concentrations were higher at E222045 than other sites and in May the Ministry chronic guideline for napthalene (1 µg/L) was exceeded (1.8 µg/L). There was some temporal variation observed in surface microlayer PAH concentrations which were higher in May than in August.

Water column PAH concentrations were below analytical detection limits or below guideline levels.

Metals

Generally, surface microlayer metal concentration results were higher than the underlying water column although no results exceeded guideline levels. Only E222045 was sampled in August and at this time the water column showed higher concentrations of aluminium, copper and lead.

Toxicity Tests

The results of the MicroTox EC50® tests are presented in Appendix 3. For all of the sites, the MicroTox EC50® five and 15 minute test results were greater than 90% indicating little or no toxicity in the surface microlayer and the top of the water column. Therefore, it is not expected that the organisms present in the Shawnigan Lake microlayer are any more likely to be stressed than those in the deeper in the water column.

6.3.3 Surface Microlayer Interpretation

Surface microlayer sampling results are a direct reflection of current water conditions (Warrington, 1999). In Shawnigan Lake, the majority of surface microlayer parameter concentrations measured were greater than those in the underlying water column. Sources of microlayer contaminants include atmospheric deposition, terrestrial runoff, petroleum spillage (e.g., boating), effluent discharges and biosynthesis (Nagpal, 1993).

This study's results indicate that the surface microlayer of Shawnigan Lake is relatively free from contamination. Overall, levels were found to be minimal and generally below analytical detection limits or guideline levels.

Site E222045 (Galley Restaurant) illustrated some PAH concentration variability between sampling dates. It was expected that PAH microlayer concentrations would be higher in August than in May as the contamination risk would increase with human activity (i.e. boats, jet-skis); this was not the case. Lower surface microlayer concentrations in August may have been caused by increased overall water turbulence from boating traffic which may disrupted the settling of contaminants in the surface microlayer.

The PAH concentration may have also been altered by ultraviolet radiation photo-degradation, which is dependent on water temperature, dissolved oxygen concentration, and the amount of solar radiation received (Fasnacht and Blough, 2003). Solar radiation would have been higher in August and may have intensified PAH degradation.

The low PAH and metal concentrations for both the microlayer and the water column samples for Shawnigan Lake suggest there is no immediate risk to water quality or aquatic life. Increased sampling frequency would clarify temporal microlayer PAH concentration trends and determine true divergences from baseline values, however, the overall low results of this work indicate this is not warranted at this time. It should be noted that the criteria used here were designed for the protection of aquatic life throughout the water column - not the surface microlayer alone.

6.4 Biological Analysis

Biological sampling is an important component of water quality monitoring. Organisms respond to a range of environmental conditions and can provide clearer understandings of the functional relationships within an aquatic ecosystem. In this study, phytoplankton and zooplankton were collected to determine their abundance and dominance and help identify any linkages between water quality and anthropogenic activities.

Variances in phytoplankton community composition may signal changes in water chemistry and nutrient concentration. Nutrient enrichment affects phytoplankton density and diversity and can create phytoplankton surface blooms which reduce water quality (Palmer, 1977). Water quality impacts associated with phytoplankton blooms include taste and odour problems, filter and screen clogging, corrosion, increased turbidity (Palmer, 1977, Nordin and McKean, 1984), reduced water clarity, reduced hypolimnetic oxygen levels and the risk of toxins produced by blue-green algae.

Chlorophyll *a* is a measure of phytoplankton biomass and relates to the productivity of a waterbody. Agriculture, sewage effluent, forest harvesting, urban development, and recreational activities can add nutrients to a lake, increasing chlorophyll *a* concentrations (Cavanaugh *et al*., 1998). Chlorophyll *a* is an ideal measurement because it is simple and universally applied (Nordin and McKean, 1984). There are no provincial chlorophyll *a* lake guidelines, but phosphorus guidelines are designed to limit its concentrations.

Zooplankton hold an important intermediate position in the aquatic food web. Although they do not cause problems with water quality or aesthetics directly, they are sensitive to changes in water quality and are used as indicators. Specifically, zooplankton respond to dissolved oxygen concentrations, contaminants, and food quality/abundance.

6.4.1 Methods

Phytoplankton samples were collected by taking one litre grab samples at the surface. Chlorophyll *a* samples were collected using a hand-operated vacuum pump to filter 500 mL of surface water through a 0.45 micron membrane filter; the filter paper was then analyzed for chlorophyll *a*. Zooplankton were collected using a 10 m vertical tow in a Wisconsin-style net with a mouth area of 0.07 m^2, a net opening diameter of 0.5 m and a mesh size of 80 µm. All samples were collected following the Ministry of Water, Land and Air Protection approved methods.

6.4.2 Biological Results

Phytoplankton, chlorophyll *a,* and zooplankton concentrations are listed in Appendix 4 and are discussed in the following sections.

6.4.2.1 Phytoplankton

Phytoplankton results were summarized and the dominant species are presented in Table 10.

These results show differences in dominant species from what was reported by Nordin and McKean (1984). The only dominant species occurring in the same month as previously reported were the diatoms *Asterionella formosa* and *Cyclotella bodanica* and the golden-brown *Dinobryon divergens* in May, and the golden-browns *D. divergens* and *D. bavaricum* in June. Two genera of blue-greens, *Anacystis* and *Gomphosphaeria*, were common to both studies in May, June, July and August.

Several of the genera present are characteristic of oligotrophic conditions including the diatoms *Asterionella*, *Cyclotella*, and *Melsoira*; the green *Botryococcus*; and the golden-browns *Dinobryon* and *Peridinium*.

The diatoms were dominant in February and May (76% and 41%, respectively) although in May the diversity of the phytoplankton assemblage had increased. In June, the dominance of the blue-greens became evident and peaked in August at 77%. This dominance began to decrease in September and by October the greens and cryptophytes were more significant. In November, the cryptophytes were the dominant group (59%) and again in February 2004 (55%), with the diatoms becoming more abundant (36%). This interpretation of the results should be taken with caution because of the wide range in size of the individual species. An equal amount of cells of one species may be much more significant than another based on the larger size of one of the species. This approach does illustrate the shift in phytoplankton community composition through the year.

Table 10: Dominant phytoplankton species for Shawnigan Lake (cells/100 mL).

Group	Species	Site	11-Feb-03	13-May-03	25-Jun-03	23-Jul-03	13-Aug-03	23-Sep-03	21-Oct-03	18-Nov-03	12-Feb-04
Diatoms	*Asterionella formosa*		35	147		32		64			26
	Cyclotella bodanica		17	180	20						
	Melosira italica		259	67	49	46	11		11	28	77
	Percent of total		76%	41%	5%	10%	3%	9%	1%	8%	36%
Blue-green	*Anacystis elachista*			71	305	250	194	182	193	77	
	Anacystis limneticus			39	371	61	26	14	58		
	Gomphosphaeria aponina					79	40	67	174	45	
	Percent of total			9%	55%	63%	77%	46%	46%	15%	
Green	*Botryococcus braunii*				134	45	16		78	22	34
	Gloeocystis ampla			92	234	85	30	37	139	26	17
	Quadrigula closterioides			17		11	17	23	34	34	
	Sphaerocystis schroeteri			41	126						
	Percent of total			14%	32%	19%	10%	9%	22%	10%	7%
Cryptophyte	*Chroomonas acuta*		86	90	43	26	12	58	160	171	132
	Cryptomonas ovata			86	16	17		11	66	32	17
	Percent of total		23%	18%	4%	5%	1%	12%	27%	59%	55%
Golden-brown	*Dinobryon bavaricum*			50	15	13	14	14	30		
	Dinobryon divergens		14	134	36		95	124	25	26	11
	Percent of total		1%	18%	3%	2%	9%	24%	4%	8%	2%

Overall, phytoplankton concentrations were minimal in the winter and late summer months and the highest total concentrations were found in June with a second, smaller peak noted in October (Figure 14). Considerable rainfall occurred in October 2003, and the second spike in phytoplankton concentrations may have been due to increased nutrients from runoff in the watershed.

