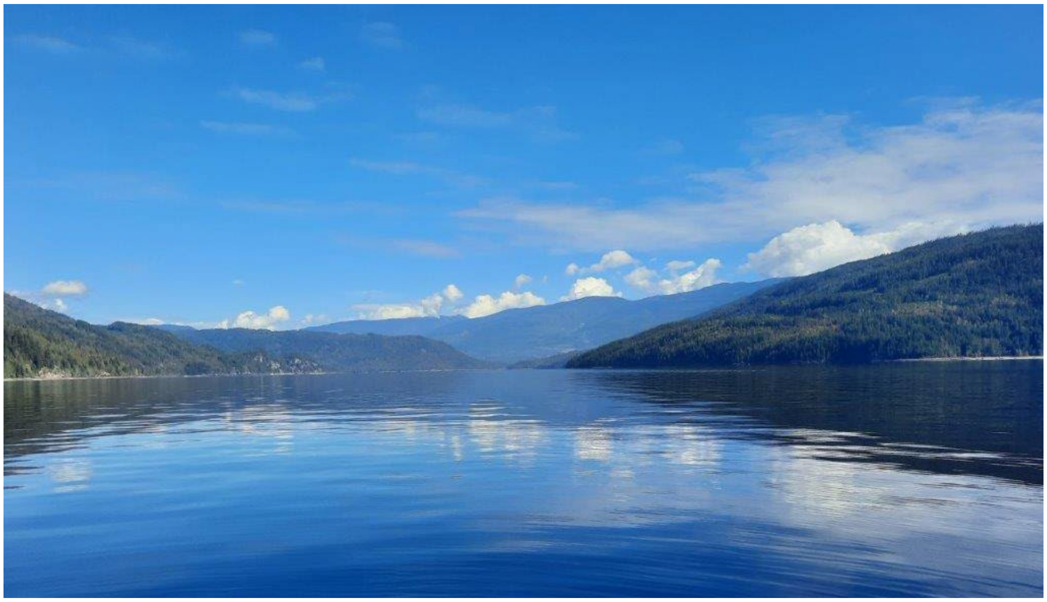
ENVIRONMENTAL QUALITY SERIES

WATER QUALITY ASSESSMENT FOR SHUSWAP LAKE



January 2022

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The Assessment Report was developed by Burke Phippen of BWP Consulting from adapting and updating the preliminary report.

This 2022 document has been revised by Dennis Einarson, B.Sc., R.P.Bio. along with edits from other ENV staff.

EXECUTIVE SUMMARY

Located within the traditional territory of the Pespeselikwe te Secwépemc and Neskonlith Indian Band, Shuswap Lake is an important water body in British Columbia because of its significant cultural, ecological, economic, and recreational values (RDNO 2014). For each of these values, good water quality is essential.

The Ministry of Environment and Climate Change Strategy has undertaken a water quality assessment for the Shuswap Lake to provide the information for future management decisions and plans in and around the lake as well as towards the development of Water Quality Objectives (WQOs). This assessment examines existing water quality in the context of the most-sensitive designated uses—specifically, as habitat for aquatic life, recreation and aesthetics, and domestic source water—to determine if these uses are being diminished. Furthermore, long-term trends in water quality were examined to identify potential parameters for which WQOs could be developed to ensure Shuswap Lake maintains its ecological, cultural, and social values.

Based on its current chemical and biological conditions, Shuswap Lake is best described as oligotrophic, having low biological productivity, clear water, and low nutrient concentrations. However, higher nutrient levels and primary productivity near Salmon Arm indicate mesotrophic conditions in this area. Water quality in Shuswap Lake is strongly influenced by stream flow, precipitation, and groundwater infiltration. Tributaries have been identified as a major source of nutrient inputs into Shuswap Lake, with non-point sources such as agricultural and urban runoff contributing more to total phosphorous and total nitrogen loadings in Shuswap Lake than point sources such as wastewater treatment plants.

The water quality parameters assessed in this report included:

- total phosphorus, total dissolved phosphorus
- chlorophyll *a*
- total nitrogen, ammonia, nitrate, and nitrite
- dissolved oxygen
- water transparency
- bacteria
- total organic carbon and dissolved organic carbon

Earlier studies found that water quality in Shuswap Lake was generally good, except for the Salmon Arm, where water quality was found to be fair. The findings of this assessment are consistent with those earlier studies. In the Main Arm, water quality was sufficient to promote a healthy aquatic ecosystem. Near Sicamous (in the Salmon Arm), surface waters were primarily oligotrophic, but with occasional periods of mesotrophic conditions. Conditions in the Salmon Arm do not appear to have changed much from earlier studies and continued to be classified as mesotrophic. Seymour and Anstey Arms were not included in the main assessment, but additional information examined in an addendum (see Appendix B) noted declining trends in some water quality parameters.

TABLE OF CONTENTS

LIST OF TABLES

PAGE NO.

LIST OF FIGURES

PAGE NO.

1 INTRODUCTION

Shuswap Lake and two connected lakes, Mara Lake and Little Shuswap Lake, are located within the traditional territories of the Pespeselikwe te Secwépemc and Neskonlith Indian Band and are the heart of the economic, social, and environmental sustainability of the Shuswap region in the Southern Interior of British Columbia (Figure 1). Shuswap Lake provides habitat for many fish species and other aquatic life, is the nursery lake for the Adams River sockeye salmon and provides a world-class rainbow trout fishery (NHC 2014b).

In addition to their ecological and First Nations values, the lakes support tourism, boating, angling, both recreational and residential property development, and are one of the most important house-boating destinations in Canada. Each of these values depends upon good water quality in the lake. As part of the overall strategy to protect water quality in Shuswap Lake, Mara Lake, and Little Shuswap Lake, the Ministry of Environment and Climate Change Strategy (ENV) has undertaken a water quality assessment of Shuswap Lake to provide information and an interpretation of existing water quality to support future management decisions.

Several key documents have provided essential background information and data for this assessment of Shuswap Lake and its watershed. Documents, many of which were produced for the Shuswap Lake Integrated Planning Process (SLIPP)1, include:

- Quarterly reports to the SLIPP Steering Committee, December 2012 to March 2014
- 2011-2012 and 2011-2013 Water Quality Summary reports
- Water Quality reports for 2011, 2012 and 2013 by Northwest Hydraulic Consultants (NHC)
- Sources of Nutrients Report by Tri-Star Environmental
- Review of Greywater Management Strategies by NHC
- Recreation Management Plan Situation Analysis Report
- Best Practices – Lake-based Recreation Management Report
- Recreation Management Plan Intercept Survey Results Final Report
- Backgrounder on Recreation Management Plan
- Char and Trout Habitat Report
- Shoreline Management Guidelines: Shuswap and Mara Lakes - Mabel Lake
- Shuswap Watershed Atlas (http://cmnmaps.ca/SHUSWAP/)
- SLIPP Final Report

A comprehensive tabulation of all documents, including their purpose, content and direct online link, is provided in Appendix A. To keep this report concise for readers, the detailed information contained in these documents is either summarized in text or tables or incorporated by reference.

