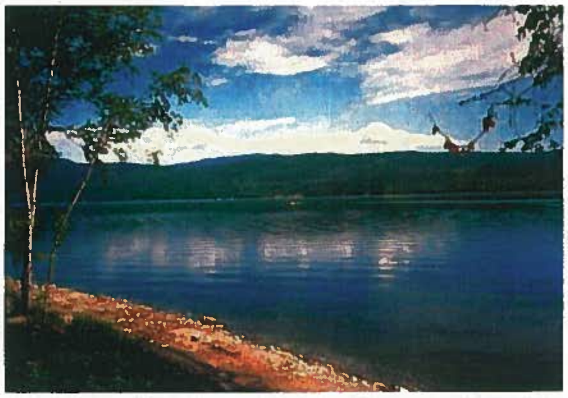

Final Report
November 7th 2010

Integrated Water Quality Monitoring Plan for the Shuswap Lakes, BC

Prepared for the:
Fraser Basin Council
Kamloops, BC

northwest hydraulic consultants

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Project 35138

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NHC. 2010. *Integrated Water Quality Monitoring Plan for the Shuswap Lakes, BC.* Prepared for the Fraser Basin Council. November 7th[th], 2010.

CREDITS AND ACKNOWLEDGEMENTS

We would like to acknowledge to Mike Crowe (DFO, Kamloops), Ian McGregor (Ministry of Environment, Kamloops), Phil Hallinan (Fraser Basin Council, Kamloops) and Ray Nadeau (Shuswap Water Action Team Society) for supporting the development of the Shuswap Lakes water quality monitoring plan. Special thanks to Gabriele Matscha for comments on the draft report, and Bob Grace and Dennis Einarson (MOE, Kamloops) for permitting access to their draft report entitled "A Preliminary Assessment of Water Quality and Limnology of Shuswap Lake" and to Carol Danyluck (MOE, Kamloops) for the grey water data they collected on Shuswap Lake in 2008. Thanks to Don Holmes and Dr. Rick Nordin, MOE (retired) for their previous contributions to monitoring the water quality of Shuswap Lake.

EXECUTIVE SUMMARY

Shuswap Lake, along with Little Shuswap, Adams and Mara lakes are the centerpiece of the economic, social and environmental sustainability of the Shuswap basin. They collectively support a thriving tourism industry and an expanding residential and commercial property market. Shuswap Lake is the centre of Canada's houseboat industry, the nursery lake for the world famous Adams River sockeye salmon and the source of drinking water for several local communities and hundreds of lakeshore residents.

The current pace and scale of largely unregulated near-shore residential, commercial and industrial development, and upland agricultural activities in the Shuswap watershed, is threatening the water quality and recreational attractiveness of the Shuswap lakes. A widespread noxious algae bloom occurred in Shuswap Lake in June 2008, and Mara Lake in May 2010, demonstrating that despite their large size and rapid flushing rate, these lakes are susceptible to water quality degradation due to increased anthropogenic loading of limiting nutrients from within the Shuswap watershed.

Numerous limnological monitoring programs and water quality studies have been carried out on Shuswap Lake and Mara Lake since the early 1970s, largely due to agency and public concerns about the effects of various point and non-point discharges (i.e., sewage, industrial, agricultural and urban runoff) on water quality and fish habitat. These studies concluded that the overall water quality in Shuswap Lake and Mara Lake was generally good, with the exception of some specific areas. For example, water quality in Tappen Bay was declining (mesotrophic to eutrophic) due to development pressures. Salmon Arm water quality ranged from oligotrophic to meso-eutrophic. Seymour and Anstey Arm had the highest water quality, and were rated as ultra-oligotrophic to oligotrophic. The Main Arm of Shuswap Lake was oligotrophic, but was also showing signs of declining water quality in some embayments along the north and south shores of the main arm (e.g., Blind Bay). Some minor nutrient enrichment was detected in the Sicamous area, and the south end of Mara Lake.

Shuswap Lake and Mara lakes are now exhibiting initial signs of declining water quality. Although this only occurs in isolated areas, and the deep lake stations in Shuswap Lake are still relatively pristine, subtle shifts in water quality are appearing, some areas are already eutrophic, and the first appearance of a lake-wide algae bloom in Shuswap Lake in June 2008, and Mara Lake in May 2010, provided a harbinger of possible future water quality conditions. The main threat is the old nemesis of eutrophication i.e., the excessive addition of nitrogen and phosphorus from a variety of human activities: sewage treatment plant discharges, agricultural runoff, improperly installed and operated septic systems and poorly designed urban runoff.

The degree to which emerging contaminants (e.g., personal care products, flame retardants, pharmaceuticals) are present in Shuswap Lake, Mara Lake and major tributaries is unknown, due to limited monitoring budgets and the traditional scope of regional water quality monitoring programs. Based on surveys from other large lakes in Western Europe, the US and Canada, it is likely that some emerging contaminants are already present in Shuswap Lake, Mara Lakes and some tributaries (i.e., Shuswap River), although the concentrations are likely quite low, and the ecological implications uncertain at this time. Illegally introduced species of fish are already present in Adams Lake (and were recently removed from several small lakes surrounding Shuswap Lake), and may have migrated into Shuswap Lake, placing this important sockeye salmon aquatic ecosystem at risk.

A five year comprehensive monitoring program is outlined to monitor the *known* and *emerging threats* to drinking water quality and aquatic ecosystem health in Shuswap and Mara lakes, and the surrounding tributaries. The program builds on the current Ministry of Environment monitoring program, and must address the immediate *known concerns* from eutrophication, grey water discharges and urban and agricultural runoff, as well as assess the significance of *emerging threats* to sources of drinking water and aquatic ecosystem health. This new program is estimated to range in cost from $148,574 in Year 1 to $118,200 in Years 4 and 5, assuming MOE provides a sampling crew, seaworthy vessel and monitoring equipment, and prepares the annual State-of-the-lakes report.

The best defense for preventing further water quality degradation in the Shuswap area lakes is a detailed assessment and analysis of the nutrients and contaminants being discharged into these lakes, followed by concrete action plans to reduce or eliminate nutrients and contaminant loading as required. The entire process rests on the foundation of a scientifically defensible basin wide monitoring program that can identify sources and track trends in water quality and aquatic ecosystem health through time. The threats to Shuswap area lakes in the 21st Century are much greater than the early 1970s when 'climate change', 'emerging contaminants', 'houseboat capitals', '*E. coli* O157:H7' and 'agricultural intensification' were unknown terms.

The monitoring program must be integrated with water quality monitoring programs that are being conducted by Regional Districts or municipalities within the Shuswap basin. This will reduce monitoring costs, eliminate redundant sampling, and provide a diversity of funding sources to ensure the long term viability of the monitoring program. The data collected from the monitoring program should be made widely available to the public once the raw data has been checked for errors and omissions. A web-based data base is the logical way to disseminate the data to the public at the least cost.

A "State-of the Lakes" water quality report should be issued annually, once all of the current years monitoring data has been reviewed, interpreted and disseminated in a standard reporting format. The reports should be posted on a Shuswap lakes web-site to minimized printing costs. These activities will build credibility with the public and generate long term regional support for the monitoring program.

It is crucial to involve the public and Shuswap and Mara lake NGO's in the development and implementation of the Shuswap lakes monitoring program. The public and area NGO's attended various SLIIP presentations throughout 2007 and 2008 and provided considerable input to the development of the SLIPP process and final report. Protecting and improving the water quality of Shuswap and Mara lakes was consistently ranked among the highest priority concerns by Shuswap area residents.

It is unlikely that the water quality and aquatic ecosystem health of the Shuswap lakes can be adequately protected over the long term unless an integrated comprehensive monitoring program exists, followed by concrete action plans to reduce nutrient and contaminant loadings as required. The hard lesson that has been repeatedly demonstrated around the world, is that it is safer and far less expensive and environmentally disruptive to prevent water quality problems from developing through early detection and proactive control/elimination, rather than attempting expensive and uncertain remedial actions after the problem has become widespread. As our grandmothers used to remind us *"An ounce of prevention is worth a pound of cure"*.

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1 INTRODUCTION

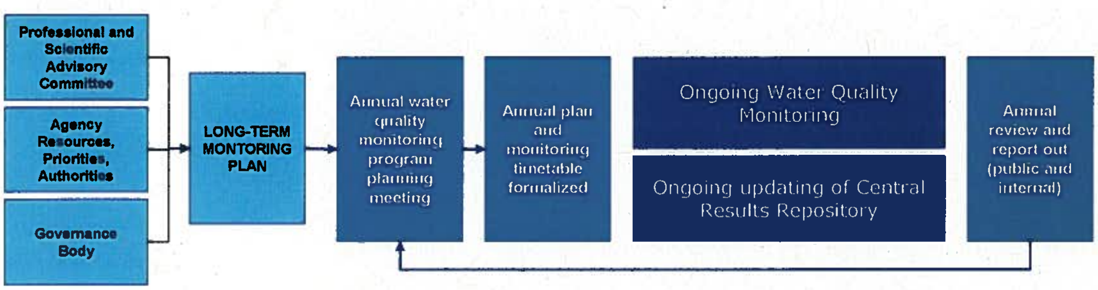
1.1 BACKGROUND

Shuswap Lake, along with Little Shuswap, Adams and Mara lakes are the centerpiece of the economic, social and environmental sustainability of the Shuswap watershed. Shuswap Lake and Mara Lake support a thriving market for tourism, residential and recreational property development, and is the centre of Canada's houseboat industry. Shuswap Lake is the nursery lake for the world famous Adams River sockeye salmon and associated world class rainbow trout fishery. Adams Lake supports both early and late run sockeye stocks which were decimated in the early 1900s, and have recently been the target of stock rebuilding efforts, including lake fertilization.

However, the current pace and scale of largely unregulated near-shore residential, commercial and industrial development, and upland agricultural activities in the Shuswap drainage is threatening the water quality and recreational attractiveness of Shuswap Lake. A large, noxious algae bloom occurred in Shuswap Lake in June 2008, and Mara Lake in May 2010, and were the subject of considerable local, provincial and national media attention. These algal blooms confirm that Shuswap and Mara lakes, despite their large size and rapid flushing rates, are susceptible to water quality degradation due to increased anthropogenic loading of limiting nutrients from within the Shuswap watershed.

In 2008, the Shuswap Lake Integrated Planning Process (SLIPP) issued a Strategic Plan that recommended the development and implementation of an inter-agency lake, foreshore and tributary water quality monitoring program (Figure 1) on Shuswap Lake and Mara Lake to establish their current trophic status, relate this to past trophic states and identify trends in trophic trajectory.

Figure 1. Flow chart of the SLIPP annual water quality monitoring process



An annual, comprehensive basin-wide water quality monitoring program will allow early spatial and temporal detection of changes in water quality, identify dominant sources of nutrient loading, and track the water quality and food web implications of climate change in Shuswap Lake, thus enabling regulatory agencies to enact appropriate legislation and take the necessary corrective measures to control nutrient loading and protect water quality.

The monitoring program will build on the strengths of prior Ministry of Environment, Columbia Shuswap Regional District and Department of Fisheries and Oceans monitoring efforts to ensure maximum continuity. The SLIPP Strategic Plan states the implementation of a basin-wide in-lake and tributary water quality monitoring program will result in:

Improved access to credible and scientific knowledge on water quality to support decision making;

1. Increased efficiency and coordination in the allocation of monitoring resources, with priority areas receiving necessary attention;
2. Enhanced understanding of water quality issues and trends to support decision making;
3. Increased collective access to and management of water quality and monitoring data.

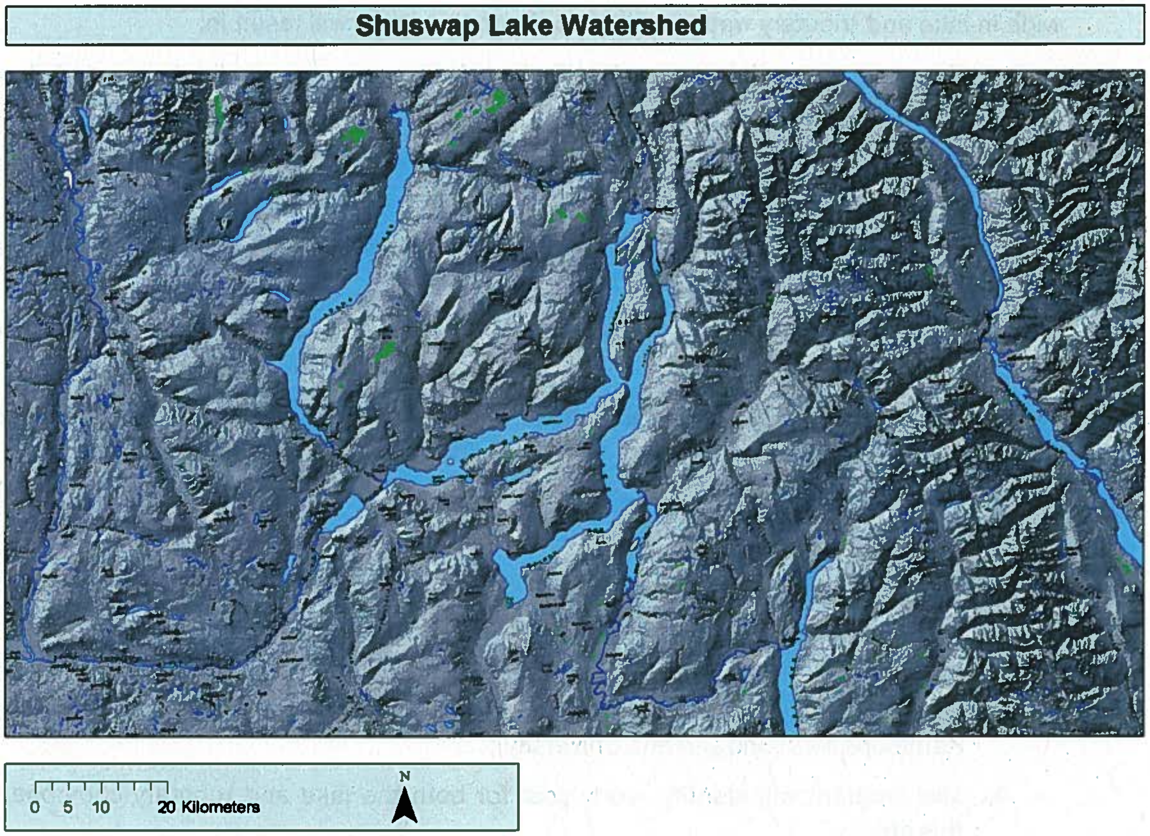
In response to the SLIPP recommendations, the Fraser Basin Council issued a contract to Northwest Hydraulic Consultants Ltd. with the following project deliverables:

1. Develop a comprehensive, annual integrated water quality monitoring program with a 3-5 year scope to protect water quality;
2. The monitoring program will be designed to identify the spatial and temporal requirements of a basin-wide monitoring program;
3. Components of the monitoring program will include physical, chemical and biological parameters, and assessment of lake sediment core data (currently underway by Kamloops MOE and Queens University);
4. The program will identify yearly cost for both the lake and tributary components of this study;
5. The program will identify basic water quality monitoring costs after the 3-5 study is completed; and
6. The contractor will present the findings to the SLIPP Water Quality Technical Team for implementation.

1.1.1 General characteristics

Shuswap Lake is a large (310 km^2) valley bottom lake located in the south eastern portion of the Fraser River drainage basin at an elevation of 347 m. The lake has a complex shape; with four roughly 'H' shaped arms, several bays and a constrictive narrows (i.e., Cinnemosun Narrows) between Seymour Arm and Anstey Arm (Figure 2). The surrounding watershed is quite large, covering 15,354 km^2, and consists of middle elevation plateaus, several highlands (i.e., Columbia Highland) and the rugged Monashee mountain range to the East and North.