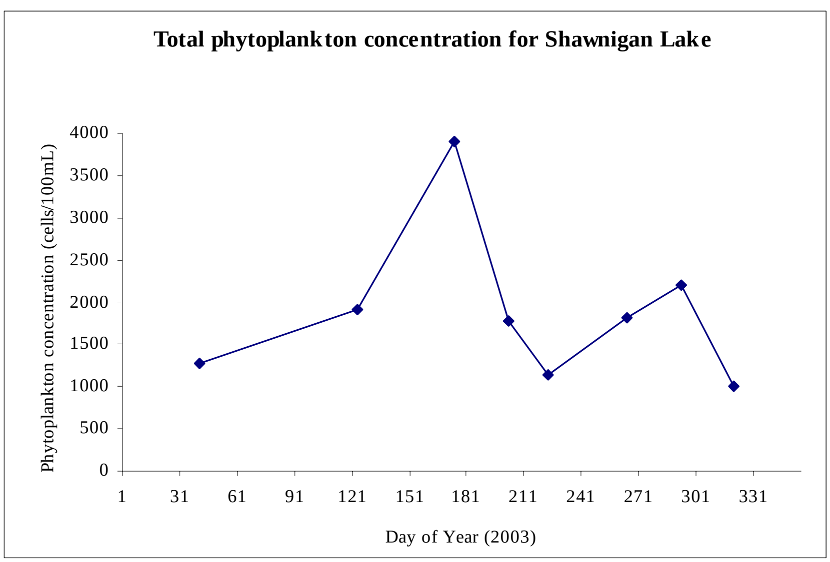

Figure 14. Total phytoplankton concentrations over time for Shawnigan Lake, February to November, 2003 (all sites).

6.4.2.2 Chlorophyll *a*

Chlorophyll *a* results are presented in Table 11. The chlorophyll *a* concentrations from all sites were low suggesting good water quality. The majority of samples were below 3 µg/L, which is the upper threshold for oligotrophic conditions (Kalff, 2002). There was an overall decrease in mean chlorophyll *a* concentrations for 1977 to 2003, suggesting a difference in primary productivity.

Table 11: Shawnigan Lake average chlorophyll *a* concentrations (µg/L).

	1977 - 1979			2003 - 2004		
Site	Mean	Std. Dev.	n	Mean	Std. Dev.	n
1199901	3.04	1.72	12	0.77	0.39	7
1199902	2.95	1.63	10	0.93	0.46	7
1199903	2.24	0.74	8	1.28	0.93	6
1199904	0.30	0	3	0.76	0.55	7

6.4.2.3 Zooplankton

Zooplankton results are presented in Table 12. Overall concentrations were typical of systems with low levels of nutrients during the sampling period. Rotifers were dominant throughout in terms of total numbers and peaked in June 2003. *Keratella cochlearis* was the most common rotifer species; it was dominant six out of the nine months sampled. *Ptygura libera* was the dominant species in July, *Kellicotia longispina* in September and *Polyarthra sp.* in November 2003.

Zooplankton species diversity increased during the winter and autumn. Cyclopoid copepods concentration, especially nauplii, peaked in November, 2003, representing 10% of all zooplankton present. The other orders of *copepods*, Calanoida and Cladocera, had low abundance throughout the study period and comprised little of the overall species assemblage.

Overall, the zooplankton abundance showed two peaks throughout the sampling period in June/July and November (Figure 15). The high summer concentrations may be a consequence of increased food quality and quantity, while the November peak could be the result of nutrient inputs associated with fall freshet.

Carl's (1940) and Nordin and McKean's (1984) reports were used as benchmarks to compare crustacean zooplankton species assemblages for Shawnigan Lake over time (Table 13). Carl's report focussed entirely on crustacean zooplankton, so comparisons using other phyla could not be made. In addition, Carl did not include species concentrations, so only absence/presence assessments could be performed. Rare species, in this report, were defined as species whose total abundance was less than 1% of the total number of organisms collected. Carl (1940) found six cladoceran species in Shawnigan Lake, compared to eight (two of which are rare) for Nordin and McKean's (1984) and 15 (14 of which are rare) in this study. *Daphnia rosea*, *Sida crystallina* and *Leptodora kindtii* are the only species appearing in all three assessments, however *S. crytallina* and *L. kindtii* were rare in this study. For copepods, Carl found two species, compared to three for Nordin and McKean's and eight (six of which are rare) for this study. *Epischura nevadensis* was the only copepod found in all three assessments, however it was rare in this study.

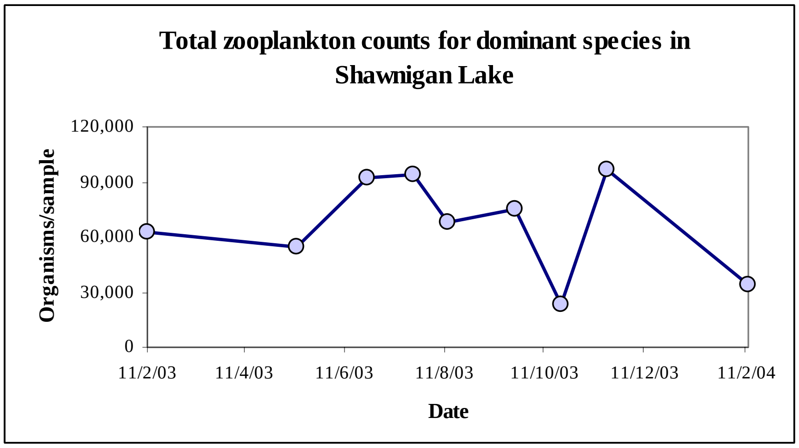

Figure 15: Total concentrations for dominant zooplankton species for Shawnigan Lake, February, 2003 to February, 2004.

An overall increase in zooplankton abundance for sites 1199901 and 1199902 was observed since 1977 and 1978 (Tables 14 and 15). *Keratella cochlearis* was the species that showed the greatest increase in abundance; this species has been shown to be associated with P- limited oligotrophic lake conditions (Ramos-Rodriguez and Conde-Porcuna, 2003). *Daphnia rosea* increased in abundance in May and June at 1199901 and June and July at 1199902 but decreased in abundance later in the season. Also contributing to the large overall increases in zooplankton abundance were the large increases in copepod nauplii (i.e. larva) present in most samples.

Table 12: Dominant zooplankton species for Shawnigan Lake, February 2003 – February 2004 (organisms/sample).

Phylum/Class	Order	Species	11-Feb-03	13-May-03	25-Jun-03	23-Jul-03	13-Aug-03	23-Sep-03	21-Oct-03	18-Nov-03	12-Feb-04
Copepoda	Cyclopoida	Nauplii	18,192.7	19,083.4	4,000.0	7,483.3	10,133.2	14,533.3	6,116.7	19,466.6	10,466.7
		Diacyclops thomasi	5,724	1,025					1,492	9,740	2,740
		Percent of Total	38%	37%	4%	8%	15%	19%	26%	30%	39%
	Calanoida	*Diaptomus sp.*				1,140					480
		Percent of Total				1%					1%
Branchiopoda	Cladocera	*Daphnia rosea*	2,270	3,500	2,967	1,167		1,167			560
		Percent of Total	4%	6%	3%	1%		2%			2%
Rotifera		*Kellicotia longispina*	4,024	4,717	8,233	5,133	4,000	20,867	2,425	8,733	1,600
		Keratella cochlearis	32,567	20,367	35,867	14,733	27,067	17,467	9,258	25,267	15,167
		Polyarthra sp.		5,750	15,050	14,817	20,400	17,200	4,242	33,733	3,067
		Ptygura sp.			25,733	49,433	6,133	4,200			
		Percent of Total	58%	57%	93%	90%	85%	79%	74%	70%	58%

Table 13: Comparison of Shawnigan Lake crustacean zooplankton species collected in the 1930’s (Carl, 1940), 1970’s (Nordin and McKean, 1984) and 2003.