[1] Reports are archived at: http://www.fraserbasin.bc.ca/SLIPP_Resource_Archive.html

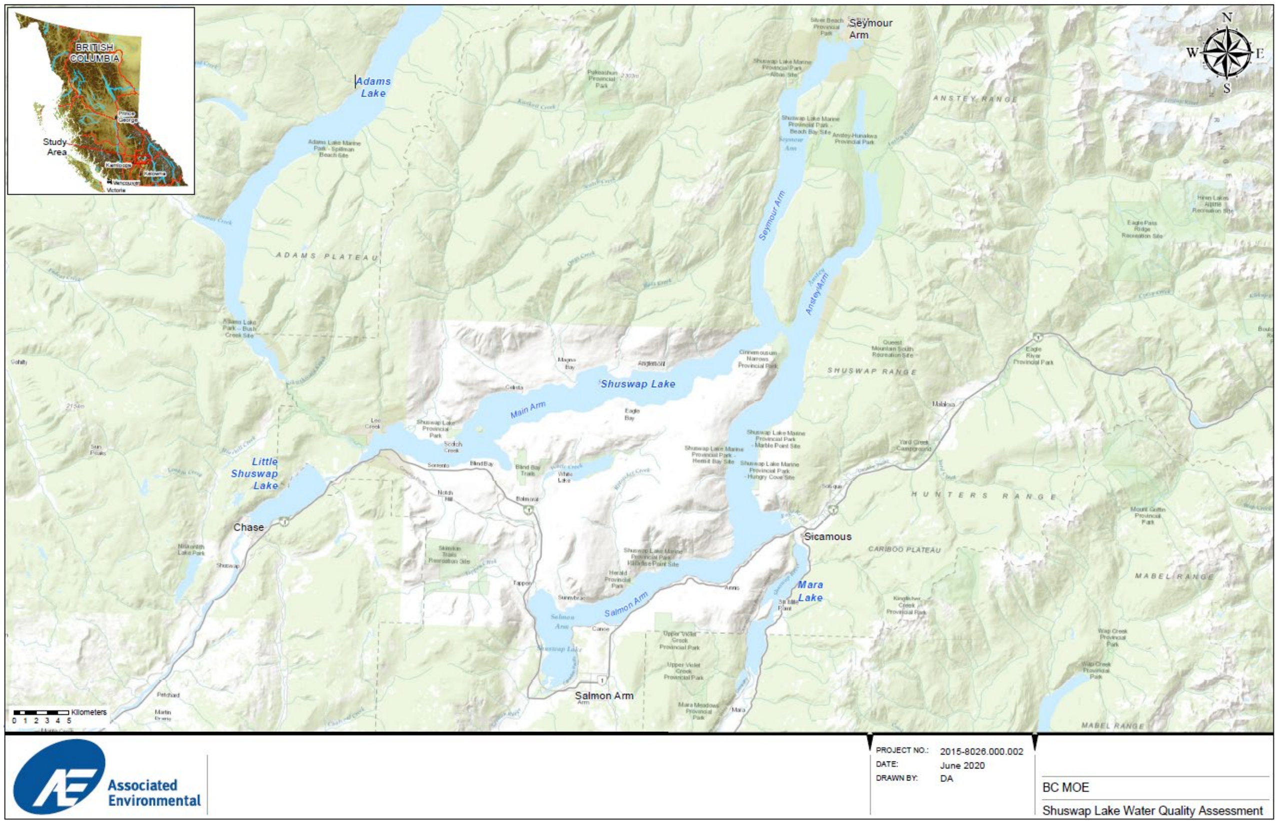


Figure 1: Shuswap Lake location and site overview.

Sections 1 through 4 of this report review the hydrology and physical limnology, water uses, and point and non-point sources of nutrients for Shuswap Lake and include a discussion of the anthropogenic and natural influences on the lake. Section 5 provides background, methodology and a history of water sampling of Shuswap Lake that has been undertaken by ENV and others. Section 6 assesses various water quality parameters related to nutrient inputs. Section 7 offers a discussion of the report's findings and Section 8 provides recommendations for monitoring. Since several years have passed since the original assessment for this report was undertaken, an addendum examining data collected between 2015 and 2019 has been included in Appendix B.

2 WATERSHED PROFILE

2.1 Physical Characteristics and Hydrology

Shuswap Lake is located at approximately 347 metres (m) above sea level within the South Thompson River drainage basin, which is part of the Fraser River drainage basin. It has an atypical "H" shape comprised of four long "arms" called Salmon Arm, Main Arm, Anstey Arm and Seymour Arm (Figure 2). These arms are further sub-divided into reaches, which will be the focus of the assessments in Section 6 of this report.

The lake's average depth is 62 m with a maximum lake depth of 171 m in Seymour Arm. Maximum depths in the other arms are 136 m in Salmon Arm, 122 m in Anstey Arm, and 110 m in the Main Arm[2]. The physical characteristics of Shuswap Lake are summarized in Table 1.

Like many large temperate lakes, long-term temperature profiles indicate that Shuswap Lake thermally stratifies during the summer and exhibits turnover from fall through to spring as ice cover (necessary for stratification during the winter) seldom occurs. No reports were available on reach-specific water movement, water residence times, flows, seiches or other physical limnological characteristics.

Table 1: Physical characteristics of Shuswap Lake

Shuswap Lake	
Elevation	347 m
Surface Area	310 km^2
Perimeter	342 km
Catchment Area	17,478 km^2
Mean Depth	62 m
Maximum Depth	171 m
Volume	19 km^3
Mean Water Residence Time	2.1 years
Outlets	1
Permanent Inlets	34

Sources: Shuswap Lake Watch (2003), except catchment area from *Delineated watershed using ArcGIS*

Shuswap Lake's watershed is relatively large at 17,478 kilometres squared (km2) compared to its surface area of 310 km2 (Shuswap Lake Watch 2003), and its hydrology is influenced by 13 upstream and downstream sub-drainages and three of which flow into Mara Lake before going to Shuswap Lake (Table 2 and Figure 2).

[2] Depths taken from chart 3053, bathymetric map of Shuswap Lake, available from Fisheries and Oceans Canada at http://www.charts.gc.ca/charts-cartes/charts-cartes-eng.asp?num=3053

Table 2: Summary of sub-drainage basins within the Shuswap Lake/South Thompson watershed and major inflows to Shuswap Lake

SUB-DRAINAGE BASIN	AREA (KM^2)	MAJOR INFLOW TO SHUSWAP LAKE	STREAM LENGTH (KM)	INLET LOCATION
SHUSWAP RIVER	5,468	Shuswap River	196	Mara Lake
ADAMS RIVER	3,333	Adams River	131	Shuswap Lake-Main, between Sorrento and Little River
SALMON RIVER	1,564	Salmon River	146	Salmon Arm, at Salmon Arm
EAGLE RIVER	1,249	Eagle River	76	Sicamous Reach, at Sicamous
SEYMOUR RIVER	806	Seymour River	71	Seymour Arm, at Seymour Arm
BESSETTE CREEK	796	Shuswap River	18	Mara Lake
SCOTCH CREEK	600	Scotch Creek	57	Shuswap Lake-Main, at Scotch Creek
MOMICH RIVER	476	Adams River	15	Shuswap Lake-Main, between Scotch Creek and Little River
PERRY RIVER	438	Eagle River	126	Sicamous
CAYENNE CREEK	368	Adams River	131	Shuswap Lake-Main, between Scotch Creek and Little River
WAP CREEK	344	Shuswap River	110	Mara Lake
ANSTEY RIVER	235	Anstey River	30	Anstey Arm
CELISTA CREEK	289	Celista Creek	17	Seymour Arm, at Albas

Sources: Shuswap Lake Watch (2003) and delineated watersheds using ArcGIS.

The Shuswap Lake system includes two other smaller lakes: Little Shuswap Lake and Mara Lake. Shuswap Lake flows into Little Shuswap Lake via the Little River3 from the Main Arm. Little Shuswap Lake then discharges to the South Thompson River at the town of Chase (Shuswap Lake Watch 2003). Mara Lake is connected to Shuswap Lake by a large open channel at Sicamous. In contrast to Shuswap Lake, Mara and Little Shuswap Lakes are both relatively shallow at 46 m and 59 m respectively.