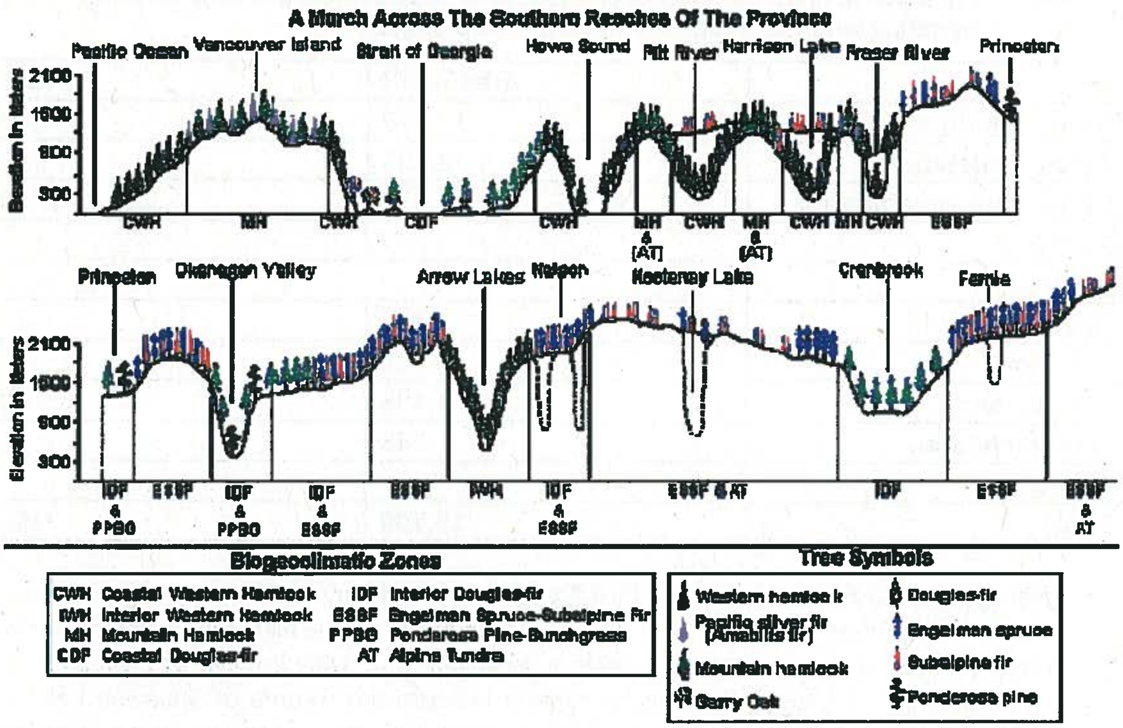
Figure 2. Shuswap Lakes watershed



The Shuswap watershed is sufficiently large that it spans two biogeoclimatic zones (Figure 3). The eastern portion of the watershed lies in the wet Interior Western Hemlock biogeoclimatic zone, which receives 60-145 cm of annual precipitation and is comprised mainly of erosion resistant low nutrient Precambrian granitic rock. The geology of Seymour Arm and Anstey Arm is mainly granitic. The western portion of the Shuswap Lake watershed is in the Interior Douglas Fir biogeoclimatic zone, which receives only 35-60 cm of annual precipitation, and is comprised primarily of more nutrient rich Jurassic period limestone formations. A large limestone formation is located on the northwestern shores of Salmon Arm.

The higher elevation areas of the Shuswap watershed lie in the Engleman Spruce-Subalpine Fir zone, Montane Spruce Zone, and Alpine tundra zones. As a result of the watersheds' variable geology, soil type, vegetation cover and prevailing weather patterns, the hydrological responses and nutrient export coefficients of the various drainages and sub-drainages vary considerably throughout the Shuswap catchment basin.

Figure 3. Biogeoclimatic zones of Southern British Columbia



This has important consequences with respect to land use activities, and the resulting nutrient loading potential and water quality in the Shuswap basin lakes. The land use in the Shuswap Lake watershed was dominated by natural woody vegetation, followed by pasture land, herbaceous vegetation and crop fields (Table 1; Stockner, 1994).

There are 18 major and numerous minor tributaries in the Shuswap Lake drainage basin, which is one of the few large lakes in BC without a dam or flow control structure on the main lake (Table 2). BC Hydro maintains a dam and generation facility with 5.2 MW capacity at the outlet of Sugar Lake, and a second dam with 5.2 MW capacity generation facility at Shuswap Falls on the Shuswap River.

Table 1. Land use in Shuswap Lake catchment area in 1986. Note: MOE is currently updating land use information though a GIS project.

	Area (km^2)	Percent
Natural landscape	13,770	85
Woody vegetation	12,393	90
Herbaceous vegetation	1,377	10
Swamp	-	-
Others	-	-
Agricultural land	2,430	15
Crop field	729	30
Pasture land	1,458	60
Settlement area	243	10
Others	-	-
Total	**16,200**	**100**

The average volume Shuswap Lake is 19.13 x 10^9 m^3 (Stockner, 1994), resulting in natural water level fluctuations of 3-4 m each year. As a result of these high runoff volumes, the residence time of water in Shuswap Lake is relatively low, with an average whole lake residence time of ~ 2 years. Note: some reports indicate the volume of Shuswap Lake is 15.7 x 10^9 m^3, based on an early UBC Fisheries computer graphics program used by Holmes (1987), however the value of 19.13 x 10^9 m^3 is used in this report.

Table 2. Major tributaries of Shuswap Lake

Shuswap Lake basin	Major tributaries
Salmon Arm	Salmon River, Tappen Creek, White Creek, Canoe Creek
Sicamous Arm	Shuswap River, Eagle River
Anstey Arm	Anstey River, Four Mile Creek, Queest Creek, Hunakwa Creek
Seymour Arm	Seymour Creek, Two Mile Creek, Five Mile Creek, Blueberry Creek, Celista Creek
West Arm	Adams River, Scotch Creek, Ross Creek

In terms of consumptive water use, Shuswap Lake is the supply source of domestic water for several local communities and hundreds of lakeshore residents (Table 3). It should be acknowledged that there are a large number of unlicensed domestic intakes that are not included in Table 3 (G. Matscha, pers. comm., Kamloops MOE).

Table 3. Summary of Shuswap Lake potable use water licenses*

Type of water license	No. of active and pending licenses
Domestic	576
Waterworks – local authority	30
Waterworks - other	8

*Current Shuswap Lake water license data obtained from:
http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input

The outflow from Shuswap Lake, after passing through little Shuswap Lake, is a major source of domestic, irrigation and industrial process water for Chase, Pritchard, and the City of Kamloops. The Domtar plant at Mission Flats is the second largest northern bleached Kraft mill in North America, with a pulp production capacity of 477,000 tonnes yr^{-1}. Hence, the raw water quality of Shuswap Lake is important for domestic and industrial use, even far outside the main lake basin.

Shuswap Lake is internationally known as the Houseboat Capital of Canada, and the industry boasts of having the largest houseboat fleet in Canada, and one of the largest in the world. Shuswap Lake is also the nursery lake for the world famous Adam River sockeye run. Sockeye salmon returns to Shuswap Lake are strongly cyclic, and comprised of a strong dominant year, a smaller subdominant year, and two small non-dominant years in each four year cycle. Escapement in the 1980s were quite large (e.g., 4 million), however, since 1990 both dominant and subdominant escapements have declined and were substantially below predicted optimum escapements (Shortreed et al., 2001). All of these uses depend on clean, high quality water.

1.1.2 CIRCULATION, MORPHOMETRY AND LIMITING NUTRIENTS

Shuswap Lake develops strong vertical thermal stratification during summer, then cools and circulates completely throughout the fall, winter and spring months, and is therefore classified as a 'warm monomictic' lake. The lack of regular ice cover during winter and complete vertical mixing results in isothermal temperature profiles and homogenous water column chemistry profiles throughout the lake. Stockner and Shortreed (1991) suggested the term 'warm dimictic' is applicable due to occasional calm periods of cold weather and inverse thermal stratification. However, with the onset of climate change and warmer winters in the Southern Interior, this classification will likely disappear. The thermocline in Shuswap Lake is generally strong but shallow (i.e., ~10 m) from May to October due to prevailing calm winds and warm summer conditions. Similarly sized interior lakes and reservoirs (i.e., Kamloops Lake and Arrow Lakes) typically have thermocline depths of ~30-40 m due strong wind driven mixing of epilimnetic layers.

Epilimnetic temperatures (likely epilimnetic diurnal stratification) in Shuswap Lake can exceed 20 °C in summer, which has implications for salmon growth and survival, and general water quality. The high surface temperatures can exclude juvenile sockeye from feeding on the epilimnetic plankton community, and has a negative effect on juvenile sockeye growth rates. Shuswap Lake sockeye fry are substantially smaller (range 1.5-3.6 g) than sockeye produced at similar densities in less productive Fraser drainage nursery lakes (e.g., Chilko Lake and Quesnel Lake; Shortreed et al., 2001). High epilimnetic temperature appear to provide a thermal refuge for zooplankton, which restricts juvenile sockeye growth rates, but may provide some water quality protection against increased nutrient loading by virtue of the grazing capability of the seasonally protected epilimnetic zooplankton community. This natural phenomenon should not be relied upon as passive protection against excessive nutrient loading, as the June 2008 algae bloom clearly demonstrated.

Shuswap Lake has the largest surface area and largest watershed area of the 4 main Shuswap area lakes, and is the second deepest. Adams Lake, by virtue of its extreme depth, has the largest lake volume, followed by Shuswap Lake, Mara Lake and Little Shuswap (Table 4). The bulk hydraulic residence time of Shuswap Lake is quite short, only 2.1 years, which reflects the high runoff volume from its large watershed. Localized flushing rates are therefore important, and have been estimated as ~2-3 months for the Main Arm and ~ 3 years for Salmon Arm (G. Matscha, pers. comm., Kamloops MOE).

The flow rates at the Inland Waters Directorate stream gauge number 08LE031 on the South Thompson River at Chase have ranged from a minimum of 179 $m^3\ sec^{-1}$ in 1929 to a maximum of 415 $m^3\ sec^{-1}$ in 1976 (Water Survey of Canada, 1985). Over the 69 period of record, the mean outlet flow was 288 $m^3\ sec^{-1}$. Using this mean discharge, the simple volumetric replacement time (i.e., lake volume divided by mean annual discharge) results in a volumetric replacement time for Shuswap Lake of 2.1 years, assuming the volume of Shuswap Lake is $19.13 \times 10^9\ m^3$, and not the earlier estimate of $15.7 \times 10^9\ m^3$.

The nutrient concentration of Shuswap Lake varies throughout some of the numerous arms and bays of the lake due to the spatially variability of towns, point source discharges, residential developments and tributary inputs which are reflective of non-point source watershed activities (Figure 4). For example, Sandy Point and Fraser's Beach exhibit higher nutrient concentrations than Sorrento (G. Matscha, pers. comm., Kamloops MOE). In general, Shuswap Lake, *as a whole*, can be currently classified as mid-upper oligotrophic, or low in nutrients and high in quality for fish, contact recreation and domestic uses. However, as will be discussed later, there are significant spatial and temporal differences within Shuswap Lake that deviate from this high quality *main lake* trophic state, and water quality monitoring and subsequent trophic classifications must be conducted on a site by site basis to capture the spatial complexity of Shuswap Lake.

Table 4. Morphometric features of Shuswap, Little Shuswap, Adams and Mara Lake

	Shuswap Lake	Little Shuswap	Adams Lake	Mara Lake
Surface area (ha)	30,960	1,813	13,760	1,942.6
Drainage basin area (km^2)	15,354	Incl.	4,144	9,065
Drainage basin/surface area ration	49.7	n/a	30.1	466.6
Maximum depth (m)	161.5	59.4	397	45.7
Mean depth (m)	61.6	14.3	169	18.3
Elevation (m)	347	347	407	347
Volume (m^3)	19.13×10^9	260.66×10^6	23.19×10^9	357.75×10^6
Thermocline depth (m)	10	n/a	7.5	n/a
Residence time (years)	2.1	0.03	10	0.13
Shoreline length (km)	1,430	21.2	149.5	42.3
Location 00 00 N; 000 00 W	50° 56' 119° 17'		51° 15' 119° 30'	

Limnological data collected between 1987 and 1993 at centrally located monitoring stations revealed that spring overturn total phosphorus were 6.4 ug L^{-1} and spring overturn nitrate-nitrogen were 75 ug L^{-1}. Nitrate-nitrogen became depleted during summer months (i.e., < 1 ug L^{-1}), hence Shuswap Lake is likely nitrogen limited for part of the growing season (Table 5) (Shortreed et al., 2001). Macrozooplankton and Daphnia sp. biomass were 1,005 mg dry wt m^{-2} and 400 mg dry wt m^{-2} respectively, which is consistent with the mid-upper oligotrophic classification. Mean photosynthetic rates in Shuswap Lake (i.e., PR_{mean} = 171 mg C m^{-2} d^{-1}) were higher than in most Fraser system sockeye lakes (Shortreed et al., 2001).

The other absolute differences in numerical water chemistry values are difficult to assess because many are so close to the minimum detection limit. Of note, is that whenever nitrate-nitrogen was non-detectable, total phosphorus and total dissolved phosphorus was also non-detectable. Individual N:P ratios are also variable, partly due to the very low numerical values and small differences between values, hence N:P ratios may sometimes change drastically temporally and spatially. This may lead to possible N and P co-limitation periods in Salmon Arm, but not in the Main Arm (G. Matscha, pers. comm., Kamloops MOE).

Figure 4. Town sites, recreations areas, and major tributaries to Shuswap Lake

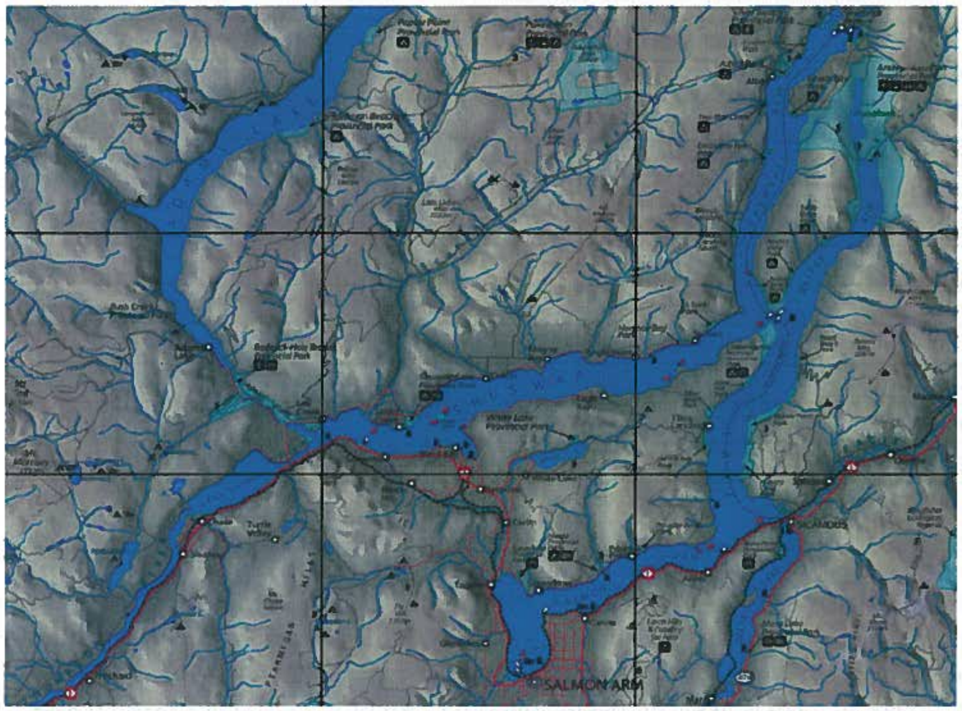


Table 5. Average spring surface nutrients in Shuswap Lake (*sample size = 7).

Shuswap Lake	Spring overturn NO_3-N (ug L^{-1})	Mean photosynthetic rate (mg C m^{-2} d^{-1})	Seasonal minimum NO_3-N (ug L^{-1})	Total P at spring overturn (ug L^{-1})	Daphnia sp. biomass (mg dry wt m^{-2})
Value	75*	171	< 1	6.4*	400

1.1.3 PREVIOUS MONITORING PROGRAMS

Several limnological monitoring programs and water quality studies have been carried out on Shuswap Lake and Mara Lake since the early 1970s, largely due to agency and public concerns about the effects of various point and non-point discharges (i.e., sewage treatment plants, industrial, agricultural and urban runoff) on water quality and fish habitat. The first provincial study was initiated by the Waste Management Branch in 1971 and continued to 1979. The sampling design consisted of a single sample collected in mid-summer, or two samples collected in late spring and early fall. This low intensity sampling program was unable to detect any temporal changes in water quality; however, it was sensitive enough to detect spatial differences in water quality within Shuswap Lake, especially in Tappen Bay.