Cladocera	**1930's**	**1970's**	**2003**
Acroperus harpae			Yes (rare)
Bosmina longirostris		Yes	Yes (rare)
Bosmina obtusirostris	Yes		
Ceriodaphnia reticulata		Yes	
Ceriodaphnia sp.			Yes (rare)
Chydorus sp.			Yes (rare)
Chydorus sphaericus		Yes (rare)	
Daphnia cf ambigua			Yes (rare)
Daphnia longiremus		Yes	Yes (rare)
Daphnia pulex			Yes (rare)
Daphnia pulicaria			Yes (rare)
Daphnia rosea	Yes	Yes	Yes
Daphnia sp.			Yes (rare)
Diaphanosoma leuchtenbergionum		Yes	
Holopedium gibberum			Yes (rare)
Holopedium sp.			Yes (rare)
Leptodora kindtii	Yes	Yes	Yes (rare)
Polyphemus pediculus	Yes		Yes (rare)
Schapholeberis mucronata	Yes		
Sida crystallina	Yes	Yes (rare)	Yes (rare)
Copepoda			
Cyclops bicupidatus	Yes	Yes	
Diacyclops sp.			Yes (rare)
Diacyclops thomasi			Yes
Diaptomus franciscanus			Yes (rare)
Diaptomus oregonensis		Yes	Yes (rare)
Diaptomus sp.			Yes
Epischura nevadensis	Yes	Yes	Yes (rare)
Macrocyclops sp.			Yes (rare)
Skistodiaptomus oregonensis			Yes (rare)

Note: For the 2003 study, rare species were defined as those whose abundance was less than 1% of the total number of organisms collected.

Table 14: Comparison of north basin (1199901) zooplankton species (organisms/sample) between 1977/78 and 2003.

Date	*Epischura nevadensis*	*Bosmina longirostris*	*Daphnia rosea*	Nauplii and Copepodites	*Kellicotia longispina*	*Keratella cochlearis*	*Keratella quadrata*	Sum of all species reported
11-May-77	32	56	136	328	640	1,104	120	3,256
16-May-77		16	136	8	640	2,152	240	4,016
25-May-77	32	8	152	32	400	760	96	2,168
8-May-78	16	240	112	224	1,808	304	176	4,592
29-May-78	24		56	216	1,392	152	16	2,888
13-May-03	10	21	1,800	6,540	1,667	5,400	2,133	12,273
14-Jun-77	12		112	84	184	40		676
27-Jun-77	24		176	416	208	72		1,504
25-Jun-03	5	240	1,100	4,000	4,300	15,200		29,800
18-Jul-77	96		104	664	64	68		1,556
25-Jul-78	20	12	40	1,376	140	52		2,132
23-Jul-03		38		2,750	1,600		7,600	46,390
16-Aug-77	132		320	376	116	52		1,532
28-Aug-78		16	356	832	268	148	12	3,044
13-Aug-03	3	50		2,533	733	5,200		46,713
29-Sep-77	8	24	656	88	72	32	8	2,672
23-Sep-03	23	60		4,933	2,467	5,800		22,933

Table 15: Comparison of south basin (1199902) zooplankton species (organisms/sample) between 1977/78 and 2003.

Date	*Epischura nevadensis*	*Bosmina longirostris*	*Daphnia rosea*	Nauplii and Copepodites	*Kellicotia longispina*	*Keratella cochlearis*	*Keratella quadrata*	Sum of all species reported
11-May-77	16	92	136	48	568	452	40	2,120
25-May-77	40		168	16	640	632		2,168
8-May-78	8	56	8	24	1,016	216	208	2,368
29-May-78	12		116	108	608	276	8	2,292
13-May-03		9		7,800		7,733	3,467	64,021
14-Jun-77	16		244	64	240	152	8	760
27-Jun-77	60		60	228	76	28		680
25-Jun-03			1,867		1,067	12,667		22,600
25-Jul-78	60	28	28	856	76	16	8	1,720
23-Jul-03	1	2	1,167	2,533		1,000		47,592
16-Aug-77	60		136	480	12		12	1,088
28-Aug-78	4	64	624	648	320	164	8	3,332
13-Aug-03	2	5		2,133	733	5,200		52,646
03-Nov-77		24	324	12	32	16	4	908
18-Nov-03	6	367		7,733	3,067	10,733		77,010

6.4.3 Interpretation

Phytoplankton and zooplankton populations are seasonally variable and are regulated by both chemical (nutrients and other essential elements) and physical factors (e.g., light, temperature, pH).

Phytoplankton concentrations for Shawnigan Lake did not depart from natural or acceptable levels during the sampling period, as indicated by lower chlorophyll *a* concentrations, than measured in earlier assessments. Although blue-green algae dominated the phytoplankton community in the summer months, it does not necessarily indicate a decline in water quality. Peaks in blue-green algae appeared to follow nitrate+nitrite trends in the surface water (epilimnion); blue-green dominance was the greatest in the summer months (June – September) when nitrate+nitrite concentrations were lowest (2 μg/L). Blue-green dominance diminished in the fall and winter months when epilimnetic nitrate+nitrite concentrations increased. Epilimnetic total phosphorus concentrations were low throughout the summer and did not alter the N:P ratio such that it would create nitrogen limiting conditions that favour the blue-greens. Finally, the dominant blue-greens found did not include species that are typically associated with eutrophic conditions (e.g. *Anacystis aeruginosa*, *Aphanizomenon* and *Anabaena*).

There is likely considerable variance in phytoplankton community composition from year to year related to environmental conditions at the time and this study demonstrated these differences between sampling periods. For example, the diatom *Tabellaria fenestrata,* the chlorophyte *Spondylosium planum* and the blue-green *Rhabdoderma gorskii*, were dominant in Nordin's report but absent from the results of this study. The dominant groups for each time period, however, were similar. Diatoms, for example, were dominant in May for both reports.

Shawnigan Lake mean chlorophyll *a* concentrations indicated oligotrophic conditions and the decrease in mean concentrations since the 1970's suggests that primary productivity has also declined. A large decrease in average chlorophyll *a* concentrations was noted over the period of study and there is no obvious explanation for this decline.

There were differences in zooplankton assemblages noted between this study and with Nordin and McKean's (1984) and Carl's (1940) assessments which concentrated on the cladocerans and copepods. In comparing our results with the earlier assessments we observed a more diverse zooplankton community in Shawnigan Lake than previously reported because of the greater occurrence of rare zooplankton species (Table13). Neither of the previous assessments included rotifers in their examination of species diversity which is problematic as they were a major constituent of the contemporary species assemblage. One reason for this may be the sample collection methods used. We used an net with an 80 μm mesh size. If the others used nets with a larger mesh size, this could account for the small-sized species (like rotifers) being absent from earlier results. Changes in species names, classifications and identification keys may also account for some of the increase in rare species presence.

An increase in zooplankton abundance was also noted despite the fact that Shawnigan Lake has remained in an oligotrophic condition throughout both sampling periods. The rotifer *Keratella cochlearis* was a dominant species and has been shown to have high growth rates when algae are under phosphorus limitation (Ramos-Rodriguez and Conde-Porcuna, 2003). The ability of *K. cochlearis* to excel under low P conditions may help explain this dramatic rise in zooplankton abundance.

Generally, healthy lakes are comprised of small cell-size phytoplankton, large body-size zooplankton, high zooplankton and macrozooplankton biomass, low microzooplankton concentration and a high ratio of zooplankton to phytoplankton biomass (Xu *et al*., 1999). With respect to zooplankton body size, this is not the case in Shawnigan Lake where the majority of zooplankton have small body sizes. The zooplankton species composition is probably influenced by planktivorous fish like kokanee (*O. nerka*) and juvenile rainbow trout (*O. mykiss*) and possibly the introduced bass (*M. dolomieui*) and perch (*P. flavescens*). This is illustrated by the disproportionate number of copepod nauplii compared to copepod adults (Table 12).