Three relatively large lakes drain into the Shuswap Lake system: Adams, Mabel, and Sugar Lakes (Table 3). Additional hydrology and morphometric information about these lakes is available on the Shuswap Lake Watch website.4

[3] Also known as Little Shuswap River

[4] http://www.shuswaplakewatch.com/research/resfacts.html

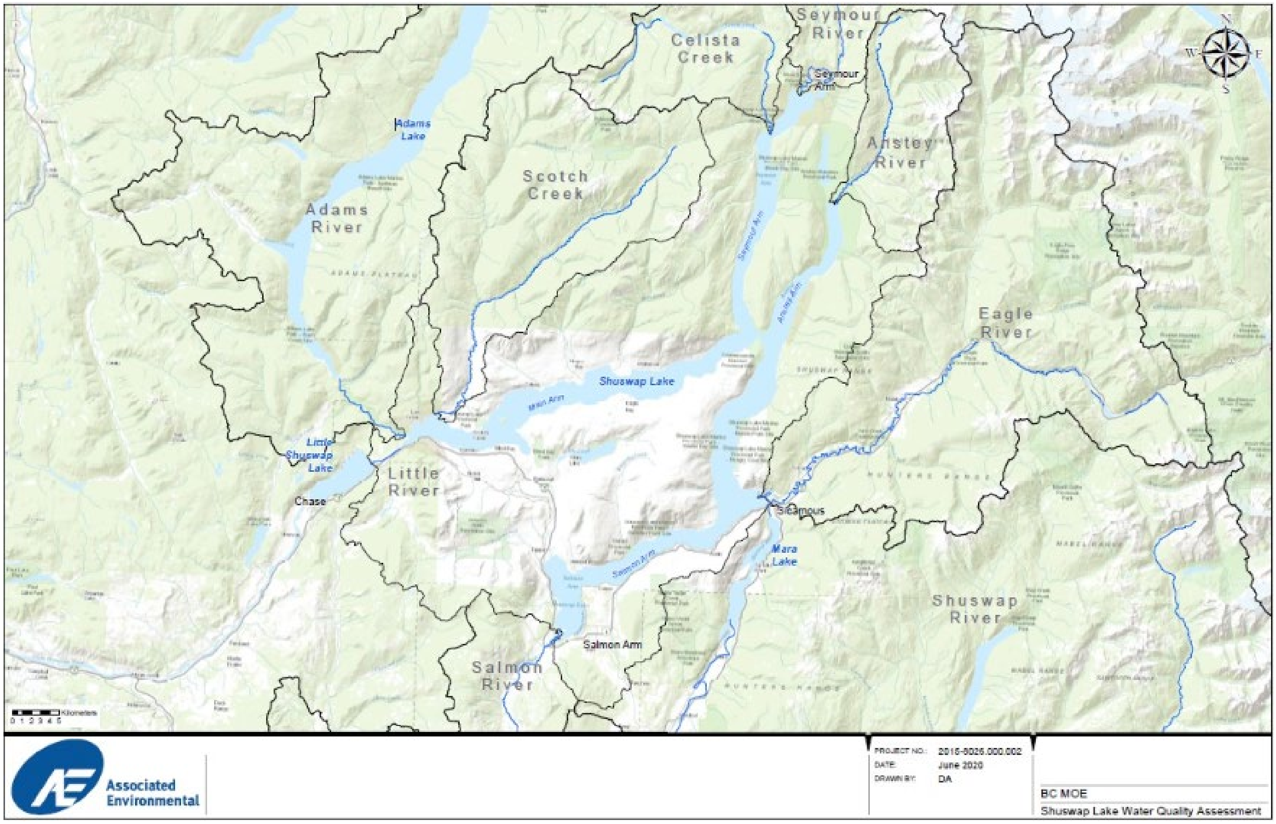


Figure 2: Watershed catchments of major tributaries to Shuswap Lake

The Water Survey of Canada (WSC) currently operates six hydrometric stations on the major inlet and outlet streams of Shuswap Lake (Table 4). The total mean annual inflow to Shuswap Lake from the main inlets is 236 cubic metres per second (m3/s), whereas the mean annual outflow from Shuswap Lake (based on the hydrometric station at the South Thompson River at Chase) is 292 m3/s. The annual outflow has historically ranged from a minimum of 45.8 m3/s (1929) to a maximum of 1,410 m3/s (1948) (WSC 2015). The higher outlet than inlet flow indicates that the main inflows listed in Table 3 do not represent all water flowing to Shuswap Lake. As a result of the many inflowing streams and large watershed relative to the outflow volumes, Shuswap Lake has a short hydraulic residence time of 2.1 years (Nidle and Shortreed 1996).

Shuswap Lake water levels are monitored by the WSC station at Salmon Arm (WSC Station 08LE070). The highest lake water levels typically occur in June and July, following spring freshet (Figure 3). The lowest lake water levels typically occur in March and April. The drainage areas shown in Table 3 and Table 4 below differ slightly due to the location of the WSC gauge. Table 2 provides the total area of each basin, whereas Table 4 provides the drainage area for the WSC gauge.

Table 3: Summary of morphometric characteristics of large lakes in the Shuswap Lake drainage

Lake	Surface Area (km^2)	Elevation (masl)*	Mean Depth (m)	Maximum Depth (m)
Shuswap Lake System				
Shuswap Lake	310	347	62	161
Little Shuswap Lake	18	347	14	59
Mara Lake	19	347	18	46
Other Lakes Draining into the Shuswap Lake System				
Adams Lake	138	408	169	457
Mabel Lake	60	395	120	201
Sugar Lake	21	606	35	83

Source: Shuswap Lake Watch (2003)
*masl = metres above sea level

Table 4: Summary of active WSC Stations on major streams of Shuswap Lake and in Shuswap Lake

WSC Station Name (Station ID)	Inflow / Outflow	Drainage Area (km^2)	Record Length	Regulation Type	Coordinates		Mean Annual discharge	
					Latitude	Longitude	m^3/s	$L/s/km^2$
South Thompson River at Chase (08LE031)	Outflow	15,800	1911 - Present	Natural	50° 45' 54'' N	119° 44' 25'' W	292	18.5
Adams River near Squilax (08LD001)	Inflow	3,210	1911 - Present	Natural	50°56' 18" N	119°39' 16" W	70.2	21.9
Salmon River near Salmon Arm (08LE021)	Inflow	1,550	1911 – Present	Natural	50° 41' 35'' N	119° 19' 40'' W	4.88	3.15
Shuswap River near Enderby (08LC002)	Inflow to Mara Lake	4,720	1911 - Present	Regulated at Sugar Lake Dam and Wilsey Dam	50° 32' 45'' N	119° 00' 47'' W	87.2	18.5
Eagle River near Malakwa (08LE024)	Inflow	932	1913 - Present	Natural	50°56' 11''N	118° 47' 59" W	37.6	40.3
Seymour River near Seymour Arm (08LE027)	Inflow	805	1914 – Present	Natural	51°15'45. 0''N	118° 56' 48" W	36.2	45.0
Shuswap Lake at Salmon Arm (08LE070)	-	-	1951 – Present	Natural	50°42' 23" N	119°16' 52" W	-	-