A follow-up study by DFO was conducted in the 1980's to examine water quality in the Salmon Arm/Tappen Bay area, and compared this to 'control' sites in Seymour Arm. Not surprisingly, the study confirmed the earlier findings of the Waste Management Branch and concluded the Tappen Bay area of Salmon Arm was mesotrophic to eutrophic, i.e., considerably more productive than the oligotrophic conditions at the main lake stations. The study concluded the nutrients originated from the Salmon River, the Wastewater Treatment Plant (WWTP) in Salmon Arm and non-point source runoff from urbanized areas within Salmon Arm.

In 1978 and 1979, the Environmental Protection Service of Environment Canada conducted a detailed, physical, chemical and biological monitoring program in 3 areas of Shuswap Lake: the Tappen Bay area, the main section of Salmon Arm and one transect in Seymour Arm. A second study was conducted concurrently in 1978 to identify nutrient sources and loadings in Salmon Arm. Environment Canada concluded the water quality in Tappen Bay was mesotrophic to eutrophic, Salmon Arm was oligotrophic to meso-eutrophic and Seymour Arm was ultra-oligotrophic to oligotrophic. They also identified the Salmon River and the Salmon Arm Wastewater Treatment Plant as the major sources of nutrient loading to the Salmon Arm/Tappen Bay area (Ross, 1984).

In 1986 the Columbia Shuswap Regional District (CSRD) funded a public Secchi disk monitoring program in Shuswap Lake, and collected 1,300 individual readings between late June and September of 1986 from around the entire shoreline of Shuswap Lake and Mara Lake. The report concluded the water quality of Shuswap Lake was generally high; however, the Tappen Bay/Salmon Arm area had significantly lower water quality and was eutrophic. Other areas identified in Shuswap Lake that raised concern were the extreme western end near Scotch Creek, some minor enrichment in the Sicamous area, and the south end of Mara Lake. The report also made a number of recommendations with respect to water quality monitoring in Shuswap Lake, and recommended the formation of an "Implementation Committee" to oversee all activities in the Shuswap drainage which would have an impact on water quality (Urban Systems, 1987).

From 1987 to 1993, DFO conducted a series of limnological programs on Fraser basin sockeye nursery lakes, including Adams Lake and Shuswap Lake (Nidle and Shortreed, 1996; Morton and Shortreed, 1996). The monitoring on Shuswap Lake took place between 1987 to 1993, and consisted of monthly (April to November) sample collections, along with 34 collections of limnetic fish data. The DFO study concluded Shuswap Lake, as a whole, was mid-upper oligotrophic, and that juvenile sockeye production was less than expected due to the warm epilimnion which seasonally excluded them from grazing on limnetic zooplankton. DFO concluded that a sockeye fertilization program on Shuswap Lake would not be effective due to the warm epilimnion, and the likely conflicts arising from high recreational and residential use of the lake. Instead, the study identified increasing sockeye fry recruitment through increased adult escapement as the most effective way of rebuilding Shuswap Lake sockeye stocks (Shortreed et al., 2001).

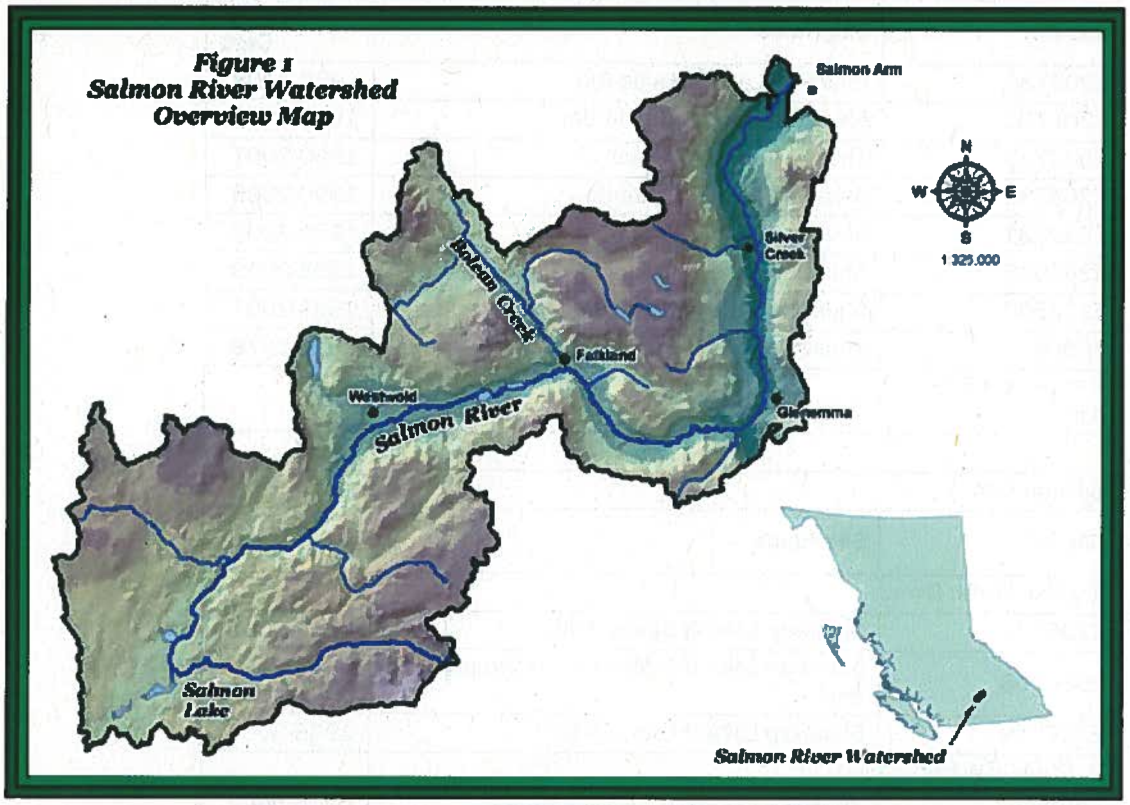
In 1990, the Ministry of Environment initiated a mid-summer sampling program in Shuswap Lake to monitor water quality during the highest use season. These one-time samples reflected one seasonal snapshot during an annual cycle, and the results may vary from year to year, depending on the time with the cycle that the sample was collected. Thus it is not clear if changes between annual results were due to sample timing or actual changes in water quality between years. To ensure comparability between years, the program was changed to include higher frequency sampling throughout the summer. An expanded study program was initiated in 2003 consisting of bi-monthly sampling in the Main Arm and monthly since 2007. Increased monitoring of the Salmon Arm stations commenced in 2006 with monthly sampling each year since (G. Matscha, pers. comm., Kamloops MOE).

In 1991, the University of Calgary released a Masters thesis on the water quality and recreational usage issues in Shuswap Lake (Kearney, 1991). The objectives of the study were to establish a water quality data base in Upper Seymour Arm, and investigate land and water-based activities that could have detrimental effects on water quality, including grey water from houseboats. Water samples were collected from 3 composite deep water sampling stations and 7 shallow water sampling stations from May 9 to October 3, 1988 in Upper Seymour Arm near Bughouse Bay. The study concluded the water quality of Upper Seymour Arm was generally high, but expressed concerns about cumulative anthropogenic impacts.

In terms of specific watersheds and tributaries, the Salmon River watershed of Shuswap Lake has been monitored by the Salmon River Watershed Society for several years, as part of a larger federal-provincial-local area stream water quality monitoring program (Figure 5). The Salmon River Watershed Roundtable Project started in 1991 with the City of Salmon Arm's Environmental Committee and Dorothy Argent, in response to concerns about the well known water quality problems in Tappen Bay/Salmon Arm and declining salmon stocks, degraded fish habitat, lost riparian vegetation, eroding stream banks, high water temperatures and low summer flows in the Salmon River.

The Salmon River Water Shed Society recognized these water quality and habitat problems were the symptoms of larger watershed land use, and that they needed to look upstream into the watershed to address the core issues influencing the watershed. Elder Mary Thomas of the Neskonlith Band was instrumental in starting the SRWS. The SWRS is currently developing a consensus-based watershed sustainability plan with a 20-200 year perspective (www.srws.ca).

Figure 5. Salmon River watershed.



A list of the provincial water quality monitoring stations used over the last 30 years in the Main Arm of Shuswap Lake are identified in Table 6.

Table 6. List of provincial water quality stations established in the Main Arm of Shuswap Lake from 1971 to 2011) (from MOE, Kamloops)

Main Arm		
Site No.	Site Name	Years of Data
1. Deep Water Sites:		
E208723	Shuswap Lake off Armstrong Pt.	1990-2006
E208724	Shuswap Lake off McBride Pt.	1990-2006
E0500123	Shuswap Lake West of Sorrento	1971-2008
E208719	Shuswap Lake at Cinnemousun Narrows	1990-2002
2. Shallow Water Sites:		
500557	Shuswap Lake - Blind Bay Control	1976-1979
500556	Shuswap Lake - Blind Bay N.W.	2008-2009*
500555	Shuswap Lake - Blind Bay S.E.	1976-2009
E208729	Shuswap Lake @ Anglemont	1990-2007
E208732	Shuswap Lake @ Celista	1990-2007

Main Arm		
Site No.	Site Name	Years of Data
E208730	Shuswap Lake @ Eagle Bay	1990-2008
E208731	Shuswap Lake @ Magna Bay	1990-2007
E208733	Shuswap Lake @ Scotch Cr.	1990-2007
E208734	Shuswap Lake @ Sorrento	1990-2009
E222131	Shuswap Lake @ Wild Rose Bay	1995-2009
E242918	Shuswap Lake East of Park	1995-2009
E227530	Shuswap Lake @ Horseshoe Bay	1997-2007
500557	Shuswap Lake @ Blind Bay control	1976-1979
* plus early 70s data		
Salmon Arm		
Site No.	Site Name	Years of Data
1. Deep Water Sites:		
E206771	Shuswap Lake @ Sandy Point	1987-2007
E206768	Shuswap Lake @ Fraser Beach (Tappen Bay)	1987-2007
E207579	Shuswap Lake @ Canoe Wharf	1988-2007
2. Shallow Water Sites:		
E206770	Shuswap Lake @ Christmas Island	2000-2007
500685	Shuswap Lake @ S. Mallard Pt.	1974-1979
E206767	Shuswap Lake Tappen Bay #1	1986-1988
E221478	Shuswap Lake at Annis Bay	1997-2002
E208727	Shuswap Lake at Heralds Bay	1990-2002
Siccamous Arm		
Site No.	Site Name	Years of Data
1. Deep Water Sites:		
E500124	Shuswap Lake Opposite Marble Pt.	1971-2011
E208718	Shuswap Lake off Canoe Pt.	1990-2011
2. Shallow Water Sites:		
E208725	Shuswap Lake at Canoe	1990-2002
E208728	Shuswap Lake at Bastion Bay	1990-2011
Anstey Arm		
Site No.	Site Name	Years of Data
1. Deep Water Sites:		

Main Arm		
Site No.	Site Name	Years of Data
E208721	Shuswap Lake off Broken Pt.	1990-2011
Seymour Arm		
Site No.	Site Name	Years of Data
1. Deep Water Sites:		
E208722	Shuswap Lake off Encounter Pt.	1990-2011

1.1.4 CURRENT MONITORING PROGRAMS

The current monitoring program on Shuswap Lake and Mara Lake is conducted by Ministry of Environment's Environmental Quality Section, based in the MOE office in Kamloops, BC. To address the spatial complexity of the Shuswap basin, the monitoring program has divided Shuswap Lake and Mara Lake into 3 areas: (1) Main Arm; (2) Salmon Arm and (3) Seymour Arm, Anstey Arm, Sicamous Arm and Mara Lake. The Environmental Quality Section recommends a 3-5 year rotation depending on need and Ministry of Environment funding, so that field crews collect samples for 3 years in each area, and then repeat the cycle after 3 to 5 years (G. Matscha, pers. comm., Kamloops MOE). The monitoring is currently in the second year of the Sicamous area.

In terms of sampling sites and locations, the MOE monitoring program is structured as follows (Table 7 and Figure 6):

Table 7. List of current provincial water quality stations in Shuswap and Mara lakes.

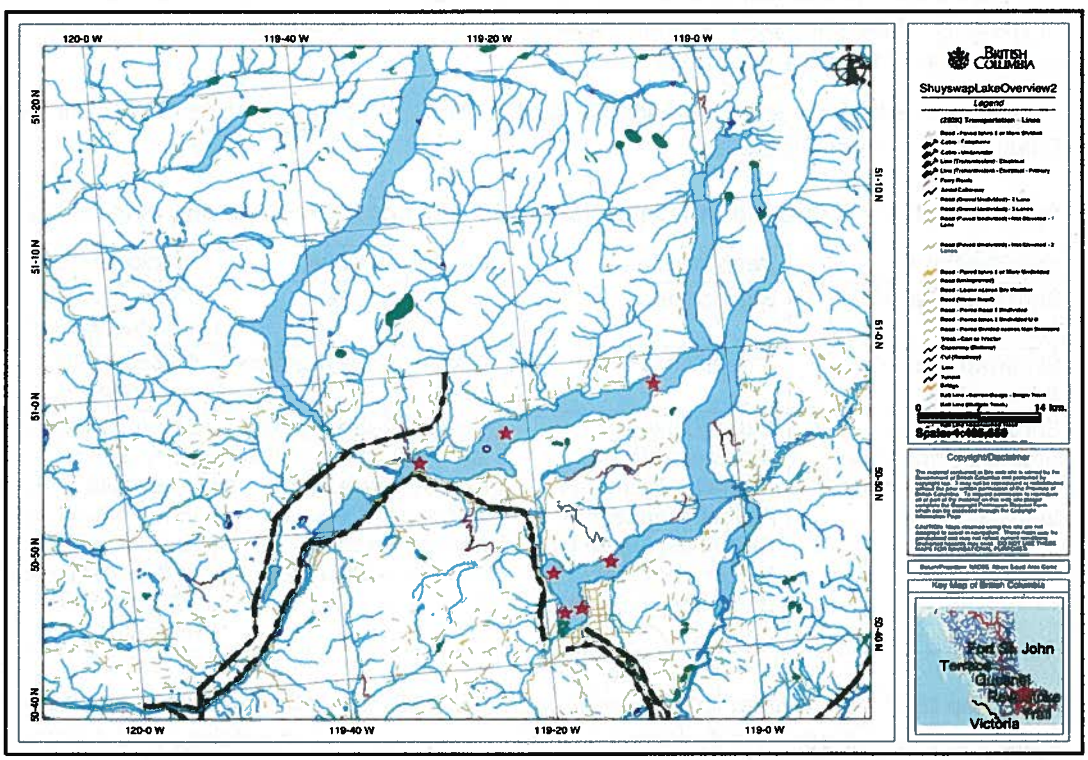
Lake Section	Deep stations	Shallow stations	Additional tasks
Shuswap lake – Main Arm	3 deep sites	10 shallow sites	65 Secchi disk monitoring sites
Shuswap lake – Salmon Arm	3 deep sites	1 shallow site (Bastion Bay)	40 Secchi disk monitoring sites
Shuswap Lake – Seymour Arm, Anstey Arm, Sicamous Arm and Mara Lake	3 deep sites (Encounter Pt - Seymour, Broken Pt - Anstey, Marble Pt - Sicamous, Canoe Pt and north Mara) (5 deep sites in Sicamous Arm)	6 shallow sites along the south shore and 13 seepage sites on the foreshore of the Sorrento area (1 shallow in Sicamous Arm)	3 year nutrient loading study on 6 tribs; houseboat grey water work; mid summer bacteria sampling at 2 or 3 moorage beaches; 32 Secchi disk monitoring sites

The deep sites were limited to 46 m prior to 2005. In 2008, MOE purchased additional deep water cabling and deep sonde instrumentation, which permits monitoring of the entire water column, including the 165 m site at Encounter Point (G. Matscha, pers. comm., Kamloops MOE).