Two biological indicators that were not addressed in this report, but could be considered in the future, are macrophytes (aquatic plants) and fish. Both are of concern to users of the lake. Excessive weed growth in the littoral zones (shallow, shoreline areas) is an issue with lakeshore residents and attempts by individuals to remove macrophytes may in fact promote their growth because many are able to propagate from small fragments of plants that are broken off. With fish, the relatively recent introductions of bass and perch into Shawnigan Lake may have an impact on the salmonid species, and other organisms, that might not be immediately apparent.

Biological indicators can have significant amounts of incidental or unexplained variance which can affect results and therefore caution must be exercised when using phytoplankton or zooplankton to indicate anthropogenic disturbances. Biological indicators are complex and may contain many elements capable of corresponding differently and in unpredictable ways to a range of physical and biological factors (Stemberger, 2001). Recognizing these limitations, it appears that the current phytoplankton assemblages in Shawnigan Lake are similar to those observed in the late 1970's, while the mean chlorophyll *a* concentration has decreased. Increasing phosphorus limitation, as suggested by lower chlorophyll *a* concentrations, may have resulted in an increased abundance of smaller bodied zooplankton species like rotifers. Overall, the biological analysis component of this study indicates no impairment to water quality.

6.5 Microbiology

The fecal micro-biota of warm-blooded animals is potentially pathogenic and fecal contamination of water can cause many illnesses including scarlet fever, diarrhoea, pneumonia and meningitis. Potential fecal contamination sources for Shawnigan Lake are: livestock, waterfowl, leaky septic systems, inadequate locations of sewage disposal fields, and storm-water runoff (Nordin and McKean, 1984; Webber, 1996).

The human health risks of fecal contamination in Shawnigan Lake were assessed using the presence of the microbiological indicator species *Escherichia coli* and enterococci. *E. coli* was the primary enteric illness indicator, while enterococci were supplementary. Fecal coliform and streptococci concentrations were also measured but not relied on to indicate human enteric health risks because of concerns about their value as indicators (Section 4.4.3).

6.5.1 Methods

Surface water grab samples were collected according to Ministry approved sampling procedures and tested for *E. coli*, enterococci, fecal coliforms and fecal streptococci at nine sites: four lake perimeter sites, four inflow sites, and one outflow site. Results are reported in colony forming units (CFU)/100 mL. The lake basin sites (1199901, 1199902, 1199903, 1199904) were not tested for bacteriological parameters because of the distance from domestic intakes. There were two distinct sampling periods for this assessment in which five samples were collected for each site in a 30-day period: August/September (summer flow-flow) and October/November (fall freshet). Ninetieth percentile concentrations and geometric mean concentrations were calculated to determine whether concentrations exceeded provincial water quality guidelines for raw drinking water with disinfection and recreational primary contact, respectively.

6.5.2 Results

Indicator bacteria concentrations are listed in Appendix 5 and are summarized in Tables 16 and 17.

During the summer low flow period, 90th percentile concentrations exceeded drinking water guideline levels at only one lake site, West Shawnigan Lake Park (E222055). Enterococci and fecal coliform guidelines were exceeded and the *E. coli* concentration was at the guideline level of 10 CFU/100 mL. All the inflow sites (1199906, 1199909 and 1199911) and the outflow site (1199912) exceeded the drinking water guidelines.

Table 16: 90th Percentile concentrations (CFU/100 mL) for bacteriological indicators for Shawnigan Lake, 2003. Guideline levels (CFU/100 mL) for raw drinking water with disinfection only are provided in parentheses.

Site Name	Site #	Summer Low Flow			Fall Freshet		
		E. coli (10)	Enterococci (3)	Fecal coliforms (10)	*E. coli* (10)	Enterococci (3)	Fecal coliforms (10)
Lake sites:							
Galley Restaurant Area	E222045	2	2	2	58	123	110
Easter Seal Camp Beach	E222048	1	0	3	27	121	107
West Shawnigan Lake Park	E222055	10	8	32	857	388	1,185
Shawnigan Lake Resort	E246900	1	1	1	20	225	138
Inflow/Outflow sites:							
Shawnigan Creek Inflow	1199906	820	54	1,432	54	13	373
McGee Creek	1199909	64	58	93	74	76	131
West Arm Inflow	1199911	19	62	35	65	74	77
Shawnigan Creek Outflow	1199912	150	120	200	35	70	86
Inflow on East Shawnigan Rd.	1199916				20	34	89

During the fall freshet period, 90th percentile values at all sites exceeded the drinking water guidelines.

The primary recreational contact guidelines were met much more consistently and during the summer low flow period guidelines were only exceeded at the inflow and outflow sites. The *E. coli* guideline was exceeded at Shawnigan Creek inflow site (1199906) and the enterococci guideline was exceeded at Shawnigan Creek, McGee Creek, the west arm inflow and the Shawnigan Creek outflow.

During the fall freshet, only the enterococci guidelines were exceeded at West Shawnigan Lake Park (E222055) and Shawnigan Lake Resort (E246900).

Table 17: Geometric mean concentrations (CFU/100 mL) for bacteriological indicators for Shawnigan Lake, 2003. Guideline levels (CFU/100 mL) for recreational primary contact are provided in parentheses.

Site Name	Site #	Summer Low Flow			Fall Freshet		
		E. coli (77)	Enterococci (20)	Fecal coliforms (200)	*E. coli* (77)	Enterococci (20)	Fecal coliforms (200)
Lake sites:							
Galley Restaurant Area	E222045	1	1	1	7	10	15
Easter Seal Camp Beach	E222048	1	1	2	4	12	7
West Shawnigan Lake Park	E222055	2	3	5	28	51	44
Shawnigan Lake Resort	E246900	1	1	1	6	25	27
Inflow/Outflow sites:							
Shawnigan Creek Inflow	1199906	99	24	161	8	4	19
McGee Creek	1199909	27	34	47	15	11	28
West Arm Inflow	1199911	8	22	14	10	11	17
Shawnigan Creek Outflow	1199912	68	55	100	10	16	17
Inflow on East Shawnigan Rd.	1199916				7	7	19

6.5.3 Microbiology Interpretation

The presence of *E. coli* in water is a strong indication of human sewage or animal waste contamination because it rarely multiplies in the environment (Leclerc *et al*., 2001) and has been statistically associated with an increase in the relative risk of gastrointestinal illness in freshwater studies (Wade *et al*., 2003; Pruss, 1997). Currently, *E. coli* is considered to be the superior freshwater fecal bacterial contamination indicator.

There has been debate on whether enterococci should be used as an indicator of freshwater enteric illness (Atherholt *et al*., 2003; Kinzelman *et al*., 2003). Enterococci have been considered by the US Environmental Protection Agency (EPA) to be a better indicator of human fecal contamination than fecal coliforms (Griffin *et al*., 2001), although supplementary to *E. coli*. Therefore, enterococci were used as an additional bacteriological indicator in this assessment.

Fecal coliforms are included to provide comparison to earlier assessments of Shawnigan Lake (Nordin and McKean, 1984, Webber, 1996), although no statistically significant association between the risk of illness and the concentration of fecal coliforms has been found (Wade *et al*., 2003) and the US EPA has recommended that fecal coliforms no longer be used as an indicator for recreational freshwater quality (Wade *et al*., 2003; US EPA, 1986;).

Fecal streptococci were measured but not used to assess contamination. Fecal streptococci are known to have environmental origins, compromising their ability as indicators of fecal contamination. Currently, the associations between gastrointestinal illness and fecal streptococci are contradictory (Pruss, 1998) and not generally supported as an indicator of health risk (Wade *et al*., 2003; Godfree *et al*., 1997).

Nordin and McKean (1984) observed higher levels of fecal contamination in near shore areas compared to the deep water sites and the inflows showed the highest levels of contamination. Webber (1996) found all sites sampled to meet the primary recreational contact guidelines; however, three lake sites exceeded the guidelines for raw drinking water with disinfection. The Vancouver Island Health Authority (Central Island Unit) performs tests at three Shawnigan Lake sites (West Shawnigan Lake Provincial Park beach, Easter Seal camp beach and Mason's beach) for fecal and total coliforms to determine the surface water's suitability for recreational use and their results for 2002 and 2003 were all within guideline levels.