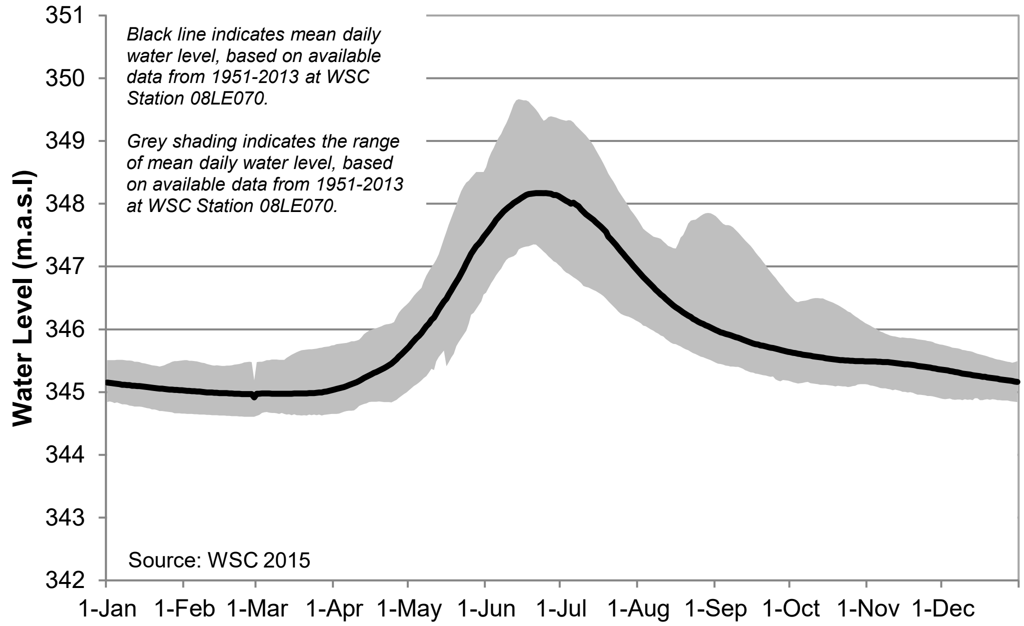


Figure 3: Mean daily water level for Shuswap Lake at Salmon Arm (WSC Station: 08LE070; Period of Record: 1951-2013)

2.2 Trophic Status

Trophic status is a classification system that rates lakes based on their biological productivity. This classification system describes the basic chemical and biological conditions of a lake and allows for comparisons among lakes. The rating quantifies various lake characteristics, including water clarity, oxygen depletion, algal biomass, and nutrient concentrations.

Using this system, Shuswap Lake is described as primarily oligotrophic, which means it is characterized by relatively low biological productivity, clear water, and low nutrient concentrations. Representative water chemistry data from four key water quality monitoring sites are typical of the low primary productivity and dilute nature of this large, deep lake (Table 5). However, the higher nutrient levels and primary productivity indicators off Sandy Point suggest Salmon Arm may have a mesotrophic status. Sections 5 and 6 of this report provide further details about the water chemistry of Shuswap Lake.

Table 5: Average values for select parameters within four reaches of Shuswap Lake

Parameter	Average concentration or value			
	Salmon Arm Reach off Sandy Point TB#5	Sicamous Reach opposite Marble Pt.	Main Arm Reach off Armstrong Pt.	Sorrento Reach west of Sorrento
Date range for sample collection	**1987-2014**	**1971-2014**	**1990-2014**	**1971-2014**
pH[1]	7.8	7.8	7.5	7.6
Total phosphorus (µg/L)[1]	12.1	4.8	3.3	4.2
Dissolved phosphorus (µg/L)[1]	7.8	3.5	3.0	3.3
Total nitrogen (mg/L)[1]	0.22	0.17	0.13	0.15
TN:TP ratio (mass)[2]	28:1/18:1	35:1/28:1	45:1/29:1	39:1/29:1
Chlorophyll-*a* (µg/L)[3]	3.6	1.8	1.5	1.5
Alkalinity, as $CaCO_3$ (mg/L)[1]	56.9	42.7	36.1	36.1
Total organic carbon (mg/L)[1]	3.01	2.73	1.98	2.42
Dissolved organic carbon (mg/L)[1]	2.60	2.12	1.92	2.01
Specific conductance (µS/cm)[1]	123.6	99.6	84	91
Secchi depth (m)	4.0	7.7	9.5	8.2
Sulphate (mg/L)[1]	8.47	6.45	5.3	5

Data provided by ENV

Notes:

1. Average was calculated using surface and deep measurements combined.
2. Calculated using average total nitrogen and average total phosphorus in surface samples during spring turnover. TN:TP ratio by mass >15 indicates a phosphorus limited system.
3. Chlorophyll *a* samples were collected from the zone of light penetration (photic zone).

A water quality monitoring program conducted between 2011 and 2013 found water quality in Shuswap Lake was generally good, and most samples met guidelines for drinking water, recreation, livestock, wildlife, and fish protection (SLIPP 2014). The monitoring program included both offshore (“mid-lake”) water quality monitoring to detect long-term changes in water quality, and near shore/littoral monitoring to identify short-term changes in water quality from both point and non-point sources. Results from this monitoring effort indicated that mid-lake water quality was generally good, although elevated nutrients sometimes occurred in Tappen Bay near the City of Salmon Arm (NHC 2013). Near shore monitoring results also showed variation in concentrations of nutrients (nitrogen and phosphorus) and other parameters that appear related to the resuspension of sediments from the shallow foreshore area (NHC 2013). Section 4 of this report provides further details on nutrients in Shuswap Lake.

2.3 Climate

Located within the Interior Plateau of B.C., Shuswap Lake experiences seasonally warm summer temperatures and cold winters. Despite the cold winters, Shuswap Lake rarely freezes. Due to the size of the lake (which spans several biogeoclimatic zones), the weather often varies among the four arms. The closest Environment Canada climate station is at the Salmon Arm Airport (Climate ID: 1166R45), located approximately 4 km southeast of the Lake and at an elevation of 527 metres above sea level, roughly 200 m higher than the surface of Shuswap Lake (Environment Canada 2015).

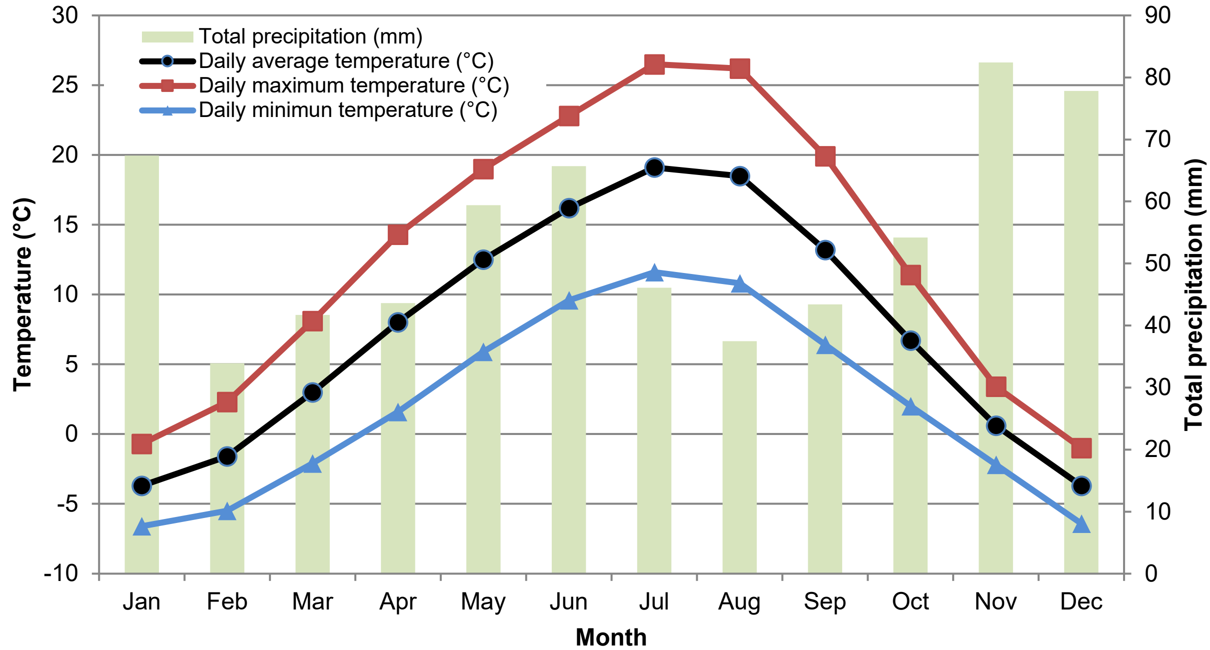
Climate normal data (1981-2010) for the Salmon Arm Airport station are summarized in Table 6 and Figure 4. During the 1981-2010 period, the mean annual temperature was 7.4 degrees Celsius (^{0}C), with average daily temperatures ranging from -3.7 to 19.1^{0}C in January and July, respectively (Environment Canada 2015). Annual average total precipitation was 653 millimetres (mm), and monthly average total precipitation ranged from 33.9 mm (February) to 82.4 mm (November). Given the slight difference in elevation between the climate station and Shuswap Lake, the proportion of precipitation falling as rainfall is likely to be similar at the lake as at the climate station, although variation around the lake is likely (see Section 3.6).