The current MOE monitoring program is more comprehensive than prior water quality monitoring programs. For 2009, MOE has reinstated the 1986 CSRD Shuswap Lake Secchi disk program, which is a key component for ensuring public participation in water quality monitoring. MOE has also initiated investigative monitoring of microbial and chemical composition in specific areas where large numbers of houseboat moor for extended periods (e.g., Nielson Beach and Marble Point).

Increased monitoring attention is now being directed at near shore areas since 2007, using information obtained during shallow water sampling conducted in the 1970s and 1980s, and an earlier fluorometer study. This is an appropriate strategy, as near shore areas respond more rapidly to nutrient loading than well flushed deep water sites, hence are more valuable for detecting short terms trends in water quality, and assist in identifying point and non-point nutrient sources. In recent years, no statistical difference between the deep and shoreline shallow sites has been identified for the Main Arm (G. Matscha, pers. comm., Kamloops MOE). The current MOE monitoring program has also started sampling of key tributaries, which is critical component of developing a phosphorus loading model for Shuswap and Mara lakes.

Figure 6. Shuswap Lake, Salmon Arm showing 3 deep sampling site locations in the Main Arm and 3 deep and one shallow site in Salmon Arm.



1.1.5 TRENDS IN WATER QUALITY

Numerous water quality summary reports have been issued on Shuswap Lake and Mara over the past 30 years. The conclusions from virtually all of these reports are similar: Shuswap Lake, *as a whole*, can be currently classified as mid-upper oligotrophic. However, there are significant spatial differences within Shuswap Lake that deviate from this high quality *main lake* trophic state. Consequently, *trends in lake water quality*, and any water quality monitoring and subsequent trophic classifications and trend analysis must be conducted on a site by site basis to capture the spatial complexity of Shuswap Lake. As a minimum, Shuswap Lake should be divided into at least five separate main lake areas: Anstey Arm, Salmon Arm, Seymour Arm, Sicamous Arm, and the West (i.e., Main) Arm. Within each arm, numerous localized sites are required to accurately reflect local in-lake and upland activities, and tributary inputs.

Ross (1984) concluded the water quality in (1978 and 1979) Tappen Bay was mesotrophic to eutrophic, Salmon Arm was oligotrophic to meso-eutrophic and Seymour Arm was ultra-oligotrophic to oligotrophic. They also identified the Salmon River and the Salmon Arm Wastewater Treatment Plant as the major sources of nutrient loading to the Salmon Arm/Tappen Bay area;

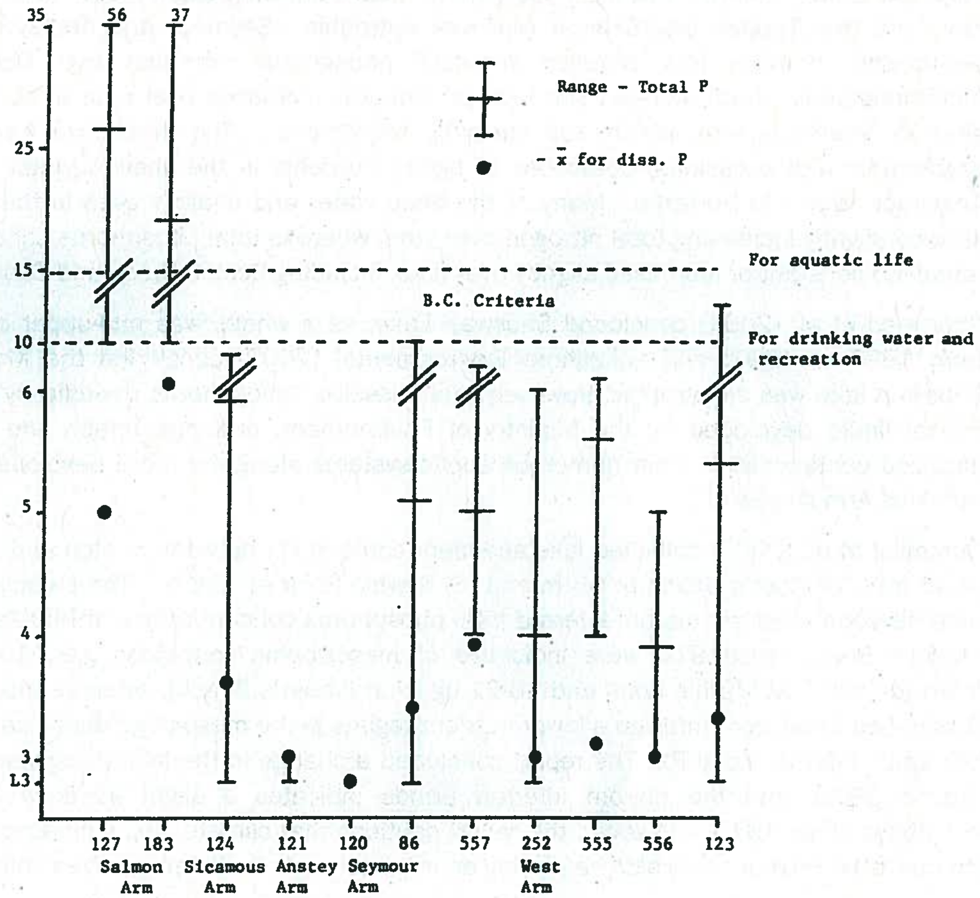
Nordin (1986) provided a preliminary assessment of Shuswap Lake water quality in response to a request from the Planning and Assessment Division of the Ministry of Environment. Nordin (1986) concluded the major areas of concern were eutrophication from nitrogen and phosphorus, and bacterial contamination from point and non-point sources. Nordin stated there were no discernable trends in water quality since 1980, however, there were insufficient shallow water monitoring stations, which is where eutrophication would most likely be detected i.e., close to sources of nutrient loading. Nordin (1986) recommended a long term monitoring program be established, focusing on specific problems or questions, and should increase the monitoring intensity on shallow water sites, and maintain the existing network of deep water stations. In addition, Nordin (1986) recommended future monitoring efforts should include monitoring of the major watersheds (i.e., Salmon, Shuswap and Eagle rivers) to determine the effect of land use practices on nutrient loading;

Urban Systems (1987) concluded the water quality of Shuswap Lake in 1986 was generally high; however, the Tappen Bay/Salmon Arm area had significantly lower water quality and was eutrophic. Other areas identified in Shuswap Lake that raised concern were the extreme western end near Scotch Creek, some minor enrichment in the Sicamous area, and the south end of Mara Lake;

Holmes (1987) provided a preliminary overview of Shuswap Lake in the five main arms. This study concluded the Tappen Bay area of Salmon Arm was trending towards eutrophic due to limited circulation and nutrient inputs from the Salmon Arm WWTP and the Salmon River. The Main Arm of Salmon Arm was rated as meso-oligotrophic. Sicamous Arm, Anstey Arm, Seymour Arm were rated as oligotrophic. The West Arm has generally good water quality, however, the potential for widespread near shore water quality degradation is high based on extensive development in the West Arm (Figure 7). Blind Bay water quality was rated as good. One near shore station (Site 555) had high ammonia nitrogen, conductivity and coliform values, which was either a laboratory/sampling error or indicative of septic tank leachate entering the bay. To date, MOE monitoring of seepage entering Shuswap Lake has found to be high in nutrients, but small in volume. In samples collected frequently in the shallow sites near these seepages, no elevated nutrient concentrations (compared to the deep stations) were detected, thus the effects of these seepages could not be shown in the receiving water (G. Matscha, pers. comm., Kamloops MOE).

Ministry of Environment (1987) provided an environmental management plan for Shuswap Lake, based on input from Nordin (1986) and Holmes (1987). The report concluded that Seymour, Anstey and Sicamous Arms have good water quality, and can be classified as oligotrophic. The West (Main) Arm has generally good water quality, but leachate tests conducted in Blind Bay, Anglemont and Corning Creek demonstrated elevated nutrient concentrations. Dye tracer and fluorescence monitoring along the West Arm north side detected numerous septic system short circuiting to shallow water sites. Salmon Arm was rated as eutrophic as a result of nutrient loading from the Salmon Arm WWTP and various agricultural activities within the Salmon River watershed. The environmental management plan recommended an expanded lake water quality monitoring program, shoreline leachate studies in the Mara Lake and Eagle River areas, a reduction of agricultural nutrient loadings in major river systems, and a detailed water quality assessment of water quality in Seymour and Anstey Arms. The LWMP for Area E (Sicamous and Mara Lake) requires another fluorometer study.

Figure 7. Means and ranges of total phosphorus and means for dissolved phosphorus in Shuswap Lake (Holmes, 1987).



:e 3. Means and Ranges of Total Phosphorus and Means of Dissolved Phosphorus in Shuswap Lake

Note: *Y axis units in ug L^{-1}

Stockner and Shortreed (1991) classified Shuswap Lake, *as a whole*, as oligotrophic, based on spring turnover phosphorus concentrations of <10 ug L^{-1};Kearney (1991) concluded the water quality of Upper Seymour Arm in 1988 was generally high, but expressed concerns about cumulative anthropogenic impacts; and Nidle and Shortreed (1996) and Morton and Shortreed (1996) concluded Shuswap Lake, as a whole, was mid-upper oligotrophic, and not a suitable candidate for lake enrichment;

McGarvie (1997) provided a water quality summary and literature review of Shuswap Lake. The report concluded mild eutrophication has occurred in Salmon Arm, along with nuisance introductions of Eurasian water milfoil (*Myriophyllum spicatum*), mainly a result of considerable nutrient loading from agricultural activities in the Salmon River watershed. The water quality in the remaining areas of the lake (Anstey, Seymour and the Main Arm) was rated as good;

Stroh (1999) conducted a summary review of Shuswap Lake water quality from 1985 to 1998 and performed a trend analysis on each arm of Shuswap Lake. Stroh (1999) concluded total nitrogen and total phosphorus was increasing slightly over time in Salmon Arm, and that Tappen Bay/Salmon Arm was eutrophic. Seymour and Anstey arms were oligotrophic, however total nitrogen and total phosphorus increased over time at both monitoring sites. Total nitrogen and total phosphorus increased over time at all monitoring sites in Sicamous Arm, which was currently oligotrophic. The West Arm was basically oligotrophic with occasional detections of higher nutrients in the shallow water sites from Angelmont down to Sorrento. Many of the deep water and shallow sites in the West Arm showed slightly increasing total nitrogen over time, whereas total phosphorus concentrations remained constant or increased slightly over time, including Scotch Creek and Blind Bay.

Shortreed et al. (2001) concluded Shuswap Lake, as a whole, was mid-upper oligotrophic from 1987 to 1993; and Lakeshore Environmental (2002) concluded the Main Arm of Shuswap lake was oligotrophic, however, total dissolved phosphorus periodically surpassed critical limits developed by the Ministry of Environment, and presumably are related to localized contamination from numerous septic systems along the more developed areas of the West Arm shoreline;

Cumming et al. (2007) collected lake sediment cores at (1) between Scotch and Lee creeks at 95 m, (2) Fraser's Beach at 66 m and (3) Marble Point at 136 m. The paleolimnological analysis concluded the diatom-inferred total phosphorus concentrations at Marble Point and Fraser's Beach post-1970 were indicative of mesotrophic conditions (i.e., 10-16 ug L^{-1} inferred Total P at Marble Point and 20-21 ug L^{-1} at Fraser's Beach), whereas the post-1970 Scotch-Lee Creek core inferred a lower nutrient regime in the meso-oligotrophic category (i.e., 5-9 ug L^{-1} inferred Total P). The report concluded a change in the lake ecosystem occurred around 1970, and the diatom inferred trends indicates a slight increase in nutrient conditions since 1970. However, the report cautions that climate, i.e., increased periods of thermal stratification, may also be playing an important role in diatom species shifts.

As previously mentioned, trophic classification and water quality trend analysis must be conducted on a site by site basis to capture the spatial complexity of Shuswap Lake, hence it should be divided into at least five separate main lake areas: Anstey Arm, Salmon Arm, Seymour Arm, Sicamous Arm, and the West (i.e., Main) Arm and Mara Lake. An arm by arm water quality trend summary of the *deep water quality* stations in Shuswap Lake and Mara Lake, based on the published reports we have reviewed and cited, is presented in Table 8.

Table 8. **Summary of trophic status and water quality trends in Shuswap and Mara lakes deep water stations.**

Lake Area	Deep water trophic status	Trend direction
Anstey Arm	Oligotrophic	Increasing total nitrogen and total phosphorus
Salmon Arm/Tappen Bay	Mesotrophic to eutrophic	Slightly increasing total nitrogen and total phosphorus
Seymour Arm	Oligotrophic	Increasing total nitrogen and total phosphorus
Sicamous Arm	Oligotrophic	Increasing total nitrogen and total phosphorus
West Arm	Oligotrophic	Slightly increasing total nitrogen, total phosphorus constant or increasing slightly over time
Mara Lake	Oligotrophic	Increasing total nitrogen and total phosphorus in some areas

In summary, most deep water stations in Shuswap Lake remain oligotrophic, with the exception of Salmon Arm/Tappen Bay, which has been mesotrophic/eutrophic since at least the 1970s. However, the trend analysis indicates the concentration of limiting nutrients is increasing slightly lake-wide, even in the deep water stations, which have previously been unaffected. This finding is cause for concern given the large volume and rapid flushing rate in Shuswap Lake, and indicative of the requirement for a more intensive, proactive water quality monitoring program to protect water quality and publish health.

Note: this preliminary conclusion has several caveats, namely that the number of monitoring sites has been inadequate until recently, monitoring efforts have been on again/off again over the years, methodologies and the timing/frequency of sample collection has changed, and monitoring for some parameters has not been conducted at all. The trend in shallow water monitoring stations also warrants attention, and is indicative of near-shore eutrophication at multiple sites, and potential public health/water quality impairment due to leachate breakthrough from poorly constructed/maintained of domestic wastewater treatment systems, and where large numbers of houseboats congregate on beaches for extended periods.

For reference purposes, Table 9 shows the mean and range of key trophic indicators for oligotrophic, mesotrophic and eutrophic lakes and reservoirs.

Table 9. General trophic classification of lakes and reservoirs in relation to phosphorus and nitrogen (adapted from Wetzel, 2001).

Parameter (annual mean value)	Oligotrophic	Mesotrophic	Eutrophic
Total P (mg m^{-3}) Mean Range	 8.0 3.0 to 17.7	 26.7 10.9 to 95.6	 84.4 16 to 386
Total N (mg m^{-3}) Mean Range	 661 307 to 1,630	 753 361 to 1,387	 1,875 393 to 6,100
Chlorophyll a of phytoplankton (mg m^{-3}) Mean Range	 1.7 0.3 to 4.5	 4.7 3 to 11	 14.3 3 to 78
Secchi transparency depth (m) Mean Range	 9.9 5.4 to 28.3	 4.2 1.5 to 8.1	 2.5 0.8 to 7.0

1.1.6 MAIN CONCERNS TO WATER QUALITY

A consistent, and long list of water quality concerns in Shuswap Lake and Mara Lake has been expressed in each of the water quality monitoring reports since the late 1970s. The most frequently expressed concerns are as follows:

- Discharge of nutrients, bacteria, household chemicals, pharmaceutical, and personal care products (PPCP) in grey water from increasing numbers of large recreational and commercial boats:
- Shortage/absence of grey water/black water pump-out stations for boats and houseboats, and inadequate size/impending closure of the MOE Parks pump-out at the Cinnemousin Narrows. ;
- Increased nutrient and sediment runoff from upland and near shore residential subdivisions;
- Contaminant runoff into Shuswap and Mara lakes from urban storm water;
- Nutrient runoff from upland soil disturbances caused by forest harvesting;
- Nutrient, pesticides and chemicals from agricultural runoff, especially from the Salmon River;
- Concerns about dairy farm densification, and nutrient/manure storage and runoff in the Shuswap River;
- Nutrient loading into Tappen Bay/Salmon Arm from the Salmon Arm wastewater treatment plant (WWTP);
- Nutrient loading into the Shuswap River from the Enderby WWTP;
- Nutrient loading into Eagle River and Shuswap Lake from the Sicamous WWTP

- Nutrient leaching into foreshore areas in the Main Arm from overloaded, and improperly constructed or maintained septic tank systems, particularly in Sorrento, Blind Bay and the north shore developments from Scotch Creek, Celista, Magna Bay and Anglemont;
- Potential for nutrient leaching into groundwater and Shuswap Lake from upland sewage seepage pits (dry wells) and rapid infiltration basins;
- Increased abundance of invasive aquatic plants, especially in Tappen Bay/Salmon Arm;
- Increase growth of algae on rocks in some near-shore shallow water zones.