With respect to drinking water, the lake sites are probably of more significance because the largest licenced withdrawals are all from the lake itself; however, there are 28 licenced withdrawals on Shawnigan and McGee creeks authorizing withdrawals of over 1,300 m^3/d. Although most of the lake sites met the drinking water guidelines (disinfection only), with the exception of the West Shawnigan Lake Park site, during the summer low flow, all of the lake sites exceeded the guidelines during the fall freshet. The fact that all the inflow sites exceeded the drinking water guidelines during both sampling periods should be of concern; this also suggests that, because the lake sites were predominantly exceeded only during fall freshet, there may be other contributing sources of contamination other than the inflow streams. The most obvious source would be septic systems and the very heavy rain storms that were experienced in this area during the fall freshet sampling period could have contributed to increased fecal contamination in Shawnigan Lake.

There are many single home intakes in Shawnigan Lake, most of which are likely not treating the water prior to use. Although the guidelines for raw water with disinfection were mostly met at the lake sites during the summer low flow, the guideline for raw water without treatment for all parameters is 0 CFU/100 mL and emphasizes the importance of treating raw water prior to consumption to avoid health risks.

The bacteriological guidelines for recreational primary contact were exceeded for *E. coli* (1 exceedance) and enterococci (4 exceedances) at the inflow and outflow sites during the summer low flow period. The enterococci guidelines were exceeded at two of the lake perimeter sites during the fall freshet period, while the fecal coliform concentrations were always within the guidelines. It is interesting to note that the recreational *E. coli* and enterococci guidelines in the inflows were only exceeded during the summer low flow period and were generally lower during the fall freshet suggesting that the source may be seasonal (e.g. wildlife, recreational use, livestock) or that the loadings are diluted with the increasing flows of the fall freshet.

Although the water chemistry and biological results indicate good water quality in Shawnigan Lake, the bacteriological results are cause for concern. A more extensive bacteriogical monitoring program should be considered to focus on sites in close proximity to the major domestic intakes on Shawnigan Lake. To further protect Shawnigan Lake as a drinking water source, *E. coli* and enterococci should be added to the fecal coliform objective proposed by Nordin and McKean (1984). The provisional objectives recommended for Shawnigan Lake for *E. coli* is a concentration no greater than 10 CFU/100 mL (90^{th} percentile of a minimum of 5 samples taken within 30 days) and for enterococci is a concentration no greater than 3 CFU/100 mL (90^{th} percentile of a minimum of 5 samples taken within 30 days).

7 Conclusions and Recommendations

Shawnigan Lake continues to provide a desirable community in a natural, rural setting close to Victoria. Over the years summer cabins have been replaced with permanent residences and now many of the residents commute to work in Victoria and Duncan. Growth and development has been considerable in recent years and the population has increased from about 1,000 in 1967 to over 7,000 in 2004. Associated with the growth and land development are the risks to water quality, like runoff from impervious surfaces, sewage disposal and increased recreational use of power boats on the lake itself. Other land uses in the watershed, like forestry and agriculture, create additional risks to water quality.

In addition to quality is the issue of water quantity. The growing domestic demand on Shawnigan Lake has been offset by an increased dependency on groundwater, however the lake remains the main source of domestic water in this watershed and the impacts of human land-use must be considered to prevent human health risks and other water quality problems.

Despite the increased development and changes to human land use within the watershed, the overall water quality of Shawnigan Lake, from both chemical and biological perspectives, remains remarkably good at the present time. Spring overturn phosphorus levels appear to be decreasing; however, there's no obvious explanation for this trend at this time. This same observation was made in the 2000 report *Water Quality Trends in Selected British Columbia Waterbodies* (BC MELP and Environment Canada, 2000). The provisional water quality objectives for phosphorus (i.e., 8 μg/L) have been met since proposed in 1984. All forms of nitrogen measured showed no obvious trends in concentration since the late 1970's. This, in conjunction with lower phosphorus concentrations, has resulted in a trend of higher N:P ratios over the period of study. Based on these observations, it can be said that Shawnigan Lake continues to be oligotrophic (low productivity). Total organic carbon concentrations were below guideline levels; this is important because the domestic water systems on Shawnigan Lake treat the water with chlorine disinfection and meeting the TOC guidelines will minimize the risk of disinfection by-product formation. The fairly high flushing rate (approximately one year) of Shawnigan Lake, which is typical of coastal lakes, likely contributes to the maintenance of chemical water quality. Any accumulation of contaminants through terrestrial runoff or internal loading, in the case of phosphorus, is flushed out of the system during the winter rainy season. In addition, the morphometry of the lake provides two relatively deep basins which provide a catchment for nutrients to settle out.

The results of this assessment showed other water chemistry parameters, both in the water column and the surface microlayer, to be low and do not suggest any problems at this time. The turbidity levels measured at all sites met the provisional water quality objectives (5 NTU). Suspended solids were not measured in the inflow streams; however, the low turbidity results for these sites suggest that the provisional water quality objective of 25 mg/L would easily be met.

Dissolved oxygen concentrations were higher than previously reported with greater periods of oxygen supersaturation in surface waters and greater hypolimnetic oxygen concentrations, while other limnological characteristics (water temperature, thermal stratification patterns and clarity) remained the same.

The biological parameters measured also suggest good water quality in Shawnigan Lake. Chlorophyll *a* concentrations were lower than measured in earlier assessments suggesting a decrease in primary productivity of the lake. This is to be expected given the lower concentrations of nutrients measured in recent years. Several species of phytoplankton common to oligotrophic conditions were observed and although dominance by blue-green algae was noted throughout the summer this appears to be related to nitrogen-limited conditions created by a decrease in nitrogen concentrations in the summer months rather than an increase in phosphorus. Results of zooplankton sampling are consistent with these observations in that species typical of oligotrophic conditions (e.g., *Keratella cochlearis*) have become more prevalent.

The microbiological results are consistent with what has been previously reported and indicate water quality issues with respect to drinking water sources. All of the lake sites sampled except one met the drinking water guidelines for raw water with only disinfection during the summer low flow period; however, all of these sites exceeded the guidelines during the fall freshet period. In addition, the major inflows to Shawnigan Lake with domestic water licences (Shawnigan Creek and McGee Creek) exceeded the drinking water guidelines during both periods. The results showed that while the inflows and the outflow exceeded the drinking water guidelines during both sampling periods, the 90^{th} percentile values remained fairly consistent. In contrast, the majority of lake sites were within the drinking water guidelines in the summer low flow period but concentrations increased substantially during the fall freshet. The lake site concentrations were considerably higher than the inflow concentrations suggesting that bacterial contamination is reaching the lake through other pathways besides the inflows. The most likely source would be infiltrating water exposed to septic systems and tile fields. This may seem contradictory to the decrease in nutrient levels in the lake in recent years but can be explained by the high affinity for phosphorus from sewage disposal fields of the soils in this watershed (Wiens and Nagpal, 1983).

While the chemical water quality of Shawnigan Lake remains good, the fact that it's primary use for residents is as a domestic water supply should not be overlooked. Continuing growth and development within the watershed in addition to a high level of recreational boating will present challenges to protecting water quality in the future. Efforts to protect the existing chemical water quality of Shawnigan Lake and address the problems with bacteriological contamination must be driven at the local level. Local government agencies, water purveyors and lake stewards should be encouraged to take action to protect the water quality for current and future uses. Activities include public outreach and awareness to promote maintenance of on-site sewage systems, environmentally sound development practices to limit the impact on water quality and responsible land use practices to prevent contamination from other sources like forestry and agriculture.