Table 6: Climate normal temperature data for 1981-2010 (Climate ID: 1166R45)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
						Temperature							
Daily Average (°C)	-3.7	-1.6	3	8	12.5	16.2	19.1	18.5	13.2	6.7	0.6	-3.7	7.4
Standard Deviation	2.6	2.5	1.6	1	1.5	1.3	1.7	1.3	1.7	1	2.8	2.9	2.6
Daily Maximum (°C)	-0.7	2.3	8.1	14.3	19	22.8	26.5	26.2	19.9	11.4	3.4	-1	12.7
Daily Minimum (°C)	-6.6	-5.5	-2.1	1.6	5.9	9.6	11.6	10.8	6.4	2	-2.2	-6.4	2.1
						Precipitation							
Rainfall (mm)	11.2	14.7	32.5	43.1	59.4	65.7	46.1	37.5	43.4	53.6	50.7	11	468.9
Snowfall (cm)	56.2	19.2	9.2	0.6	0	0	0	0	0	0.7	31.6	66.8	184.2
Total Precipitation (mm)[1]	67.4	33.9	41.7	43.6	59.4	65.7	46.1	37.5	43.4	54.2	82.4	77.8	653

Source: Environment Canada (2015).

[1] Total precipitation is the sum of measured rainfall plus the estimated water equivalent in snowfall (calculated by dividing the amount of snow by 10).



Source: Canadian Climate Normals (Environment Canada 2015)

Figure 4: Average temperature and precipitation at Salmon Arm Climate Station 1166R45 from 1981 to 2010

2.4 Water Balance Variations and Climate Change

Water quality in Shuswap Lake is greatly influenced by the variability in the annual water balance, which affects the rate of water movement through the lake. The lake's major stream inflows are strongly influenced by winter snowpack in the drainage basin, direct precipitation, and groundwater flow, whereas the major outputs are evaporation and the outflow through Little River. Climate change may alter the water balance in the future, which could have long-term implications for water quality and environmental conditions in Shuswap Lake.

Table 7 summarizes the climate change effects anticipated for the Columbia Shuswap Regional District (CSRD) by the 2050s, as obtained from Pacific Climate Impacts Consortium's (PCIC) Plan-to-Adapt tool (PCIC 2016) and based on results from several climate change models. The warmer average temperature will result in greater lake evaporation, an increase in rainfall, and a decrease in snowfall, and while the overall annual precipitation is expected to increase, more will fall as rain over the winter and spring than as snow. As a result, stream inflows are predicted to peak earlier in the spring but with a shorter period of freshet flow. The combination of greater evaporation from the lake and greater transpiration (loss of water via evaporation from plant leaves) throughout the watershed, along with less summer precipitation, could affect water temperature and water quality in late summer and fall. In addition, more frequent springtime flooding associated with increased rain and rain-on-snow events could increase sediment loads compared to current conditions.

Table 7: Summary of climate change expected for Columbia-Shuswap in the 2050s

Climate Variable	Season	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Mean Temperature (°C)	Annual	+1.8 °C	+1.2 °C to +2.7 °C
Precipitation percent (%)	Annual	+5%	-3% to +11%
	Summer	-6%	-18% to +1%
	Winter	+9%	-1% to +16%
Snowfall (%)	Winter	-6%	-13% to +5%
	Spring	-47%	-69% to -8%
Growing Degree Days* (degree days)	Annual	+285-degree days	+156 to +429-degree days
Heating Degree Days (degree days)**	Annual	-649-degree days	-984 to -420-degree days
Frost-Free Days (days)	Annual	+23 days	+15 to +35 days

Source: PCIC (2016).

*Growing Degree-Days (GDDs) is a derived variable that indicates the amount of heat energy available for plant growth, calculated by multiplying the number of days that the mean daily temperature exceeded 5°C by the number of degrees above that threshold.

**Heating Degree-Days (HDDs) is a derived variable that can be useful for indicating energy demand, calculated by multiplying the number of days that the average (mean) daily temperature is below 18°C by the number of degrees below that threshold.

3 WATER USES

3.1 Water Licences

At the time this report was prepared, 680 current licenses had been issued by the Provincial government to withdraw water from Shuswap Lake (B.C. Government 2015). The locations of these water licences (that is, the Points of Diversion) can be viewed on the BC Water Resource Atlas.5

Of the 680 licenses, 87% are for domestic use (Table 8). However, these individual domestic licences account for only about 3% of the licensed water volume. Waterworks are the single largest use, accounting for almost 63% of the licensed volume, followed by land improvement and fire protection at 17% and 10% of the total volume, respectively. Combined, agriculture and horticulture licenses are the smallest water user group, accounting for only 1.5% of the total licenced volume. Several community water systems treat source water withdrawn directly from Shuswap Lake. Table 9 summarizes these water systems, their owners, types of treatment, and locations.

[5] http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input

Table 8: Summary of water licences authorizing direct withdrawal from Shuswap Lake (February 2015)

License Type	Purpose	Number of Licenses	Licensed Volume Cubic metres per year (m^3/yr.)	Percent of Total Volume
Agriculture	Irrigation	13	177,214	0.90%
	Nurseries	1	41,938	0.20%
	Watering	2	87,269	0.40%
Conservation & land improvement	Conservation - stored water	1	11,101	<0.1%
	Land improvement	4	3,534,451	17.30%
Domestic	Camps	1	3,321	<0.1%
	Domestic	589	525,523	2.60%
	Heat exchangers - residential	1	16,602	<0.1%
	Institutions	1	8,302	<0.1%
	Residential lawn/garden watering	7	3,922	<0.1%
Industrial & commercial	Enterprise	15	184,643	0.90%
	Fire protection	2	2,116,020	10.40%
	Heat exchangers - industrial & commercial	1	860,782	4.20%
	Processing	1	16,605	<0.1%
Waterworks	Waterworks (other)	12	186,469	0.90%
	Waterworks, local auth.	29	12,666,441	62%
	TOTAL	**680**	**20,440,606**	**100%**

Source: B.C. Government (2015).
Only water withdrawal licences with a ‘Current’ status are included above.

Table 9: Waterworks utilities that extract water from Shuswap Lake (including location and type of treatment)

Water System	Owner	Type of treatment	Location
Anglemont Estates	CSRD	Ultraviolet (UV) disinfection and chlorination	Anglemont (north shore of Main Arm)
Cedar Heights Waterworks	CSRD	UV disinfection and chlorination	Blind Bay (Sorrento Reach)
Celista Water System	Anglemont Utilities Ltd.	Chlorination	Celista (north shore of Main Arm)
Eagle Bay Estates Waterworks	CSRD	Chlorination	Eagle Bay (south shore of Main Arm)
MacArthur Heights/ Reedman Heights Waterworks	CSRD	Filtration, UV disinfection, and chlorination	Reedman Point (south arm of Sorrento Reach)
Salmon Arm	City of Salmon Arm	Filtration, UV, and chlorination	Salmon Arm (near Canoe Beach)
Saratoga Waterworks	CSRD	UV disinfection and chlorination	Scotch Creek (north shore of Main Arm)
Sorrento Water System	CSRD	UV disinfection and chlorination	Sorrento
Sunnybrae Water System	CSRD	UV disinfection and chlorination	Sunnybrae (Salmon Arm)

Note: This list is based on water systems identified on the CSRD website (http://www.csrd.bc.ca/services/water), the City of Salmon Arm website (http://www.salmonarm.ca/index.aspx?NID=141) and Gentech Engineering Inc. 2011. Additional water systems not listed in the cited sources may exist.