The most common concern is increased loading of limiting nutrients i.e., nitrogen and phosphorus, followed by growing concerns about bacteria and chemicals in grey water discharges, and urban and agricultural runoff. The dominant concern about nitrogen and phosphorus and eutrophication is well founded. In 1974, Jack Vallentyne, in his seminal book "The Algal Bowl", predicted that by the year 2000 we would be living in an environmental disaster called the Algal Bowl, due to increased anthropogenic release of nutrients into lakes, rivers and coastal waters.

His predictions are eerily accurate, as exemplified by Lake Winnipeg, one of the world's largest bodies of freshwater, which has become so eutrophic in recent years that it is likely beyond restoration (MacLeans, 2009; Schindler and Vallentyne, 2008) (Figure 8), the massive eutrophication in the Gulf of Mexico caused by agricultural nutrient runoff, and numerous culturally eutrophied lakes throughout Canada, USA, Europe, New Zealand and China. Shuswap Lake is clearly eutrophic in Salmon Arm Bay, and is now showing early signs of cultural eutrophication in the main lake deep water sites.

Shuswap Lake experienced a large algae bloom in June, 2008 (Figure 9). This was the first reported bloom of this type and magnitude on Shuswap Lake, and extended nearly 50 km from Salmon Arm Bay to Copper Island, and raising considerable alarm.

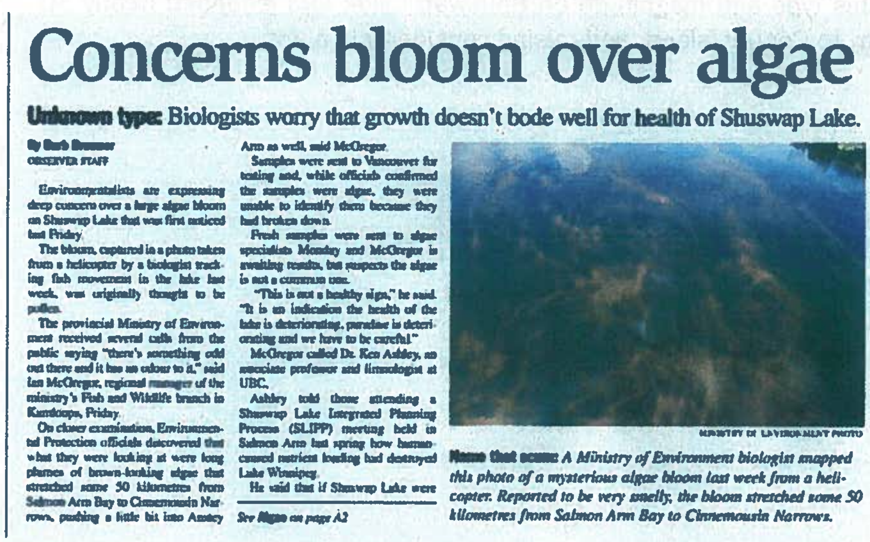
Figure 8. Widespread algae bloom in Lake Winnipeg from excessive watershed loading of nutrients – (MacLeans, August 24, 2009)

ENVIRONMENT

THE FOAMING SLUDGE at Connaught Beach on Lake Winnipeg is another sign that the lake is getting close to the tipping point

CANADA'S SICKEST LAKE

Figure 9. Cover story in June 25, 2008 Salmon Arm Observer showing photo of first widespread algae bloom in Shuswap Lake.



Concerns bloom over algae

Unknown type: Biologists worry that growth doesn't bode well for health of Shuswap Lake.

By Barb Brouwer
OBSERVER STAFF

Environmentalists are expressing deep concern over a large algae bloom on Shuswap Lake that was first noticed last Friday.

The bloom, captured in a photo taken from a helicopter by a biologist tracking fish movement in the lake last week, was originally thought to be pollen.

The provincial Ministry of Environment received several calls from the public saying "there's something odd out there and it has an odour to it," said Ian McGregor, regional manager of the ministry's Fish and Wildlife branch in Kamloops, Friday.

On closer examination, Environmental Protection officials discovered that what they were looking at were long plumes of brown-looking algae that stretched some 50 kilometres from Salmon Arm Bay to Cinnemousin Narrows, pushing a little bit into Anstey Arm as well, said McGregor.

Samples were sent to Vancouver for testing and, while officials confirmed the samples were algae, they were unable to identify them because they had broken down.

Fresh samples were sent to algae specialists Monday and McGregor is awaiting results, but suspects the algae is not a common one.

"This is not a healthy sign," he said. "It is an indication the health of the lake is deteriorating, paradise is deteriorating and we have to be careful."

McGregor called Dr. Ken Ashley, an associate professor and limnologist at UBC.

Ashley told those attending a Shuswap Lake Integrated Planning Process (SLIPP) meeting held in Salmon Arm last spring how human-caused nutrient loading had destroyed Lake Winnipeg.

He said that if Shuswap Lake were

See Algae on page A2

MINISTRY OF ENVIRONMENT PHOTO

Name that scene: *A Ministry of Environment biologist snapped this photo of a mysterious algae bloom last week from a helicopter. Reported to be very smelly, the bloom stretched some 50 kilometres from Salmon Arm Bay to Cinnemousin Narrows.*

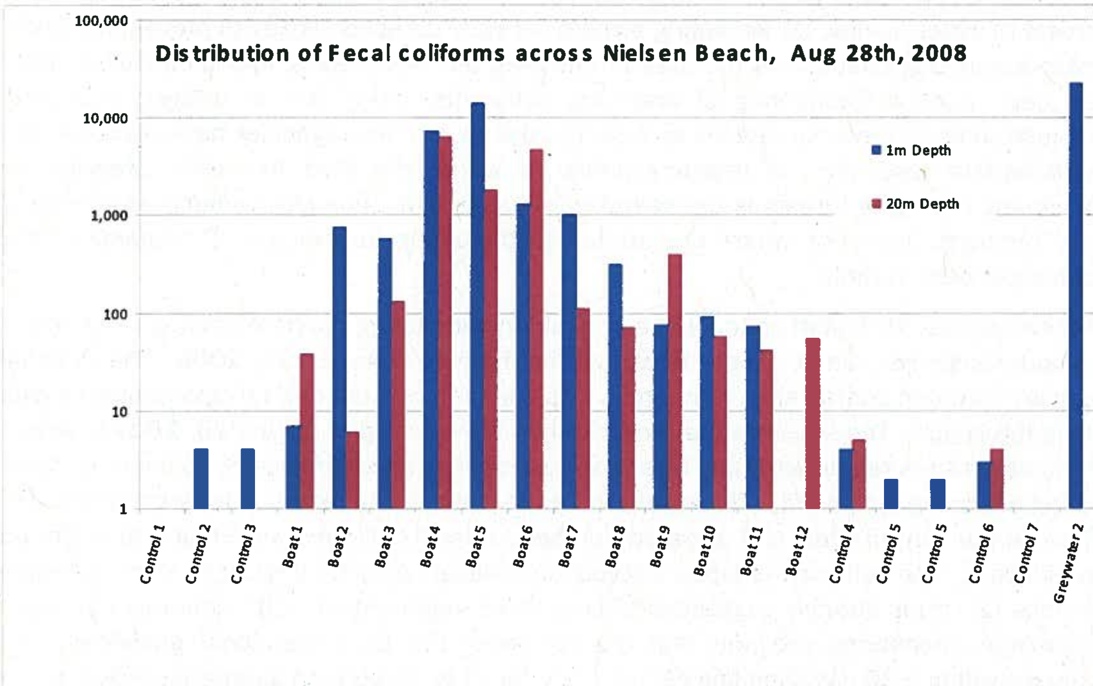
1.1.7 EMERGING THREATS TO WATER QUALITY

A comprehensive water quality monitoring program should not only include monitoring *known threats* to water quality, but *emerging threats*, as early detection is key to preventing further water quality degradation. In the case of Shuswap and Mara lakes, this is difficult as there has been minimal monitoring of emerging pollutants, partly due to budget, and partly because some of these threats are so new that the government agencies have yet to develop an adequate response. A recent example of where the MOE has been proactive on monitoring emerging threats is the sampling of vessel grey water for bacteria and personal care products, many of which are endocrine disrupting substances (D. Einarson, MOE Kamloops, pers. comm.).

In this example, MOE staff conducted a preliminary monitoring program amongst a cluster of 13 houseboats moored at Neilson Beach on the morning of August 28, 2008. The sampling program included control sites from areas with similar foreshore and no houseboats moored along the beach. The sites were re-rechecked on the morning of August 28, 2008 to ensure the controls sites remained valid. One boat was moored at control site 3, so it was not used during this sampling period. The results are quite clear: low numbers of fecal coliforms were found at the control sites, and elevated numbers of fecal coliforms were found amongst the houseboats. The bell curve shaped distribution of fecal coliforms in surface (1 m) and deep stations (20 m) is strongly suggestive of houseboat origin (Figure 10). Although this was a preliminary monitoring program that did not meet the BC recreational guidelines of 5 samples within a 30 day sampling period, it is difficult to develop an alternative hypothesis to explain this bell shaped distribution and abundance curve of fecal coliforms on this day at this particular time and site, given the low numbers of fecal coliforms detected at the control sites. This is an excellent example of the type of innovative water quality monitoring program that must be conducted to identify emerging threats to drinking water quality and aquatic life in Shuswap and Mara lakes.

In the absence of much real data, a defensible approach to indentifying and assessing emerging threats to drinking water and aquatic ecosystem health in the Shuswap basin is to use the most relevant and recent scientific publications as a guide. In this case, a 2001 Environment Canada report is the most appropriate guide for Canadian lakes (Environment Canada, 2001). This report is a summary of an invited expert workshop on the subject, and identified 15 threats to water quality in Canada. We added four additional Shuswap-area specific threats to the Environment Canada list (i.e., non-municipal private residence wastewater discharges, grey water discharge from vessels, nanoparticles and invasive species) due to the recently emerging knowledge of how these factors can negatively influence water quality and aquatic life. The following table lists the 19 threats, and provides our subjective assessments as to their importance and trends in the Shuswap basin.

Figure 10. Distribution of fecal coliforms (CFU 100 ml-1) at 1 m and 20 m depth among 13 houseboats moored at Nielson beach on August 28, 2008.



This is obviously a subjective exercise and open to revision as new information is collected, however, it should form the basis for further discussion and eventual design and inclusion into a comprehensive water quality monitoring program. In their report, Environment Canada (2001) included both existing and emerging* threats to sources of drinking water and aquatic ecosystem health, hence we follow their guide (Table 10).

Table 10. List of existing and emerging* threats to sources of drinking water and aquatic ecosystem health in Shuswap basin lakes.

Threat to sources of drinking water quality and aquatic ecosystem health	Importance in the Shuswap basin (low, medium, high or variable)	Trend direction (increasing, stable, decreasing or variable)
1. Waterborne Pathogens	High, depending on location, time of year and flushing rate, hundreds of domestic water licenses and water contact recreation	Increasing, based on preliminary houseboat grey water sampling, West Arm fluorometer monitoring and unregulated increasing near-shore development
2. Algal Toxins* and Taste and Odour	High, hundreds of domestic water licenses and world class fisheries resources	Increasing, annual algal blooms in Tappen Bay, and first widespread algal bloom in June 2008
3. Pesticides	High, hundreds of domestic water licenses and world class fisheries resources	Unknown, likely stable or decreasing
4. Persistent Organic	High, hundreds of domestic water	Unknown for mercury and

Threat to sources of drinking water quality and aquatic ecosystem health	Importance in the Shuswap basin (low, medium, high or variable)	Trend direction (increasing, stable, decreasing or variable)
Pollutants* and Mercury	licenses and world class fisheries resources	POPs, likely some POPs decreasing (PCBs) and some increasing (PBDEs)
5. Endocrine Disrupting Substances* (Note: this category includes Personal Care Products such as antibiotics, birth control pills and other Endocrine Disrupting Compounds)	High, depending on location, time of year and and flushing rate, hundreds of domestic water licenses, water contact recreation and world class fisheries resources	Unknown, likely increasing based on rate of residential development in watershed and increasing grey water discharges from larger and more numerous houseboats and power boats
6. Nutrients – Nitrogen and Phosphorus	High, lakes are phosphorus and nitrogen limited	Increasing in all areas of Shuswap Lake, first widespread algae bloom in 2008
7. Aquatic Acidification	Low, lakes are all well buffered	Stable
8. Ecosystem Effects of Genetically Modified Organisms*	Low, minimal exposure to GMO crops	Unknown, likely stable
9. Municipal Wastewater Effluents	High, lakes are phosphorus and nitrogen limited	Increasing, but Salmon Arm WWTP has state-of-the-art nutrient removal process
10. Non-municipal Private Residence Wastewater Effluents	High, lakes are phosphorus and nitrogen limited	Increasing in all areas, main concern is poorly constructed and operated non-municipal discharges
11. Grey Water Discharges from Vessels*	High, depending on location, time of year and flushing rate, hundreds of domestic water licenses and water contact recreation	Increasing, based on rapid expansion of houseboat industry, lack of grey water retention and pump-out facilities and preliminary site monitoring
12. Industrial Point Source Discharges	High, depending on location, time of year and flushing rate, hundreds of domestic water licenses and water contact recreation	Unknown, likely stable or increasing
13. Urban Runoff	High, depending on location, time of year and flushing rate, hundreds of domestic water licenses and water contact recreation	Unknown, likely increasing based on urbanization of watershed and lack of rainwater management plans by municipalities
14. Landfills and Waste Disposal	High, depending on location, time of year and flushing rate, hundreds of domestic water licenses and water contact recreation	Unknown, likely increasing based on urbanization of watershed
15. Agricultural and Forestry Land Use Impacts	High, lakes are phosphorus and nitrogen limited	Likely increasing based on forest harvesting, ranching and densification of dairy industry
16. Natural Sources of Trace Element Contaminants	High, depending on location, time of year and flushing rate, hundreds of	Unknown, likely stable

Threat to sources of drinking water quality and aquatic ecosystem health	Importance in the Shuswap basin (low, medium, high or variable)	Trend direction (increasing, stable, decreasing or variable)
	domestic water licenses and water contact recreation	
17. Impacts of Dams, Diversion and Climate Change*	High, fisheries resources sensitive to timing and amount of runoff and water temperature	Increasing, based on observed trend and die-off of Lodgepole pine and Ponderosa pine
18. Nanoparticles*	High, hundreds of domestic water licenses and world class fisheries resources	Unknown, likely increasing slowly based on increased product availability
19. Invasive Species*	High, fisheries resources sensitive to habitat disruption and competition/predation from invasive species	Increasing, based on Eurasian milfoil and introduction of non-native species of fish in the Shuswap watershed

If Table 9 is reasonably accurate, it is clear our current knowledge of emerging threats to sources of drinking water and aquatic ecosystem health in the Shuswap basin lakes is quite limited. Therefore, it is important to conduct some exploratory monitoring to determine if these emerging threats are present or not, and if present, to include them in a comprehensive water quality monitoring program.

2 LAKE AND TRIBUTARY MONITORING PROGRAM

A comprehensive monitoring program for Shuswap and Mara lakes must address the immediate *known concerns* from eutrophication, grey water discharges and urban and agricultural runoff, as well as assess the significance of *emerging threats* to sources of drinking water and aquatic ecosystem health as outlined in Table 10, and Environment Canada (2001). Using this approach, a cost effective, proactive and scientifically defensible lake and watershed monitoring program can be developed which will protect the long term drinking water quality and aquatic ecosystem health in the Shuswap area lakes.