Recommendations

- Ministry of Water, Land and Air Protection (WLAP) staff should continue spring overturn sampling, including water chemistry at multiple depths and biological parameters (chlorophyll *a*, phytoplankton, zooplankton).
- WLAP staff should conduct additional bacteriological sampling in 2004 to confirm results noted in this study. Efforts should be concentrated to areas in the lake within 10 m from domestic intakes as well as McGee Creek and the Shawnigan Creek inflow. Samples should be collected a minimum of five times in a 30-day period.
- WLAP should review and formalize the water quality objectives for Shawnigan Lake proposed by Nordin and McKean (1984). In addition to these, the following objectives should be added to protect Shawnigan Lake as a drinking water source:
    - E. coli: 10 CFU/100 mL (90^{th} percentile of a minimum of 5 samples within 30 days);
    - Enterococci: 3 CFU/100 mL (90^{th} percentile of a minimum of 5 samples within 30 days).
- Support should be provided to organized lake stewards to continue with basic water quality sampling through the BC Lake Stewardship Society. Other activities for lake stewards could include monitoring of aquatic macrophyte growth and distribution, and tracking sportfishing catches to monitor fish populations, especially bass and trout.
- The Cowichan Valley Regional District should ensure residential and commercial land development within the watershed take into account the potential impacts on the water quality of any such activities. Appropriate best management practices and planning techniques should be applied to protect Shawnigan Lake for domestic purposes and other current and future water uses.

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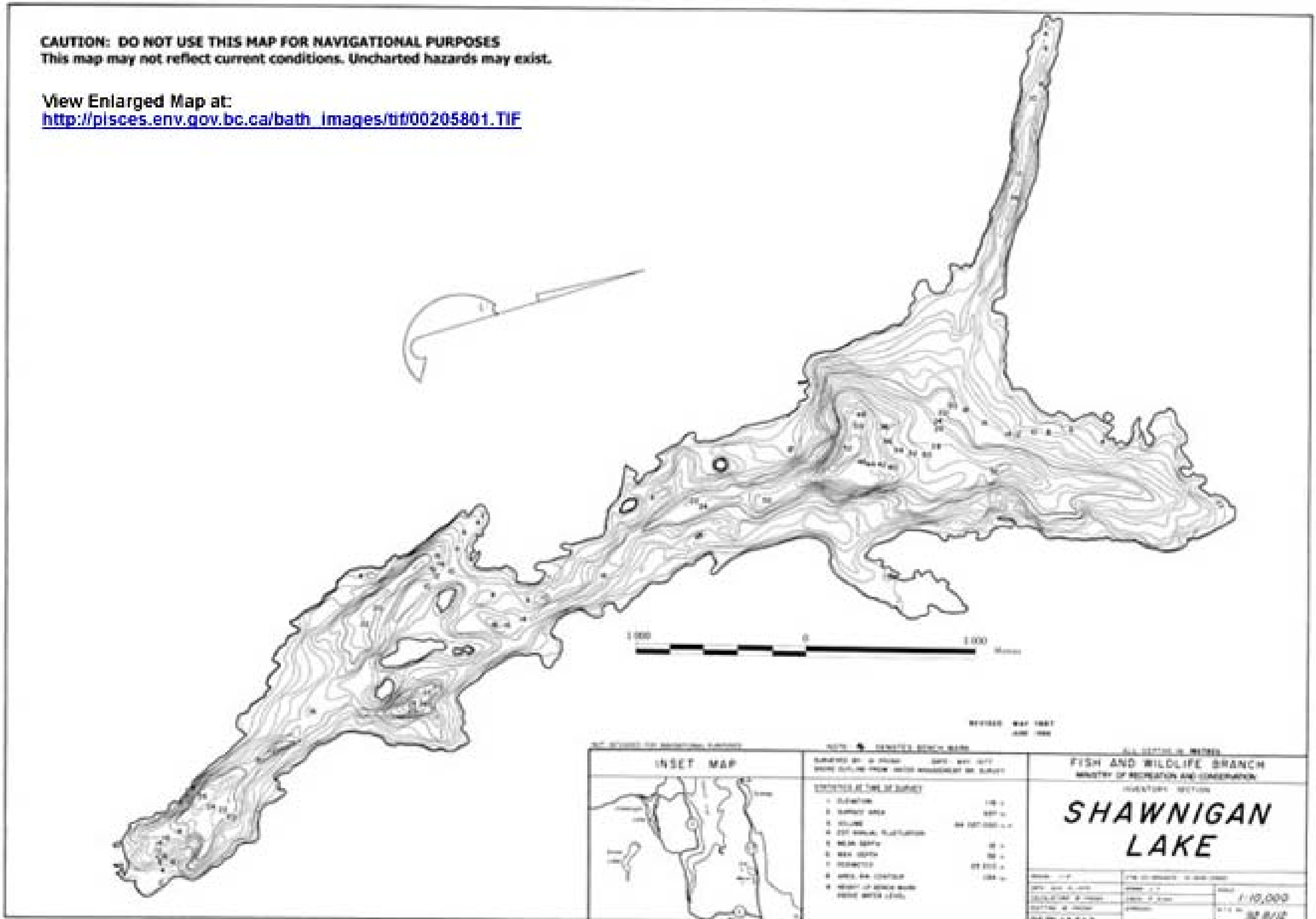
Appendix 1

Shawnigan Lake Bathymetric Map

CAUTION: DO NOT USE THIS MAP FOR NAVIGATIONAL PURPOSES
This map may not reflect current conditions. Uncharted hazards may exist.

View Enlarged Map at:
http://pisces.env.gov.bc.ca/bath_images/tif/00205801.TIF



Appendix 2

Shawnigan Lake Water Chemistry Results

Summary of water chemistry results for Shawnigan Lake site E222045 (Galley Restaurant). All results are reported in mg/L unless otherwise noted.

	1976 - 1979			1980 - 1989			1990 - 1999			2000 - Present		
	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =
General												
Alkalinity Total 4.5												
Color True (Col. Unit)										12	3	3
Color TAC (TAC)												
Hardness Total										20.5		1
pH (pH units)										7.4	0.1	2
Residue Filterable												
Residue Nonfilterable												
Residue Total												
Specific Conductance (uS/cm)										61	2	5
Turbidity (NTU)										0.49	0.06	5
Nutrients												
Ammonia Dissolved										0.015	0.023	6
Carbon Total Inorganic										3.9		1
Carbon Total Organic										3.4		1
Nitrate + Nitrite Dissolved										0.043	0.050	6
Nitrate Total												
Nitrogen Kjeldahl Total										0.16	0.02	5
Nitrogen Total										0.187	0.063	6
Organic Nitrogen Total										0.14	0.03	5
Ortho-Phosphate Dissolved												
Phosphorus Total										0.004	0.002	6
Phosphorus Total Dissolved										0.002	0	2
Metals												
Aluminum Total										0.07	0.06	3
Antimony Total										<0.06	0.03	3
Arsenic Total										<0.06	0.03	3
Barium Total										0.005	0.001	3
Beryllium Total										<0.001	0.001	3

	1976 - 1979			1980 - 1989			1990 - 1999			2000 - Present		
	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =	Mean	Std. Dev.	n =
Bismuth Total										0.00004	0.00002	2
Cadmium Total										<0.006	0.004	3
Calcium Total										6.4		1
Cobalt Total										<0.006	0.003	3
Copper Total										<0.006	0.003	3
Chromium Total										<0.006	0.003	3
Iron Total										0.012		1
Lead Total										<0.06	0.034	3
Magnesium Total										1.10		1
Manganese Total										0.005	0.004	3
Molybdenum Total										<0.01	0.006	3
Nickel Total										<0.02	0.011	3
Potassium Total										0.2		1
Selenium Total										<0.06	0.035	3
Silicon Total										1.64		1
Silver Total										<0.01	0.006	3
Sodium Total										3.30		1
Strontium Total										0.025	0.002	3
Sulfur Total										0.82		1
Tellurium Total												
Thallium Total										0.000003	0.000	2
Tin Total										<0.06	0.035	3
Titanium Total										<0.002		1
Vanadium Total										<0.01	0.006	3
Zinc Total										<0.002	0.003	3
Zirconium Total												

Appendix 3

Shawnigan Lake Surface Microlayer Water Chemistry Results

Table 1: Polycyclic aromatic hydrocarbon (PAH) results for selected Shawnigan Lake Sites (µg/L)

Date Sampled	Site	Sample	Acenaphthylene	Fluoranthene	Naphthalene	Pyrene	Total PAHs	Total Low MW PAH's	Total High MW PAH's
May 13/03	**North of**	Microlayer	< 0.01	0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01
	1199902	Water Column	< 0.01	0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01
May 13/03	**1199902**	Microlayer	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01
		Water Column	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01
May 13/03	**E222053**	Microlayer	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01
		Water Column	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01
May 13/03	**E222045**	Microlayer	0.09	0.02	**1.8**	0.003	2.7	2.7	0.05
		Water Column	< 0.01	0.01	0.02	0.001	< 0.05	0.03	< 0.01
Aug 13/03		Microlayer	< 0.01	< 0.01	0.01	< 0.01	< 0.05	< 0.01	< 0.01
		Water Column	< 0.01	0.01	< 0.01	0.01	< 0.05	< 0.01	0.02

Values that are above the Ministry Criteria are shown in **bold**.