3.2 Agriculture

Agriculture is the largest anthropogenic land use in the non-forested parts of the Shuswap watershed. While no large farms are directly on Shuswap Lake, some intensive dairy and poultry farms operate alongside less intensive beef operations and hobby farms within several kilometres of the major tributaries to Shuswap Lake (McDougall 2014). A large portion of the developed area southwest of Shuswap Lake is within the B.C. Agricultural Land Reserve (ALR). ALR land is located close to, but not immediately on the shoreline between Salmon Arm and the Sorrento Reaches of the Main Arm (Provincial Agricultural Land Commission 2015). Other, smaller areas of ALR are situated to the north and west of Shuswap Lake (Figure 5). Agricultural lands located next to major Shuswap tributaries, such as the Shuswap and Salmon Rivers, have a significant proportion of heavily fertilized, high-value forage and silage corn crops, which typically receive at least one manure application per year (McDougall 2014).

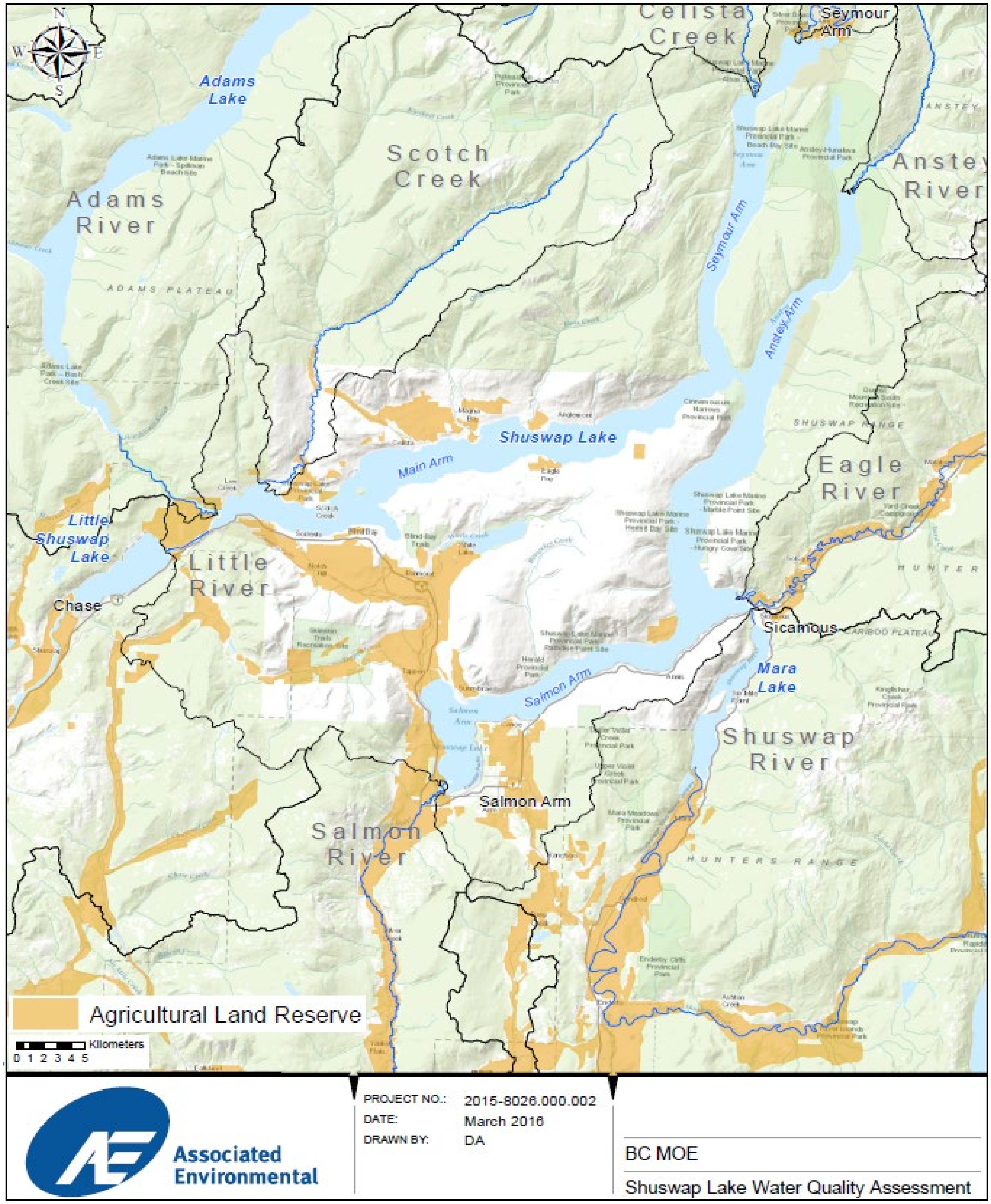


Figure 5: Agricultural Land Reserves in the Shuswap Area

3.3 Recreation

3.3.1 Background

The Shuswap watershed is one of the most important tourist destinations in the B.C. Interior (CSRD 1988, as cited in Ecoscape 2009), and provides year-round recreational activities for residents and visitors. According to BC Parks, Shuswap Lake is one of the most popular swimming, houseboating, and waterskiing areas of the B.C. Interior (ENV 2015b), and other common activities include powerboating, kayaking, canoeing, fishing, personal watercraft use (for example, jet skis), camping, and bird watching (PPA 2014).

In response to increasing concerns about the effect of water quality on attractiveness of the Shuswap region as a recreational destination, the SLIPP formed a Recreation Management Working Group to study recreation on lakes in the Shuswap watershed was completed in 2014 (SLIPP 2014). The recreation management plan (RMP) considered management strategies for lake-based recreation within the Shuswap Region, with a focus on maintaining and improving overall environmental health, economic and social values of the region, and the social and physical comfort of First Nations, residents, and visitors. The RMP identified a water-quality goal of ***"Clean lake waters supports high quality recreational activities,"*** which aimed to promote compliance with Federal and Provincial greywater and black water legislation, increase access to marine vessel sewage holding tank pump out stations, and invest in community sewer systems around the lake (PPA 2014).

3.3.2 Types of Recreational Activities

Recreational use in the Shuswap area was assessed as a part of Peak Planning Associates' (PPA) Situational Analysis Report (PPA 2012), which served as a background document supporting the RMP (PPA 2014). Table 10, summarizes the main lake-based recreational activities in the watershed, including the number of participants, as identified in this report and from other sources.

Table 10: Summary of lake-based recreation activities in the Shuswap Area

Category	Type of activity	Comments on activity and number of participants
Motorized lake-based activities	Pleasure boating	• Boating is one of the most popular activities on Shuswap Lake; however, little is known on precise boating numbers for the area (PPA 2012). A BC Parks Statistics Report indicated that an average of 32,500 camping permits were sold annually to groups arriving by boat to the Shuswap Lake Marine Provincial Park over the 2007 to 2011 period (PPA 2012).
	Houseboating	• Shuswap Lake reportedly has the highest number of houseboats of any inland waterbody in B.C. (NHC 2010). • Informal surveys conducted between 2005 and 2009 indicated between 8,460 and 13,565 houseboats were observed each year (PPA 2012). This includes only houseboats counted when operators were present, and therefore is likely an underestimate (PPA 2012).
	Fishing	• Shuswap Lake reportedly supports one of the "most diverse recreational fisheries in the province" (PPA 2012). See Section 3.5 of this report for more details on fish species in the watershed. Between 1994 and 2010, roughly 5,000 fishing licenses were sold each year (PPA 2012).
Non-motorized lake-based activities	Canoeing and kayaking	• No precise numbers on the number of people canoeing/kayaking exist, but anecdotally numbers have increased over the past 10 years (PPA 2012).
	White-water rafting	• Rafting primarily takes place on the Lower Adams River, between Adams Lake and Shuswap Lake (PPA 2012). Statistics from BC Parks indicate that in 2011 over 2,500 people rafted the Adams River using guided services (PPA 2012).
	Swimming	• Swimming is a major attraction for residents and tourists, but numbers have historically not been documented. In addition to the provincial parks, 13 CSRD and municipal parks have designated swimming areas (See Table 6, PPA 2012 for a list of all 13).
	Birdwatching	• There are many lakes, estuaries, and wetlands in the Shuswap region (PPA 2012). The wetland in Salmon Arm Bay is one of the prime locations for birdwatching. It is one of the largest remaining wetlands in the B.C. interior (PPA 2012).