This enhanced program should build on the existing MOE Shuswap Lake monitoring program, and other long term credible monitoring programs (e.g., Salmon Arm WWTP permit monitoring). The scientific rationale and justification for including additional monitoring on *known* and *specific emerging threats* to drinking water quality and aquatic ecosystem health in Shuswap area lakes is as follows:

2.1 NUTRIENT SOURCES AND LOADINGS

2.1.1 WATERSHED AND TRIBUTARY LOADING

Nutrient sources and their impacts on the Canadian environment have been reviewed by Chambers et al., (2001). In a provincial comparison, they show that the residuals from agriculture make the largest contributions (t yr^{-1}) of both nitrogen (64.2%) and phosphorus (86.1%) loadings to surface and groundwater in British Columbia. The nutrient contamination of Shuswap and Mara lakes can originate from point (e.g., sewage treatment plants) and non-point sources many kilometers upstream in the watershed (e.g., agricultural land runoff). Mobile sources such as the extensive use of recreational boats and houseboats on these lakes can also represent a significant source of contamination if black water and grey water storage tanks are not used and adequate pump-out facilities provided.

Once the ambient lake water quality and tributary monitoring are underway, an attempt should be made to determine the important sources of nutrients and associated contaminants so that a proactive management plan can be developed to prevent further deterioration of water quality in the lake. This should be implemented in Years 2 and 3 of the monitoring program. This research and monitoring program should consist of 5 components namely: (1) land use and animal numbers; (2) septic systems; (3) sewage treatment plants; (4) houseboat use and distribution, and (5) point and non-point source tracking. Ultimately this information will be used to calculate a phosphorus loading model estimate for each lake, which will provide predictive capability for current and future trophic states.

Despite some minor arguments in the scientific literature regarding which limiting nutrient (i.e., nitrogen or phosphorus) controls lake productivity, the overwhelming number of studies demonstrates that phosphorus is the key limiting nutrient (Schindler and Vallentyne, 2008). Since phosphorus has no gaseous state, and cannot be destroyed, and is required in the highest stoichiometric ratio by phytoplankton, it is the logical element to control. Nitrogen has a gaseous state, and the atmosphere is approximately 78% nitrogen, hence trying to limit lake productivity by controlling nitrogen sources is a flawed strategy. Although nitrogen plays a secondary role in influencing lake productivity, it is the primary element responsible for nitrate contamination in ground water, as nitrate is more mobile in aquifers than phosphorus which tends to bind to soil particles and travel shorter distances. Therefore, the correct strategy is to develop land use and point/non-point control process that capture both nutrients e.g., advanced biological nutrient removal (i.e., BNR) wastewater treatment plants, similar to the wastewater treatment plant in Salmon Arm and throughout the Okanagan (e.g., Kelowna, Penticton, and Summerland).

2.1.2 LAND USE AND AGRICULTURAL TRENDS

Detailed land use maps and animal enumerations need to be developed for the Shuswap basin and the major tributary watersheds (i.e., Sugar and Mabel lakes and the Salmon, Shuswap and Eagle rivers). This was done for the Salmon River watershed, using 1981 and 1991 statistics (McPhee et al., 1996), but these data need to be updated and completed for the rest of the Shuswap basin, especially the Shuswap River watershed, due to the rapid expansion of intensive dairy operations in the watershed. Improved spatial analysis of animal distribution in winter and summer, as well as detailed crop planting and harvest information, manure and fertilizer application rates, are needed for a better spatial and temporal quantification and assessment of potential point and non-point source nutrient loading.

Current agricultural statistics along with animal unit calculations and agricultural crop requirements will allow the determination of nutrient (N, P and K) surpluses in different watershed units and help to focus a management strategy. Schreier et al., (2003) found that this was a useful exercise in the 20 management units of the Lower Fraser Valley. Once spread sheets and calculation methods have been set up it is relatively easy to update information as the agricultural census data are available. This information needs to be put into a Geographic Information System (GIS) to provide a visual and computer interactive tool to educate the managers and people who live in and create the nutrient runoff problems in the Shuswap basin.

2.1.3 Septic Systems

Shuswap Lake is a highly utilized recreational lake with many seasonal cabins as well as permanent residential areas, most of which use septic systems as a means of wastewater disposal. Many of these facilities are along the shoreline of the lake and with shallow soils over the bedrock in many areas there is the potential for ground water contamination and contaminant transport to the lake. A program needs to be developed using the information available from the municipal and regional governments to locate all of the septic systems in the different regions of the Shuswap basin and put this information into a GIS system to show the spatial distribution of these treatment systems in the tributary watersheds and around the lake.

A questionnaire needs to be developed and given to property owners to determine the cleanout frequency of their septic tanks. Septic systems do not function properly if they do not receive regular servicing. Dye tracer studies could be done on selected septic systems if there is concern with their operational efficiency and if the property owner agrees to such monitoring. This would build on previous Ministry of Environment and Shuswap First Nations fluorometry surveys done along the north shore on the West Arm of Shuswap Lake, which detected numerous instances of septic tank leakage into the lake.

2.1.4 Sewage Treatment Plant Contaminant Loadings

Sewage treatment plant discharges are usually a major source of nutrients to aquatic systems if they only utilize traditional primary and secondary treatment processes which are optimized for the removal of solids and degradable organic matter (biochemical oxygen demand – BOD). Effluent will also often be disinfected to destroy pathogens especially during the recreational season. More advanced treatment such as biological nutrient removal systems are available and have been installed in most of the Okanagan communities to prevent the nutrient pollution of the Okanagan Lakes. In addition to collecting data on the septic systems, the nutrient loading data needs to be collected from the major sewage treatment systems that discharge to Shuswap Lake and Mara Lake.

2.1.5 Boat and Houseboat Discharges

The Shuswap area is called the houseboat capital of Canada. The Canada Shipping Act and the BC Environmental Management Act (Section 13) prohibits the discharge of boat sewage to water bodies. Commercial house boats have tanks to store their black water which is discharged to municipal treatment facilities, however, there is very little policing of the these activities and the discharge of grey water contains bacteria, detergents and other contaminants (pharmaceuticals and personal care products) which can have detrimental effects on aquatic organisms. Discharges from private houseboats and water craft are not well regulated in BC inland waters.

Information needs to be collected on the houseboat activity on Shuswap and Mara lakes, if it is not readily available. Statistical information is needed on the number of boats and houseboats on the lake throughout the recreational season (mainly July and August), the number of people/days on these water craft, where they anchor for the evening, and information of the volumes of black water that they discharge to the municipal waste collection system.

These data could be collected by a summer student, but he/she would need the full cooperation of the houseboat marinas to show their records of rental activity. The student could do weekly surveys in the evening or early morning at the main anchorages used by houseboats for the July-August period. These data could also be assembled into a GIS data base to produce graphics of the weekly distribution of the houseboats at anchor. Pumped discharge information could also be collected and analyses made to determine houseboat discharge quality. These data would provide a foundation of information for loading calculations and their distribution and provide a basis to design a monitoring program for further tracking houseboat contaminants and their impacts on the shallow protected waters of Shuswap and Mara lakes.

2.1.6 Point and Non-Point Source Tracking of Contaminants

Once this nutrient loading information has been collected, and a phosphorus loading/trophic state model developed, a more detailed source tracking program can be organized to focus on areas that have been flagged as needing more investigation to confirm the sources. These studies can be organized for Years 4 and 5 of the monitoring program. Since this program is focusing on mainly nutrients and their impact on these lakes, this monitoring program will still be measuring the nutrient concentrations, but additional advanced techniques will be used to identify the sources of these nutrients. These include chemical as well as microbial indicators or markers which are known to come from specific sources.

2.1.7 Nitrogen monitoring: stable nitrate isotopes

Although much of the biologically available nitrogen is initially discharged as ammonia, aerobic nitrification processes usually convert it to nitrate rather quickly. The stable isotopes of nitrogen and oxygen in the nitrate anion can show different frequency distributions depending upon the source of the nutrient (Deutsch et al., 2006: Aravena et al., 2005, Chang et al., 2002). Chang et al. (2002) in studying nitrate sources in the Mississippi River basin, found that the riverine nitrates from different land uses had overlapping but moderately distinct isotopic signatures. Study sites with livestock had ^{15}N values that were characteristic of manure. Aravena et al. (2005) used the N and O stable isotopes of nitrate to delineate the nitrate plume associated with a septic system where ^{15}N was the most useful plume tracer. Deutsch et al. (2006) used the nitrate stable isotopes to look at the sources of agricultural nutrients from a drainage area over a hydrological year and found contamination from both organic (manure) as well as inorganic fertilizers. A recent thesis (Naugler, 2007) used the nitrate stable isotopes to trace nitrate sources in ground water in the Salmon River watershed in the lower Fraser Valley. She found inorganic fertilizer was not a dominant nitrate source but she could not differentiate between human and animal organic wastes since they had overlapping isotope signatures.

Properly designed monitoring at study sites in agricultural dominated watersheds of the Shuswap region could help to delineate the relative importance of inorganic fertilizers and animal manure as a nitrate-nitrogen source. However, these stable isotopes would probably not be of much use to differentiate between nitrate from a human septic system and animal manure. In shallow areas of the lake where there is concern about septic tank leakage directly into the lake from a poorly installed or maintained system, nitrate isotopes could help confirm the human nutrient source if there was no large contributions from animal manure. However, these isotopes could not be used to differentiate from septic system contamination and discharges from houseboats.

The nitrate must be separated from the sulphate and then concentrated from the water sample on an anion exchange column; the nitrate is eluted from the column, followed by N and O isotope quantitation on a mass spectrometer. If the samples for nitrate isotope determination are adsorbed to the column, then it costs approximately $50 per sample (2006 prices) to determine the stable O and N isotope in the nitrate at the University of Calgary mass spectrometer facility.

It is suggested that where the nutrient budget studies in Years 2 and 3 indicate a nutrient (nitrogen) surplus, that an investigation of this nutrient source be conducted over the period of a hydrological year in a sub-watershed area using stable nitrate isotopes as well as nutrient concentrations, flow measurements, and general field measurements (temperature, conductivity and turbidity) to better document the seasonal distribution of this contamination and provide a better foundation for developing a management strategy. It would probably require the analysis of 50 samples over the year and with the preparation time would probably cost $100/sample x 50 samples = $5,000 for just the nitrate isotope data. Samples would be collected more frequently (weekly) over the period of snow melt and higher runoff from the area and then reduce sampling to every other week during the low flow periods. With technician time, travel to the field, nutrient analysis, and data compilation it would probably cost $25,000 to run this component of the monitoring program successfully. Any monitoring of septic tank leakage to the lake would probably require a separate budget.

2.1.8 CHEMICAL TRACERS OF SEWAGE AND GREY WATER CONTAMINATION

Various chemical compounds have been proposed to help identify human and animal sources of nutrient and pathogenic contamination of water bodies (Scott et al., 2002). These include caffeine, detergent residuals (e.g., nonylphenols from anionic surfactants), fluorescent optical clothes brighteners, and fecal sterols such as coprostanol. The main problem in using these chemical tracers is that they occur in very small concentrations which requires the extraction from larger quantities of water or sediments followed by analysis on expensive instrumentation (gas chromatograph/mass spectrometers -GC/MS). Also there is very little information on the dynamics of most of these substances in water, such as degradation (photochemical, microbial), adsorption, and biological uptake processes. Still they have found their utility in several studies in defining areas of impact of discharges. For example, Metro Vancouver has been able to determine the area of impact of large wastewater outfalls such as the Iona Island sewage treatment plant by looking at the spatial distribution of nonylphenols and coprostanol in sediment.

Detergent residuals are of special concern since they have been reported to contribute toxicity to wastewater discharges (Bradley and Berube, 2008). A possible method to get around the expensive determination of specific detergents or their degradation products is to use a technique such as the measurement of Methylene Blue Active Substances (MBAS). Anionic surfactants complex with the organic dye, methylene blue, which can be extracted with a solvent such as chloroform and quantified on a spectrophotometer (APHA et al., 1989). However, this technique is only good down to a detection limit of 25 ug L^{-1} MBAS and it does not measure the common soaps that most of us use for personal hygiene. Also, high levels of anions such as nitrate and chloride can cause some interference. However, since anionic surfactants account for 63% of the synthetic surfactant production (Encyclopedia of Surface Colloid Science, 2002) they are widely used in cleaning today and make a worthwhile group of contaminants to trace. They could be used as tracers for sewage treatment plant discharges, houseboat discharges (if they ever wash their dishes or clothes on board), or improperly operated septic systems. Reneau and Pettry (1975) reported that MBAS only moved 3 m or less in two coastal plain soils in Virginia, so they do not move far in properly operated systems.

MBAS could be used as an additional tracer to document contamination from the grey water discharges of houseboats in littoral areas where they anchor. It would be useful to sample the grey water of several houseboats and determine the MBAS concentrations prior to moving into a program to follow these substances in the littoral area of in the lake where concentrations will be considerably lower. Also, sampling of the effluent of the Salmon Arm sewage treatment plant for MBAS determination both over a diurnal period and at different seasons would be useful to determine the usefulness of MBAS as a tracer of contamination to the Salmon Arm reach of Shuswap Lake.

2.1.9 MICROBIAL SOURCE TRACKING (MST)

With recent advances in molecular biology, the fingerprinting of specific groups or species of microorganisms has been a rapidly growing field of aquatic tracer application. Earlier investigations applied the ratio of fecal coliform to fecal streptococci (FC/FS) to delineate human from animal sources of fecal contamination and possible presence of pathogens (Geldreich and Kenner, 1969). This was possible since warm blooded animals other than humans discharge large numbers of fecal streptococci. However, this technique has proven unreliable due to the variable survival rates of FS in the aquatic environment. Other methods of tracking individual microbial indicators have been reviewed by Scott et al. (2002).

For microbial source tracking, there are two major divisions in the methodology, namely phenotypic and genotypic methods. The phenotypic methods deal with tests that involve the whole cell such as multiple antibiotic resistance and immunological methods. The genotypic methods determine DNA fingerprints which are specific for an individual microorganism and thus perform better than the phenotypic methods (Scott et al., 2002; Griffith et al., 2003). PCR (polymerase chain reaction) techniques which can amplify target areas of DNA are able to help identify specific microorganisms. These DNA fingerprint assays can be measured at two levels namely 1) determination of the presence or absence of a microorganism or 2) quantitative polymerase chain reaction (qPCR) where a fluorescent tag is incorporated into the amplified DNA to give a quantitative estimate of microorganism abundance.

A recent workshop at the National Water Research Institute (NWRI) in Burlington Ontario was convened to evaluate the state of science and assess the needs for MST in Canada (Edge and Schaefer, 2006). They concluded that many techniques are still at the research stage and that application of MST is more advanced in the United States as a result of the USEPA watershed loading legislation (USEPA, 2005).

One of the most popular MST techniques appears to be the repetitive element (REP) polymerase chain reaction (PCR) analysis. It has been recently applied successfully in microbial tracking studies in Canada (Mohapatra et al., 2007 – British Columbia; Kon et al., 2009- Lake Huron, Ontario). A disadvantage of this technique is that it requires considerable 'up front' field and laboratory work to collect individual fecal samples and prepare a comprehensive library of DNA fingerprints of these known fecal sources, before the method can be applied to delineate unknown fecal sources and follow them in time and space. For example, Mohapatra et al. (2007) collected 313 known fecal samples and used 552 isolates for DNA fingerprinting for the statistical analysis necessary to identify unknown fecal sources from their 4 study sites.

The USEPA microbial source tracking guide document (USEPA, 2005) is the most comprehensive review of techniques and their application to monitoring the sources of fecal contamination of water bodies (8 case studies reported) in the United States. The measurement of antibiotic resistance analysis (ARA) was the most common phenotypic method used (3 out of 8 case studies). Of the genotypic methods, PCR ribotyping of E. coli was used in 3 cases, but again this technique requires an extensive library, from the specific watershed, to be useful at fecal source identification. The most promising PCR technique that does not require a library is to measure host specific *Bacteroides* markers (one case study reported by USEPA). DNA markers for specific fecal sources are just being developed and are becoming available commercially. For example, Source Molecular Corporation in Florida can provide fecal *Bacteroides* identification for humans, birds and cow sources and they have others under development (pig, horse, chicken and dog). However, these tests are expensive, for qPCR of two genetic markers the cost is $1,100 US (2009) with a turnaround time of 7-11 days (www.sourcemolecular.com/).