Table 2: Dissolved and total metal concentrations in Shawnigan Lake microlayer and water column waters (µg/L)

Date Sampled	Site	Sample	Aluminum		Copper		Manganense		Lead		Zinc	
			Diss.	Tot	Diss.	Tot	Diss.	Tot	Diss.	Tot	Diss.	Tot
May 13/03	**North of**	Micro.	24.3	103.4	2.12	2.79	0.645	**62.95**	0.065	0.47	1.05	3.9
	1199902	W. C.	5.7	10.1	0.54	1.06	0.07	4.17	0.015	0.08	1.1	1.3
May 13/03	**1199902**	Micro.	37.1	198	1.88	4.2	1.25	11.4	0.57	5.19	155	11.8
		W. C.	15.4	18.1	0.47	0.54	0.551	1.98	< 0.1	0.1	0.7	0.6
May 13/03	**E222053**	Micro.	50	210	1.31	3.04	0.256	48.5	0.04	3	18.1	150
		W. C.	6.5	11.6	0.43	0.57	0.039	4.21	< 0.01	0.03	0.3	0.5
May 13/03	**E222045**	Micro.	50.2	136	1.37	2.29	0.694	9.47	0.08	0.59	6.7	1.8
		W. C.	14.5	17.7	0.56	0.66	0.597	2.25	0.01	0.02	1.2	1
Aug 13/03		Micro.	6.6	11	1.41	1.79	1.41	5.12	0.02	0.17	12.6	14.6
		W. C.	15.9	257	2.31	4.81	0.585	1.59	0.09	2.22	1.9	14.3

Micro: Surface microlayer
WC: Underlying water column
Ministry criteria exceedences are shown in **bold**.

Table 3: Microtox® results for selected Shawnigan Lake Sites

Test	E222045		1199902	E222053	North of 1199902
	13-May-03	13-Aug-03	13-May-03	13-Aug-03	13-Aug-03
MicroTox EC50 5 min - SML	>90	>90	>90	>90	>90
MicroTox EC50 5 min - WC	>90	>90	>90	>90	>90
MicroTox EC50 15 min - SML	>90	>90	>90	>90	>90
MicroTox EC50 15 min - WC	>90	>90	>90	>90	>90

SML = surface microlayer
WC = water column

Table 4: Results of the Surrogate Recovery of PAH analytes for selected Shawnigan Lake Sites

Date Sampled	Site	Sample	d10-Phenanthrene	d12-Perylene
May 13/03	**North of**	Microlayer	84.5	78
	1199902	Water Column	85	73.5
May 13/03	**1199902**	Microlayer	78	76
		Water Column	75	74
May 13/03	**E222053**	Microlayer	84	82
		Water Column	81	58
May 13/03	**E222045**	Microlayer	75	70
		Water Column	76	72
Aug 13/03		Microlayer	79	78
		Water Column	77	60

Appendix 4

Biological Monitoring Results

Site 1199901 phytoplankton results (cells/mL) February 2003 - February 2004.

	Organism	11-Feb-03	13-May-03	25-Jun-03	23-Jul-03	13-Aug-03	23-Sep-03	21-Oct-03	18-Nov-03	12-Feb-04
Order:	**Centrales**									
	Cyclotella bodanica	8.4	189.0	16.8	present	present	present	present	1.4	1.4
	Cyclotella sp.			61.6	present				present	88.2
	Melosira italica	310.8	67.2			14.0	2.8	5.6	30.8	
	Melosira sp.	present		present	25.2		present	present	present	present
	Stephanodiscus sp.			present						
Order:	**Chlorococcales**									
	Ankistrodesmus cf falcatus	present								
	Ankistrodesmus sp.							present	present	1.4
	Botryococcus braunii		present	present	present	present	33.6	present	present	33.6
	Crucigenia quadrata		present	11.2		11.2	present	present	present	5.6
	Crucigenia rectangularis			present	22.4	present		present		
	Dactylococcopsis Smithii				present	present				
	Dictyosphaerium pulchellum		present							
	Elakatothrix gelatinosa	present	present	present	2.8	present	present	present	4.2	
	Kirchneriella sp.			present	5.6	5.6	present		present	
	Nephrocytium limneticum		present	present		present	present			present
	Nephrocytium sp.		present		present				present	
	Oocystis cf parva		16.8							
	Oocystis sp.	present	16.8	11.2	5.6	16.8	present	present	present	present
	Pediastrum tetras					present				
	Quadrigula closterioides		present	present	present	present	11.2	present	present	
	Quadrigula lacustris			present			present	present		present
	Scenedesmus cf arcuatus		present					present	present	
	Scenedesmus cf denticulatus		present		present	present			present	
	Scenedesmus quadricauda					22.4				
	Scenedesmus minutum				present					
	Scenedesmus sp.					present	present		present	present
	Schroederia setigera		present							
	Selenastrum minutum					present				
	Selenastrum sp.	present								
	Sphaerocystis schroeteri	present	89.6	present	present		present	present		
	Tetraedron sp.						present	present		
Order:	**Chroococcales**									
	Agmenellium glauca					present				
	Agmenellium tenuissima			present				present		
	Anacystis elachista	present	140.0	336.0	336.0	392.0	140.0	126.0	112.0	present

Site 1199901 phytoplankton results (cells/mL) February 2003 - February 2004.

	Organism	11-Feb-03	13-May-03	25-Jun-03	23-Jul-03	13-Aug-03	23-Sep-03	21-Oct-03	18-Nov-03	12-Feb-04
	Anacystis limneticus	present	56.0	492.8	56.0	28.0	5.6	28.0	present	present
	Anacystis sp.							present	present	
	Gomphosphaeria aponina				44.8	present	44.8	98.0	present	present
	Gomphosphaeria sp.								present	
	Unidentified				present					
Order:	**Cryptomonadales**									
	Chroomonas acuta	58.8	78.4	75.6	25.2	5.6	44.8	85.4	135.8	61.6
	Cryptomonas ovata/erosa	present	64.4	16.8	16.8	2.8	7.0	53.2	39.2	1.4
	Cryptomonas sp.	2.8	present		present	present	present	present	present	present
Order:	**Dinokontae**									
	Ceratium hirundinella		present	2.8	present	present	present	present	present	
	Perinidinium cf inconspicum		7.0	5.6	2.8	11.2	4.2	12.6		
	Perinidinium / Glenodinium	present	present	present		present	present	present	present	1.4
Order:	**Euglenales**									
	Euglena sp.		present					present		
	Trachelomonas sp.						present	present	present	
	Unidentified	present								
Order:	**Nostocales**									
	Anabaena cf circinalis			present						
	Anabaena cf flos-aquae					present		present		
	Anabaena sp.	present		present	8.4	5.6	2.8	11.2	present	
	Nostoc sp.							present		
Order:	**Ochromonadales**									
	Chrysosphaerella longspina					present	11.2			
	Dinobryon bavaricum	2.8	65.8	present	16.8	14.0	1.4	4.2	present	
	Dinobryon divergens	present	149.8	44.8	8.4	2.8	119.0	9.8	14.0	11.2
	Dinobryon elegantissimum			present		5.6				
	Dinobryon sertularia		18..2			present	present	present	present	present
	Dinobryon sp.	present	7.0		present		1.4	present		present
	Mallomonas akrokomonas	11.2	8.4					present		12.6
	Mallomonas producta		1.4							
	Mallomonas sp.	present	16.8	present	present			present	present	
	Synura uvella		present							
	Synura sp.							present	present	
	Unidentified						present	present	present	
Order:	**Oscillatoriales**									
	Lyngbya limnetica			present	present	28.0	present	present	present	

Site 1199901 phytoplankton results (cells/mL) February 2003 - February 2004.