Sources: PPA (2012), ENV (2009).

3.3.3 Camping and Parks

Camping is popular in the Shuswap region, and campers place a high value on a lakeside camping experience, which, in turn, is tied to the quality of the water. Provincial parks, which are popular camping destinations in the Shuswap region, provide data on the annual number of campers and day use visitors (PPA 2012) at the parks located along Shuswap Lake and the Adams River (Table 11). Except for Tsutswecw Provincial Park, which is day-use only, the parks listed in Table 11 are destinations for both camping and day-use (ENV 2015b).

Table 11: Location, size and key features of provincial parks located on Shuswap Lake

Park	Location	Size (hectares)	Key features	Approximate attendance (2013/2014)[1]
Herald Park	Northeast of Sunnybrae (Salmon Arm).	79	Road access; fully occupied during summer; major provincial park holiday destination on Shuswap Lake.	86,900
Shuswap Lake	Scotch Creek, north shore of the Main Arm. Includes Copper Island.	149	Road access; fully occupied during summer; major provincial park holiday destination on Shuswap Lake.	175,000
Shuswap Lake Marine	Includes 23 sites but excludes other Shuswap Lake parks listed here.	896	Road access; provides marine overnight sites and day-use of Shuswap Lake.	29,500
Cinnemousun Narrows	Where the four arms of Shuswap Lake meet.	176	Boat access only; heavy boat traffic area.	2,600
Anstey-Hunakwa	North end of Shuswap Lake; encompasses the northern end Seymour and Anstey Arms.	6,852	Boat or hiking access only; walk-in camping with no facilities or potable water. Protected area under Schedule D of the Protected Areas of British Columbia Act (ENV 2000).	Unknown
Silver Beach	Seymour Arm	130	Road, ferry, boat access.	8,700
Tsútswecw (Roderick Haig-Brown[2])	Along the Adams River, between Adams Lake and Shuswap Lake.	1076	Day-use only; popular destination in early October during the sockeye salmon runs.	64,100

Sources: ENV (2000), ENV (2015b), BC Parks (2015).
Notes:
[1] BC Parks statistics for 2013/2014 (BC Parks 2015). Includes total number of day use, camping, and boating attendance, rounded to the nearest hundred.
[2] Not located directly on Shuswap Lake; however, according to NHC (2014a), it is one of the largest and most important provincial parks in the area.

In addition to provincial parks, 37 regional parks (CSRD 2015a) and numerous private campgrounds operate in the Shuswap Lake area. Table 12 lists the number and type of parks owned by the CSRD.

Table 12: Number and type of parks owned by the CSRD in and around Shuswap Lake

Park type	Number of parks within Area C	Number of parks within Area F	Total (Area C, F)
Community recreation	6	4	10
Trail corridor	4	1	5
Waterfront	14	8	22
Total	24	13	37

Source: CSRD (2015a).

3.4 Cultural and Traditional Uses

The Shuswap Lake watershed is in the traditional territory of the Pespesellkwe te Secwepemc (historical campfire division of the Secwépemc Nation) Secwépemc (Shuswap people). Historically, approximately 35 Secwépemc communities lived within the Secwépemc Territory; however, today that has been reduced to 17 First Nation communities (ALIB 2015). Occupying a vast territory extending from the Columbia River Valley to the west of the Fraser River and south of Arrow Lakes (142,000 km2), Secwépemc people have lived in the high plateau of South-Central British Columbia for at least 4,000 years (SLIPP 2014).

In 1980, ten Secwépemc Bands formed the Shuswap Nation Tribal Council (SNTC) to advance the issues of indigenous rights and values (SNTC 2015). The SNTC participated on the SLIPP steering committee, representing the Pespesellkwe te Secwepemc communities and the Neskonlith Indian Band whose traditional territories include the Shuswap Lake watershed.

Due to the importance of fisheries to Secwépemc culture, the Secwépemc Fisheries Commission (SFC) was formed in 1992 to provide stewardship for fisheries within their territory and to assert traditional fisheries rights (SNTC 2015). Operating under the mandate of the SNTC, the SFC promotes ecosystem conservation and the sustainable use and harvest practices of fisheries resources.6

3.5 Aquatic Life and Fisheries

3.5.1 Habitat

In response to concerns about the effect of development on aquatic habitat in the Shuswap Lake system, the shores of Shuswap, Little Shuswap, and Mara Lakes were mapped and indexed according to aquatic life habitat (SLIPP 2014). The CSRD and Fisheries and Oceans Canada (DFO) completed two major studies (Ecoscape 2009). The first, the Foreshore Inventory and Mapping (FIM), documented the baseline conditions of the shoreline, including information on shore types, substrates, land use, and habitat modifications. The second study, the Aquatic Habitat Indexing (AHI), used the FIM data to determine the relative habitat value of the shoreline by assessing the vulnerability or sensitivity of the shoreline to changes in land use or habitat.

The studies identified the predominant land use around Shuswap Lake as natural areas (32%) and residential (21.7%), with other land uses including transportation corridors, parks, and recreational areas. The most predominant shore types around the lake were gravel beaches (40%) and rocky shores (36.7%). Aquatic vegetation occurred along 22.7% of the shore, providing important habitat for juvenile salmonids. Important salmon habitat, including staging, rearing, or spawning areas for one or more salmonid life stages were documented in nearly all FIM segments around the lakes. Stream confluences tended to contain the highest fish and wildlife diversity and served as important buffers to maintain water quality. Of the foreshore areas investigated along Shuswap Lake, the Main Arm and the Salmon Arm of Shuswap Lake were the most disturbed. Table 13 summarizes the results of the FIM and AHI studies.

[6] More information on the Secwépemc Fisheries Commission (SFC) is available at: https://shuswapnation.org/fisheries/

Table 13: Summary of FIM and AHI results for Shuswap Lake, Mara Lake, Little Shuswap Lake and Little River

Level of impact (FIM)[1] / Habitat Value (AHI)	Percent of shoreline (%)	Length of shoreline (km)
Foreshore Inventory and Mapping (FIM)		
High-level impact	42.8%	174
Moderate impact	17.4%	70.7
Low impact	31.5%	128.2
Little or no impact	8.2%	33.3
Aquatic Habitat Indexing (AHI)		
High or very high[2]	47%	190.9
Moderate	38%	154.4
Low or very low[3]	15%	60.9

Source: Ecoscape (2009).
Notes:

1. Types of impacts include lakebed substrate modification, riparian vegetation removal, construction of retaining walls and other land disturbances.
2. Areas of high or very high habitat value were in areas of known spawning, stream mouths, wetlands and other habitats.
3. Areas of low or very low habitat value were located along highly developed shorelines.