With this technology rapidly under development, it's application to fecal source and thus major nutrient source delineation in the Shuswap lakes basin should be available during the latter part of this proposed monitoring program (Years 4 and 5). This technique would be particularly useful where there are questions concerning the relative importance of fecal sources and thus nutrients that originate from humans and animals (e.g., cattle manure). These cannot be separated with any degree of confidence using the stable isotopes in nitrate (Naugler 2007). It could easily cost $50,000 or more to conduct a monitoring program using microbial source tracking when it costs well over $1,000/sample for only two genetic markers. Express transportation of samples to the microbial laboratory can also be a significant expense in these monitoring studies. It is obvious that this methodology should only be incorporated into a monitoring program to answer specific contamination questions that cannot be answered by more conventional monitoring techniques.

As noted above, we estimate it would take approximately five years of work to conduct a comprehensive water quality assessment of Shuswap and Mara Lakes, and their surrounding watershed and tributaries. A time table for a five year monitoring plan for Shuswap and Mara lakes should be established as shown in Table 10. The rational for the five year program design is as follows in the next section.

3 Lake and Tributary Monitoring Plan

3.1 Deep stations (pelagic area)

The main lake pelagic (i.e., deep water) sampling stations in Shuswap Lake have been reasonably well monitored through several on again - off again monitoring programs since the late 1970s. The overall trend in water quality has ranged from stable to a slightly increasing trend in nutrient concentrations. The large size, rapid flushing rate, and warm epilimnion (i.e., zooplankton refugia) have all contributed to protect Shuswap Lake's deep water quality stations from eutrophication.

It is important to maintain the long term monitoring database established by the Ministry of Environment and other regulatory agencies, hence we recommend that at least 2 to 3 deep stations in the main lake areas of Shuswap Lake and Mara Lake are sampled intensively in one year, then reduced to a minimum number of stations – at least one per arm – for the remaining 4 years. Under this scenario, the simultaneous monitoring of multiple deep lake stations would demonstrate if there were any spatial and temporal variations and linkages between and within the main lake deep stations. For example, multiple deep station monitoring during the large algal bloom on June 2008 would have revealed the environmental conditions in Salmon Arm which triggered the bloom, and help explain why the bloom became so widespread.

A critical piece of information missing from the Shuswap area lakes is annual ^{14}carbon uptake primary production measurements. DFO measured ^{14}C update in the 1980s and 1990s (Nidle and Shortreed, 1996; Morton and Shortreed, 1996), but this measurement has not been done since due to the specialized training, cost and availability of suitable radioisotopes. Primary production in oligotrophic lakes can only be measured by ^{14}C uptake, hence this is sensitive indicator of trophic change in algal production, and should be conducted on the deep stations once every five years. MOE routine routinely conducts ^{14}C uptake measurements on Kootenay Lake and Arrow Lakes Reservoir; hence integration with the MOE Large Lakes Committee should facilitate access to this specialized monitoring technique at less than market costs.

Paleolimnology is another very powerful technique for examining trends in lake or reservoir trophic status through time. Fortunately, core sampling has already been conducted in Shuswap Lake by Cumming et al. (2007), who collected lake sediment cores at between Scotch and Lee creeks at 95 m, Fraser's Beach at 66 m and Marble Point at 136 m. In addition, DFO has conducted extensive coring of Shuswap Lake in the 1990s. The remaining task is to obtain all of the coring data and reports and store the data in a central relational data base. Sediment coring is extremely expensive, typically $20,000 per 50 cm core, hence additional coring requirements must be carefully considered. At present, given the data available from other limnological indicators, there does not appear to be an urgent requirement for additional coring in the Shuswap basin lakes.

3.2 SHALLOW STATIONS (LITTORAL AREA)

The main lake shallow (i.e., littoral) stations have been sampled infrequently since the late 1970s, and most recently by the Ministry of Environment's expanded monitoring program on Shuswap Lake. Littoral stations are more sensitive to seasonal and annual changes in water quality, due to their shallow depth, closer proximity to upland and near-shore development, point source and non-point source pollutant sources, and likely restricted flushing rates. Shallow station monitoring would involve both water column sampling for standard parameters (nutrients, anions/cations, phytoplankton), but also through the use of fluorometric surveys with dye tracers to detect leaking septic systems, and artificial substrates to facilitate quantitative assessment of attached algae (i.e., periphyton) accumulation rates in littoral areas throughout the lake. Typically this involves using ceramic, plexiglass or styrofoam plates, suspended in the water column, or placed on the lake bottom to a maximum depth of 6 m, and sampled at ~2 week intervals, when the plates are scraped clean or core sampled, and replaced for another 2 weeks. Ross (1984) used plexiglass plates in their detailed 1979 survey of Salmon Arm's water quality.

Over the course of the summer this will produce a series of ash free dry weight and chlorophyll 'a' accrual curves, which are a simple, yet effective technique for monitoring and comparing the trophic status of shallow water areas (Ross, 1984). Since shallow water sites typically respond more quickly than deep water stations, we recommend that the shallow water stations be sampled intensively each year, starting in Year 2, and monitored at this intensity in years 3, 4 and 5. The key to defensible monitoring of shallow water sites is to select a series of representative control stations in each arm, and a number of sites in areas of known or suspected water quality impairment (e.g., Blind Bay, Magna Bay, Tappen Bay), most likely where excessive periphyton growth is evident, or where fluorometric surveys have detected septic leakage.

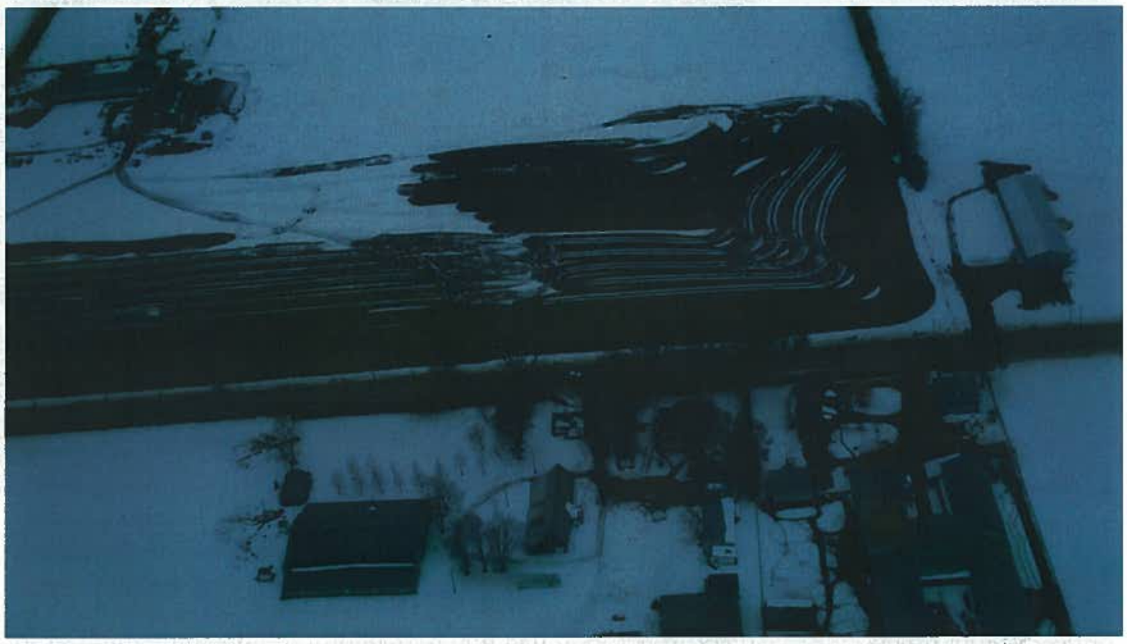
It will likely take 4 years to intensively sample all of the littoral areas in Shuswap and Mara lakes. During the intensive monitoring years, the control and target area littoral sampling stations would be moved around the lakes, and be coordinated with the information being collected from the land use and agriculture trends study, septic systems survey, WWTP contaminant loading study and the boat/houseboat discharge study in Years 2 and 3. After 4 years, this would result in a complete assessment of littoral zone control sites and areas of concern. These specific sites would be GPS identified, and then monitored over time once point and non-point nutrients reduction efforts were underway, to determine the effectiveness of the various point and non-point source nutrient control programs.

3.2.1 LAND USE AND AGRICULTURAL TRENDS

The land use and agricultural trends component of the monitoring program is quite straightforward. Prior monitoring programs in Shuswap Lake have identified sources of high tributary nutrient loading, including the Salmon and Eagle rivers, hence the monitoring program beings at the river mouth and proceeds upstream collecting samples at bifurcation points in the rivers. When combined with the land use mapping, GIS maps, animal enumeration data and known agricultural areas, it should be relatively easy to identify major sources of point and non-point source agricultural nutrient inputs.

Most of the river sampling can be conducted by vehicle, hence it is less expensive and time consuming than collecting deep and shallow station samples on the lake. For example, complaints were received by the Kamloops MOE office on April 4, 2009 regarding at least three dairy operations between Grindrod and Mara Lake that appeared to be spreading manure while the ground was still frozen and covered with snow (Figures 11 and 12).

Figure 11. Dairy farm manure being spread on snow covered frozen ground near Shuswap River on April 4, 2009.



In this type of situation, fine scale sampling immediately above and below a particular agricultural area or individual farm should easily be able to identify major nutrient contributors. When combined with the volumetric discharge of the river at that point, the mass loading of phosphorus and nitrogen can be calculated, and included in the development of an overall phosphorus and nitrogen loading model for Shuswap and Mara lakes. The land use and agricultural trends program and associated field monitoring should be conducted in Years 2 and 3 of the 5 year Shuswap lakes monitoring program.

Given the rapid expansion in the dairy industry towards intensive, large scale operations, it is important that considerable monitoring efforts occur in the Shuswap River watershed in the Enderby area, and further upriver into Sugar and Mabel lakes, to accurately document present and future water quality.

Figure 12. Dairy farm manure being spread on snow covered frozen ground immediately beside Shuswap River on April 4, 2009.

3.2.2 SEPTIC SYSTEMS

Septic system monitoring is similar to the land use and agricultural trends component of the Shuswap lakes monitoring program. Once the spatial distribution information is assembled from municipal and regional governments on the location of septic systems in different regions of the Shuswap basin and placed in a GIS system, a questionnaire is prepared and mailed out and a sequential basin-wide sampling program initiated. The questionnaires are designed to determine if the septic systems are receiving regular servicing. The monitoring can involve sampling for nutrients, fecal coliforms, and dye tracer studies could be done on selected septic systems if there is concern with their operational efficiency and if the property owner agrees to such monitoring. The septic systems questionnaire and associated field monitoring should also be conducted in Years 2 and 3 of the 5 year Shuswap lakes monitoring program, and should be closely aligned with the shallow station monitoring and fluorometric surveys.

3.2.3 SEWAGE TREATMENT PLANT CONTAMINANT LOADINGS

Monitoring the discharges from WWTPs is a key component of the Shuswap and Mara lakes monitoring program. These plants can be a major or minor source of nutrients depending on the method of treatment, and the volumetric loading and location of discharges. Since most WWTPs have either a Liquid Waste Management Plan or discharge permit from the Ministry of Environment, and a known outfall location, it is relatively straightforward to assemble the necessary information from provincial and municipal records, and follow up with a monitoring program to confirm if the WWTPs are discharging their permitted volume and concentration of nutrients. This activity is also planned for years 2 and 3 of the 5 year Shuswap lakes monitoring program.

3.2.4 BOAT AND HOUSEBOAT DISCHARGES

The Ministry of Environment has already developed a scientifically defensible sampling design to examine grey water discharges from congregations of moored or beached boats and houseboats. The preliminary sampling was conducted in 2008 at selected sites (e.g., Figure 10), and an expanded program is planned for 2009. This program should be continued in Years 2 and 3 of the monitoring program, or until sufficient data have been collected to adequately assess the magnitude and impact of grey water and possible illegal black water discharges from boats and houseboats.

If sufficient water quality information is already available from the 2008 and 2009 monitoring efforts, Years 2 and 3 should be directed towards collecting accurate statistical information on the number of boats and houseboats on the lake throughout the recreational season (mainly July and August) through ground and aerial surveys on the number of people/days on these water craft, where they anchor for the evening, and information of the volumes of black water that they discharge to the municipal waste collection system. This data should be assembled into a GIS data base to produce graphics of the weekly distribution of the houseboats at anchor. This data provides the required information for calculating loading rates and their geographical distribution, and provides monitoring program for further tracking houseboat contaminants and their impacts on the shallow protected waters of Shuswap and Mara lakes.

3.3 Point and Non-Point Source Monitoring Plan

3.3.1 Nitrogen monitoring: stable isotopes in nitrate

Stable isotope monitoring of nitrate should only be considered in Years 4 and 5 of the monitoring plan, due to the cost and unknown requirement for this type of monitoring. If the conventional monitoring in Years 1 through 3 has been unable to identify a specific nitrogen source, stable isotopes may be able to clarify the situation. Stable isotopes cannot differentiate between nitrate from a human septic system and animal manure, however, in shallow areas of the lake where there is concern about septic tank leakage directly into the lake from a poorly installed or maintained system, nitrate isotopes could help confirm the human nutrient source if there was no large contributions from animal manure. These isotopes could not be used to differentiate between septic system contamination and discharges from houseboats.

3.3.2 Chemical tracers of sewage and grey water contamination

Chemical tracing should be considered in all years of the monitoring plan, due to the proven utility of these methods. Fluorometric surveys can cover large areas of the lakes relatively quickly at low cost, and are useful for identifying control and treatment monitoring sites in littoral areas. Laboratory costs for sewage markers such as caffeine, detergent residuals (e.g., nonylphenols from anionic surfactants), fluorescent optical clothes brighteners and fecal sterols (e.g., coprostanol) are more expensive, and should be considered once fluorometric surveys have detected septic leakage in the water.

3.3.3 Microbial source tracking (MST)

Microbial source tracking should be delayed until Year 4 or 5 of the monitoring program due to the high cost and current state of this powerful, yet emerging monitoring technique. It is likely that microbial source tracking will become an invaluable tool in the near future, once the technique(s) become standardized and more readily available to the scientific an professional community.

Overall, the first five years of the Shuswap and Mara lakes water quality monitoring program would be structured as follows (Table 11).

Table 11. Initial five year comprehensive monitoring plan for Shuswap and Mara lakes.

Type of Monitoring Program					
Sampling Year	Main Lake deep stations	Main Lake littoral stations	Watershed tributaries	Nutrient Sources and Loadings	Point and Non-Point Source Tracking of Contaminants
Year 1 (2010)	Intensive deep station monitoring	Baseline littoral station monitoring	n/a	n/a	Chemical tracing of sewage and grey water contamination
Year 2 (2011)	Baseline deep station monitoring	Intensive littoral station monitoring	Watershed and tributary monitoring, land use and agricultural trends	Septic systems, sewage treatment plant contaminant loading, boat and houseboat discharges	Chemical tracing of sewage and grey water contamination
Year 3 (2012)	Baseline deep station monitoring	Intensive littoral station monitoring	Watershed and tributary monitoring, land use and agricultural trends	Septic systems, sewage treatment plant contaminant loading, boat and houseboat discharges	Chemical tracing of sewage and grey water contamination
Year 4 (2013)	Baseline deep station monitoring	Intensive littoral station monitoring	As required	As required	Chemical tracing of sewage and grey water contamination, Nitrogen stable isotopes, microbial source tracking
Year 5 (2014)	Baseline deep station monitoring	Intensive littoral station monitoring	As required	As required	Chemical tracing of sewage and grey water contamination, Nitrogen stable isotopes, microbial source tracking

3.3.4 FREQUENCY, DURATION AND LOCATION OF MONITORING STATIONS

The frequency and duration of the Shuswap and Mara lakes monitoring program should be aligned with the MOE Large Lakes Committee protocols and the large lake monitoring procedures that were developed in the Lower Mainland, Kootenay and Okanagan regions during the 1990s. Each of these regions developed and implemented long term multi-year monitoring programs on several lake lakes and reservoirs (e.g., Alouette Reservoir, Whaleach Reservoir, Okanagan Lake, Kootenay Lake and Arrow Lakes/Reservoir), hence they have had sufficient time to thoroughly examine how many deep water monitoring stations are required, which parameters to sample, which depths to monitor and frequency of sample collection. Each of these monitoring details directly influences the cost of monitoring programs through labour time to collect samples, laboratory charges for water chemistry and fees for expert plankton identification.