	Organism	11-Feb-03	13-May-03	25-Jun-03	23-Jul-03	13-Aug-03	23-Sep-03	21-Oct-03	18-Nov-03	12-Feb-04
	Lyngbya sp.							present		
	Oscillatoria cf tenuis			present						
Order:	**Pennales**									
	Achnanthes flexella		1.4	present		present	present	present	present	
	Achnanthes minutissma	2.8	5.6	11.2	5.6	2.8	present	2.8		1.4
	Amphora ovalis			present						
	Asterionella formosa	36.4	144.2	present		present	33.6	5.6	2.8	23.8
	Ceratoneis sp.		present	present				present		present
	Cocconeis placentula			present		present	present			present
	Cymatopleura cf solea		present							
	Cymbella cf affinis		present							
	Cymbella cf minuta		present				present	present	present	present
	Cymbella sp.	present		present	present	present	present	present	present	present
	Diatoma elongatum							present		
	Diatoma hiemale							present		
	Diatoma sp.			present					present	
	Diploneis sp.									present
	Epithemia sorex								present	
	Epithemia sp.					present				
	Eunotia pectinalis	present	present	present	present	present	present	present	present	present
	Eunotia sp.		present	present					present	
	Fragilaria crotonensis	2.8	5.6	present	present	present	present	present	present	present
	Fragilaria sp.	present		present		present	present	present	present	
	Frustulia rhomboides		1.4			present		present	present	1.4
	Frustulia sp.				present					
	Gomphonema constrictum		present							
	Gomphonema olicaveum							present		present
	Gomphonema sp.	present			2.8	present		present	present	present
	Navicula cf radiosa		present							
	Navicula sp.		1.4	present	2.8	2.8	present	present	present	present
	Nitzschia sp.								present	
	Pinnularia sp.	present								
	Pleurosigma / Gyrosigma		present					present		present
	Rhopalodia gibba		present	present					present	
	Stauroneis sp.							present		
	Surirella sp.		present				present	present	present	
	Synedra actinastroides		present							

Site 1199901 phytoplankton results (cells/mL) February 2003 - February 2004.

	Organism	11-Feb-03	13-May-03	25-Jun-03	23-Jul-03	13-Aug-03	23-Sep-03	21-Oct-03	18-Nov-03	12-Feb-04
	Synedra ulna		present	present				present	present	
	Tabellaria fenestrata	present	present	present	5.6	present	present	present	present	present
	Tabellaria flocculosa	present	present					present	present	present
	Unidentified	present	present		present	present	present	present	1.4	present
Order:	**Rhizochrysidales**									
	Diceras phaseolus	2.8	1.4	present	present	present	present	present	present	present
Order:	**Tetrasporales**									
	Gloeocystis ampla		98.0	277.2	89.6	44.8	56.0	84.0	11.2	22.4
Order:	**Ulothricales**									
	Ulothrix sp.		2.8							
Order:	**Volvocales**									
	Chlamydomanas sp.			2.8		present		present	present	
	Eudorina elegans			present		present				
	Unidentified			present	present	present	present	present	present	
Order:	**Zyngematales**									
	Arthrodesmus sp.				present			present		
	Closterium sp.					present	present	present		
	Cosmarium sp.	present	present	present		present	present	present	present	
	Mougoetia sp.		present			present				
	Spirogyra sp.							present		
	Spondylosium planum		present	16.8	2.8	present	present	present		
	Staurastrum paradoxum				present	present				
	Staurastrum sp.						present	present	present	
	Xanthidium sp.		present							
	Unidentified			present		present	present	present	present	
	Unidentified colonial cells		present							
	Unidentified branched filamentous algae						present		present	present
	Unidentified filamentous algae			present				present		
	Unidentified flagellates	present			present	present	present	present	present	present

Appendix 5

Bacteriological Monitoring Results

Shawnigan Lake bacteriological results: August 20 - September 18, 2003. Guideline exceedances are denoted with bold type

E. coli results (CFU/100 mL)

Site no.	Site Description	Sampling date: 20-Aug-03	27-Aug-03	9-Sep-03	10-Sep-03	18-Sep-03	90th Percentile	Geometric Mean
E222045	Galley Restaurant Area	1	2	1	<1	<1	2	1
E222048	Easter Seal Camp Beach	1	<1	<1	1	1	1	1
E222055	West Shawnigan Lake Park	17	<1	<1	<1	<1	10	2
E246900	Shawnigan Lake Resort	<1	<1	1	<1	<1	1	1
1199906	Shawnigan Creek inflow	6	44	1200	250	120	**820**	**99**
1199909	McGee Creek	12	9	70	32	56	**64**	27
1199911	West Arm inflow	11	4	3	8	24	**19**	8
1199912	Shawnigan Creek outflow	170	75	11	87	120	**150**	68
1199916	Shawnigan Lake inflow at E. Shawnigan Rd.	Insufficient flows						
							Drinking water guideline = (10 CFU/100 mL)	Recreational use guideline = (77 CFU/100 mL)

Enterococci results (CFU/100 mL)

Site no.	Site Description	20-Aug-03	27-Aug-03	9-Sep-03	10-Sep-03	18-Sep-03	90th Percentile	Geometric Mean
E222045	Galley Restaurant Area	1	<1	<1	<1	2	2	1
E222048	Easter Seal Camp Beach	<1	<1	<1	<1	<1	0	1
E222055	West Shawnigan Lake Park	5	7	8	<1	<1	**8**	3
E246900	Shawnigan Lake Resort	<1	<1	1	<1	1	1	1
1199906	Shawnigan Creek inflow	7	15	35	34	67	**54**	**24**
1199909	McGee Creek	34	12	65	35	48	**58**	**34**
1199911	West Arm inflow	85	13	14	12	28	**62**	**22**
1199912	Shawnigan Creek outflow	140	28	19	91	73	**120**	**55**
1199916	Shawnigan Lake inflow at E. Shawnigan Rd.	Insufficient flows						
							Drinking water guideline = (3 CFU/100 mL)	Recreational use guideline = (20 CFU/100 mL)

Fecal Coliform results (CFU/100 mL)

Site no.	Site Description	20-Aug-03	27-Aug-03	9-Sep-03	10-Sep-03	18-Sep-03	90th Percentile	Geometric Mean
E222045	Galley Restaurant Area	<1	2	<1	1	1	2	1
E222048	Easter Seal Camp Beach	3	2	<1	2	1	3	2
E222055	West Shawnigan Lake Park	38	24	5	<1	<1	**32**	5
E246900	Shawnigan Lake Resort	<1	<1	1	<1	<1	1	1
1199906	Shawnigan Creek inflow	31	43	2200	280	130	**1432**	161
1199909	McGee Creek	30	17	83	57	100	**93**	47
1199911	West Arm inflow	33	19	3	7	37	**35**	14
1199912	Shawnigan Creek outflow	240	118	21	120	140	**200**	100
1199916	Shawnigan Lake inflow at E. Shawnigan Rd.	Insufficient flows						
							Drinking water guideline = (10 CFU/100 mL)	Recreational use guideline = (200 CFU/100 mL)

For the purpose of calculating 90th percentile values, <1 = 0
For the purpose of calculating geometric mean values, <1 = 1