As previously indicated, a minimum of one long term deepwater monitoring station is required in each arm of Shuswap Lake and Mara lake, and in one year out of five, at least two to three replicate deep water stations are required to ensure the validity of the core long term deepwater monitoring stations. The number and location of shallow water stations are flexible, and cannot be determined in advance, and should be developed through discussions with MOE staff and local experts. All other aspects of the monitoring program are as flexible as required to address the particular issue being assessed. For the deepwater stations, Table 12 is proposed as a guide for developing the deepwater component of the Shuswap and Mara lakes monitoring program:

Table 12. Proposed Shuswap Lake and Mara Lake deep station water quality monitoring program: 2010-2014.

Parameter sampled	Sampling frequency	Sampling technique
Temperature, dissolved oxygen, pH, ORP, specific conductance and turbidity	Monthly, April to October	YSI at 1-m intervals from 0–50 m, and at 5-m intervals from 50–100 m as depth permits
Transparency	Monthly, April to October	Secchi disk (with viewing chamber)
Water chemistry TDS, specific cond., pH, silica, alkalinity and nutrients (TP, TDP, Low Level SRP, NO_3+NO_2, NH_3) Total metals	Monthly, April to October	Integrated sampling tube at 0–20 m plus a bottle sample 5 m off the bottom; plus discrete samples at 2, 5, 10, 15 and 20 m at each station from June to September June and September bottle samples at 10, 50, 100 & 150 m as depth permits
Chlorophyll a (not corrected for phaeophytin)	Monthly, April to October	Integrated sampling tube 0–20 m
Phytoplankton	Monthly, April to October	Integrated sampling tube at 0–20 m, samples fixed with Lugol's solution
^{14}C primary production measurements	June and August	2, 5, 10, 15 and 20 m (Year 1 only)
Macrozooplankton	Monthly, April to October	3 oblique Clarke-Bumpus net hauls (3minutes each) from 40–0 m (optional)
Juvenile sockeye and kokanee acoustic sampling	1 survey in the fall	Standard MOE Simrad and Biosonics hydroacoustic procedures
Juvenile sockeye and kokanee trawling	Fall trawl series	Standard MOE trawl series using oblique hauls
Adult sockeye and kokanee enumeration	Fall spawning period at selected index tributary streams	Standard MOE and DFO procedures (optional)
Paleolimnology	One time event, as required	50 cm gravity core

4 Program Management

4.1 Integration with Public Health and Permit Discharge Monitoring

It is important to integrate water quality monitoring programs that are being conducted by Regional Districts or municipalities within the Shuswap basin. Some WWTP permits require regular monitoring of the receiving environment, and Public Health agencies often monitor swimming beaches during summer months for bacterial contamination. Integrating all of these monitoring programs will reduce monitoring costs, eliminate redundant sampling, and provide a diversity of funding sources to ensure the long term viability of the monitoring program.

4.2 Central Water Quality Data Base

The data collected from the monitoring program should be made widely available to the public once the raw data has been checked for errors and omissions. A web-based data base is the logical way to disseminate the data at the least cost. This will build credibility with the pubic and generate long term support for the monitoring program.

4.3 Reporting and Web-Based Information Access

A "State-of the Lakes" water quality report should be issued annually, once all of the current years monitoring data has been reviewed, interpreted and disseminated in a standard reporting format. The reports should be posted on a Shuswap lakes web-site to minimized printing costs. This will also build credibility with the pubic and generate long term support for the monitoring program.

4.3.1 Public Involvement

It is crucial to involve the public and Shuswap and Mara lake NGO's in the development and implementation of the Shuswap lakes monitoring program. The public and area NGO's attended various SLIIP presentations throughout 2007and 2008 and provided considerable input to the development of the SLIPP process and final report. Protecting and improving the water quality of Shuswap and Mara lakes was consistently ranked among the highest priority concerns by area residents.

Comments received at the SLIPP presentations indicated the public felt that previous government testing did not measure emerging chemicals and pharmaceuticals being discharged from area sewage systems, and that the results of existing testing was not well distributed and the public is not well informed. Shuswap area NGO's believe that by involving their members, other watershed organizations, and residents, in such activities they can foster a better understanding of water quality concerns as well as garner increased support for lake protection. In addition, they hope to leverage their limited funding into additional funding from our communities, governments, and residents, to improve overall testing, thus assisting government agencies in establishing an appropriate water quality testing program in the Shuswap basin.

An excellent example of public involvement in lake monitoring was the CSRD funded Shuswap Lake Secchi disk project, originally conducted from late June to September, 1986. The MOE restarted the Secchi disk program in 2009, and this program should be expanded to include Adams, Little Shuswap, Mabel and Sugar lakes.

4.3.2 ESTIMATED COST

The estimated cost of the monitoring program will vary from year to year, depending on which parameters are monitored and the number of sampling stations. It is not possible to predict in advance how many shallow water monitoring stations will be sampled, so in Table 12 we have initially allocated $2,500 and $5,000 in Year 1 and $5,000 and $10,000 in Year 2-5 for Mara and Shuswap lakes respectively to accommodate shallow water monitoring, and this figure can be adjusted as required. The deep station monitoring costs are based on the current number of MOE deep stations in Shuswap Lake (i.e., Table 7: three in the Main Arm, three in Salmon Arm, one in Anstey Arm, one in Seymour Arm, one in Sicamous Arm and one in Mara lake) and assumes Shuswap Lake is 150 m deep at each station and Mara lake is 50 m (Table 13):

Table 13. Estimated costs for Shuswap and Mara lake water quality monitoring program: 2010-2014.

Monitoring component	Cost	Monitoring year
Land Use and Agricultural Trends	$30,000-$50,000 for a one year program depending upon the level of detail	Years 2 -3
Septic systems	$20,000-$30,000 to employ student and provide travel and computer facilities	Years 2-3
Sewage Treatment Plant Contaminant Loadings	Collection of this information would be included by the person hired to collect and assemble the septic system data	Years 1-5
Boat and houseboat discharges	$20,000-$30,000 for student summer employment, travel, computer service	Years 2-3
Deep water stations (Shuswap)	$98,270 $24,538	Year 1 Years 2-5
Deep water stations (Mara)	$30,304 $4,902	Year 1 Years 2-5
Shallow water stations (Shuswap)	$5,000 $10,000	Year 1 Years 2-5
Shallow water stations (Mara)	$2,500 $5,000	Year 1 Years 2-5
Nitrogen isotopes	$12,000 (preliminary estimate)	Year 4-5
Microbial source tracking	$22,000 (preliminary estimate)	Year 4-5
^{14}C primary production	$9,000 per lake sampling trip	Year 1 only
Paleolimnology	$20,000 per core	None scheduled*
Sockeye/kokanee assessment	$20,000	Years 1-5

*Examine existing Shuswap Lake core data from DFO and University researchers.

The annual cost for the five year integrated monitoring program for Shuswap Lake and Mara Lake is as follows:

- Year 1- $148,574 (Intensive deep station monitoring, baseline shallow station monitoring, chemical tracing of sewage and grey water, sockeye/kokanee assessment);
- Year 2 – $129,200 (Baseline deep station monitoring, intensive shallow station monitoring, land use and agricultural trends, watershed and tributary monitoring, chemical tracing of sewage and grey water, WWTP and septic system loading, boat and houseboat discharges, sockeye/kokanee assessment);
- Year 3 – $129,200 (Baseline deep station monitoring, intensive shallow station monitoring, land use and agricultural trends, watershed and tributary monitoring, chemical tracing of sewage and grey water, WWTP and septic system loading, boat and houseboat discharges, sockeye/kokanee assessment);
- Year 4 – $118,200 (Baseline deep station monitoring, intensive shallow station monitoring, chemical tracing of sewage and grey water, ^{15}N and microbial source tracking if required, sockeye/kokanee assessment);
- Year 5 – $118,200 (Baseline deep station monitoring, intensive shallow station monitoring, chemical tracing of sewage and grey water, ^{15}N and microbial source tracking if required, sockeye/kokanee assessment).

These cost estimates assume that MOE staff will maintain the water quality data base, and prepare the annual State-of-the-lakes report at no cost to the monitoring program.

5 DISCUSSION AND RECOMMENDATIONS

Shuswap Lake, Little Shuswap, Adams Lake and Mara Lake are the centerpiece of the economic, social and environmental sustainability of the Shuswap watershed. The pleasant climate, high water quality and natural resources in this area generates millions of dollars annually to resident First Nations and the Columbia-Shuswap and Thompson-Nicola Regional Districts in commercial, recreational and residential revenue, and permits a quality of life and residential property value that is among the highest in the industrialized world.

However, as has been observed all too often, the water quality of once pristine lakes can become degraded through sometimes intentional, but more often unintentional discharge of societal byproducts and wastes - typically nutrients. The process typically starts slowly, and due to the short time span of human memories and increasing societal mobility, the changes are often subtle at first, and go unnoticed by most, except for long term residents with clear memories of days gone by. This known as the *shifting baseline syndrome*, where each new generation establishes a reference point for the water quality based on what they initially perceive when moving to the Shuswap region. In the absence of a long term water quality monitoring program and reliable database, the degree of change in water quality becomes a point of argument and debate, rather than one of action and protection.

Shuswap Lake and Mara lakes are now exhibiting initial signs of declining water quality. Although this only occurs in isolated areas, and the deep lake stations in Shuswap Lake are still relatively pristine, subtle shifts in water quality are appearing, some areas are already eutrophic, and the first appearance of a lake-wide algae bloom in June 2008 provided a harbinger of possible future water quality conditions. The main threat to these lakes is the old nemesis eutrophication i.e., the excessive addition of nitrogen and phosphorus from a variety of human activities: WWTP discharges, agricultural runoff, improperly installed and operated septic systems and poorly designed urban runoff systems.

The degree to which emerging contaminants are present in Shuswap Lake and Mara Lake is unknown due to limited monitoring budgets and the traditional scope of regional water quality monitoring programs. Based on surveys from other large lakes in Western Europe, the US and Canada, it is likely that some emerging contaminants are already present in Shuswap and Mara lakes, although the concentrations are likely quite low, and the ecological implications uncertain. Illegally introduced species of fish are already present in Adams Lake, and may have migrated into Shuswap Lake, placing these sockeye dominated aquatic ecosystems at risk

As usual, during the initial stages of eutrophication, industrial, commercial and recreational users of the lakes, and individuals, communities and organizations responsible for discharging nutrients into the lake and tributaries are typically in a state of denial as to their role in the declining water quality. There is a belief that the large size and high flushing rate of Shuswap Lake will protect it from water quality degradation, so any perceived or real changes in water quality are typically blamed on someone else.

Without a reliable data base to identify nutrient and contaminant sources and examine trends, little action is taken. The rate of change accelerates slightly concomitant with the increasing population density and industrial activity that is attracted to this beautiful area, with a predicable decline in water quality.

This story has been repeated over and over again around the world: in the US – the Madison lakes and Lake Tahoe; in Europe - Lake Zurich; in China – Dianchi Lake; in New Zealand – Rotorua Lake; in Canada – Lake Erie, Lake Ontario and now Lake Winnipeg to name a few. In BC, the water quality in Osoyoos Lake, Vaseaux Lake, Quamichan Lake, Tabor Lake, Bouchie Lake, Glen Lake, Langford Lake and St. Mary Lake has all been degraded by eutrophication, and the list goes on. Some regions in BC have been proactive in reducing nutrient loading, especially in the Okanagan region, thanks to a groundbreaking Federal-Provincial Okanagan Basin Study that identified limiting nutrients from human activities as a major threat to water quality, and mandated state-of-the-art nutrient removal for any WWTP discharging effluent into these lakes (Summary Report of the Consultative Board, 1974; also see www.obwb.ca).

The best defense for preventing further water quality degradation in the Shuswap area lakes is similar to that recommend in the early 1970s to protect the Okanagan lakes: a detailed assessment and accounting of the nutrients and contaminants being discharged into these lake, followed by concrete action plants to reduce or eliminate nutrients and contaminant loading. The entire process rests on the foundation of a scientifically defensible basin wide monitoring program that can identify sources and track trends in water quality and aquatic ecosystem health through time. The threats to Shuswap area lakes in the 21st Century are much greater than the early 1970s when 'climate change', 'emerging contaminants', 'houseboat capitals', '*E. coli* 0157:H7' and 'agricultural intensification' were unknown terms.

The only real question remaining is will local, regional, provincial and federal governments, First Nations and NGO's take the necessary collaborative steps to initiate such a program, or follow the more common route of inaction and obfuscation, under the guise of "tight fiscal times", and let the drinking water quality and aquatic ecosystem health of these lakes deteriorate slowly over time? Vallentyne (1974) predicted that by the year 2000 we would be living in an environmental disaster he called the Algal Bowl. Just as the Dust Bowl of the 1930s was created by misusing western farmland, Vallentyne forecast that the continuing misuse of lakes could only lead to water quality degradation, and he conclusively demonstrated that an overload of nutrients was responsible for the explosive growth of algae. Vallentyne's efforts helped move policy makers in the North America to action in the 1970s regarding the dangers of phosphates in fresh water (Schindler and Vallentyne, 2008).

The response to these actions were spectacular in some cases, the Great Lakes and the Okanagan to name a few, but they focused mainly on point sources, as non-point sources of nutrients were more difficult to assess, and there were many obvious point source discharges to focus on. Now, in the 21st century, the non-point source issue has assumed the dominant position, and society must tackle the loss of nutrients from agricultural lands, urban runoff and small septic systems with the same intensity that point sources of nutrients were addressed in the 1970s and 1980s. Nutrient sources and their impacts on the Canadian environment have been reviewed by Chambers et al. (2001), and in a provincial comparison, they show that the residuals from agriculture made the largest contributions (t yr^{-1}) of both nitrogen (64.2%) and phosphorus (86.1%) loadings to surface and groundwater in British Columbia.

To be blunt – it is unlikely that the Shuswap lakes can be adequately protected over the long term unless an integrated comprehensive monitoring program exists, followed by concrete action plans to reduce nutrient and contaminant loadings as required. The hard lesson that has been repeatedly demonstrated around the world, is that it is safer and far less expensive and environmentally disruptive to prevent a water quality problem from developing through early detection and proactive control/elimination, rather than attempting expensive and uncertain remedial actions after the problem has become widespread. As our grandmothers used to remind us "*An ounce of prevention is worth a pound of cure*".

The following recommendations are thus offered:

1. Arrange an interagency meeting in 20010 (e.g., MOE, DFO, CSRD, TNRD, Interior Health, First Nations and NGOs) to identify monitoring stations, agree on an annual monitoring plan (AMP) within the 5 year monitoring plan time frame and secure funding to initiate the monitoring program in 2011;
2. Create a working group of commercial boating interests, First Nations, CSRD and MOE staff to resolve the inadequate grey and black water pump out facilities;
3. Expand the public Secchi disk monitoring program to include Adams Lake, Little Shuswap, Mabel, Shuswap Lake, Sugar and Mara Lake;
4. Develop a centralized data base and publically accessible Shuswap Lakes water quality web site;
5. Issue an annual State-of-the-Lakes report on the water quality of the Shuswap lakes, possibly in concert with an annual workshop, co-sponsored by SLIPP, CSRD and the BC Lake Stewardship Society;
6. Develop partnerships with local universities to explore cost-effective monitoring of emerging contaminants;
7. Conduct public meetings throughout the Shuswap in late 2010/early 2011 to explain the rationale for the water quality monitoring program, and build support for the basin-wide public Secchi disk monitoring program;
8. Specifically engage the agricultural community in the Shuswap watershed to understand the rationale for, and participate in land-based nutrient containment/reduction activities where required, with support from Federal and Provincial environmental farm plan initiatives; and
9. Continue with the aggressive MOE initiative to eradicate illegally introduced fish species in the Shuswap basin.

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