In addition to the FIM and AHI completed by Ecoscape (2009), aquatic habitat, riparian vegetation, and fish spawning locations were documented by the Community Mapping Network (CMN 2015). For further information, including a map showing the FIM and AHI around the shoreline of Shuswap Lake, refer to the Shuswap Watershed Atlas.[7]

3.5.2 Fish Species

The Shuswap Lake watershed supports 30 species of commercially, culturally, and recreationally valuable fish that are important to First Nations and recreational anglers (Table 14; ENV 2015c, d, e). Based on a search of the records, there has been no fish stocking within Shuswap Lake (FFSBC 2016).

Table 14: Fish species recorded in Shuswap Lake

Common Fish Name	Status	Common Fish Name	Status
Burbot	Native	**Longnose Sucker**	Native
Carp	Invasive	**Mountain Whitefish**	Native
Chinook Salmon	Native, threatened[1]	**Northern Pikeminnow**	Native
Chub spp.	Native	**Peamouth Chub**	Native
Coho Salmon	Native, endangered[2]	**Pink Salmon**	Native
Cutthroat Trout	Native, special concern[3]	**Prickly Sculpin**	Native
Dace spp.	Native	**Pygmy Whitefish**	Native
Dolly Varden	Native	**Rainbow Trout**	Native
Kokanee Salmon	Native	**Redside Shiner**	Native
Lake Chub	Native	**Sculpin spp.**	Native
Lake Trout	Native	**Slimy Sculpin**	Native

[7] http://cmnmaps.ca/SHUSWAP/

Lake Whitefish	Native	**Sockeye Salmon**	Native
Largescale Sucker	Native	**Sucker spp.**	Native
Leopard Dace	Native	**White Sturgeon**	Native, threatened[1]
Longnose Dace	Native	**Whitefish spp.**	Native

Source: ENV (2015c, d, e)

Notes:

1. Following the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Chinook salmon and white sturgeon (Lower Fraser River Population) are identified as threatened. Species identified as threatened are ones that are likely to become endangered if limiting factors are not reversed.
2. Following COSEWIC, Coho salmon are identified as endangered. Species defined as endangered are facing imminent extirpation or extinction.
3. Following COSEWIC, cutthroat trout are identified as special concern. Species defined as special concern are ones that may become threatened or endangered because of a combination of biological characteristics and identified threats.

3.5.3 Salmonids

Salmon are the "keystone species" in the Shuswap watershed, where they provide food for wildlife (bears, eagles, and others), fertilizer for terrestrial and aquatic ecosystems through carcass decomposition, and are an indicator of overall ecosystem health (Ecoscape 2009). Salmon stocks in the Shuswap watershed contribute substantially to First Nations' cultural values, as well as commercial and subsistence fisheries. They have also proven a draw for tourists, particularly for the Salute to the Sockeye Festival and viewing of the Adams River sockeye spawning run in the later summer and early fall (Ecoscape 2009).

The Shuswap Lake system is among the most important salmonid producing lake systems in B.C. (Ecoscape 2009). It is an important contributor to the production of salmon within the Fraser River Basin and to the genetic diversity of Fraser River salmon populations (Rosenau 2014).

Anadromous salmon species supported by Shuswap Lake and its tributaries include sockeye, chinook, coho, pink, and steelhead salmon (SNTC 2015). Non-anadromous salmonids include lake char and rainbow trout, both of which are extensively targeted by recreational fishers (Rosenau 2014). Foreshore areas around Shuswap Lake provides important habitat for spawning of both anadromous and non-anadromous salmonids (Rosenau 2014). Salmon escapements have been recorded for Shuswap Lake since 1938 (GOC 2015). The average annual sockeye salmon escapement between 1983-2013 was 6,563 (GOC 2015). Only one annual escapement record exists for pink salmon, with 16 escapements recorded in 1991 (GOC 2015).

The Adams River is one of the most important sockeye salmon breeding areas in North America, with dominant runs every four years (Rosenau 2014). Dominant years (2010, 2014 and 2018) often produce millions of sockeye salmon, whereas a sub-dominant year (like 2015) may see 100,000 sockeye salmon return in October (ARSS 2015). Further information on the salmon run can be found on the Adams River Salmon Society's (ARSS) website.[8]

[8] Adams River sockeye salmon run photo from ARSS website.

Due to the importance of salmonids in the Shuswap watershed, several studies relating to salmonids and their habitat have been published, including:

- The Shuswap Watershed Mapping Project, which included FIM and AHI mapping around Shuswap Lake (Ecoscape 2009; see Section 3.4.1 for further details).
- Nearshore Habitat Utilization by Spawning Lake Char and Rearing Rainbow Trout in Shuswap, Little Shuswap, and Mara Lakes (Rosenau 2014).
- An Overview of Foreshore Fish Habitat in Shuswap Lake, with reference to the Salmon Arm (Stalberg 1998).

Information on these studies, including links to the reports, can be found it Appendix A.

3.5.4 Aquatic Invertebrates - Zooplankton

Consistent with the oligotrophic nature of Shuswap Lake, zooplankton abundance is relatively low compared to more productive lakes. However, species richness is relatively high (Table 15). Zooplankton samples collected from Shuswap Lake seasonally between mid-March and the end of October of 2011 to 2013. The results showed a seasonal average zooplankton density of 8.5 individuals/L, of which 86% of the individuals were from the sub-class Copepoda (7.3 individuals/L), 10% were Daphnia spp. (0.9 individuals/L), and the remaining 4% were from the sub-class Cladocera (0.3 individuals/L) (Vidmanic 2013). The seasonal average total zooplankton biomass or weight was 41 mg/L. Sixty percent of the total biomass was comprised of Daphnia spp., while individuals from the sub-class Copepoda made up 35% and cladocerans made up the remaining 4%.

Table 15: Zooplankton species identified in Shuswap Lake from 2011-2013

Species	Year of Collection		
	2011	2012	2013
Cladocera			
Biapertura affinis	R[1]		
Bosmina longispina	✓[2]	✓	✓
Ceriodaphnia reticulata		R	R
Chydorus sphaericus		R	
Daphnia thorata	✓	✓	✓
Diaphanosoma birgei	R	✓	✓
Holopedium gibberum	R	R	R
Leptodora kindtii	✓	✓	✓
Scapholeberis rammneri	R	R	R
Syda cristallina			R
Copepoda			
Aglaodiaptomus leptopus		R	
Cyclops bicuspidatus thomasi	✓	✓	✓
Epishura nevadensis	R	✓	✓
Leptodiaptomus ashlandi	✓	✓	✓

Notes:
1. "R" indicates a rarely present species.
2. "✓" indicates a consistently present species
Source: Vidmanic 2013

3.5.5 Phytoplankton

In general, Shuswap Lake has low primary productivity and is known for its clear water and sparse phytoplankton populations. However, early summer algal blooms occurred on Shuswap Lake in June 2008 and Mara Lake in May 2010. The phytoplankton mainly responsible for the blooms was a Chrysophyte (Golden-Brown Algae), the flagellated algae Ochromonas sp. (shown at right9 from NHC 2010a; NHC 2014b, Stockner et al. 2014).

A study by Stockner et al. (2014) conducted from 2011 to 2013, showed phytoplankton densities and biovolumes in Shuswap were lower than in Mara Lake, and showed one, short spring peak in late May 2013 followed by a gradual decline to late fall minima (Figure 6). Off Marble Point (0500124) in the Salmon Arm, phytoplankton peaks were dominated by several flagellated Chrysophyte species – Ochromonas, Chrysochromulina, and Dinobryon, with only a small increase in diatoms (Fragilaria, Synedra) and other groups in late June and early July (Stockner et al. 2014). In comparison, in Mara Lake, flagellates were also dominant, but phytoplankton peak densities were much higher (>6,000 cells per millilitre (cells/ml) than at Marble Point (<4,000 cells/ml) in May and June. The mean phytoplankton densities off Marble Point were 3,794 cells/ml, 2,995 cells/ml, and 2,974 cells/ml in 2011, 2012 and 2013, respectively (Figure 3-2; Stockner et al. 2014).

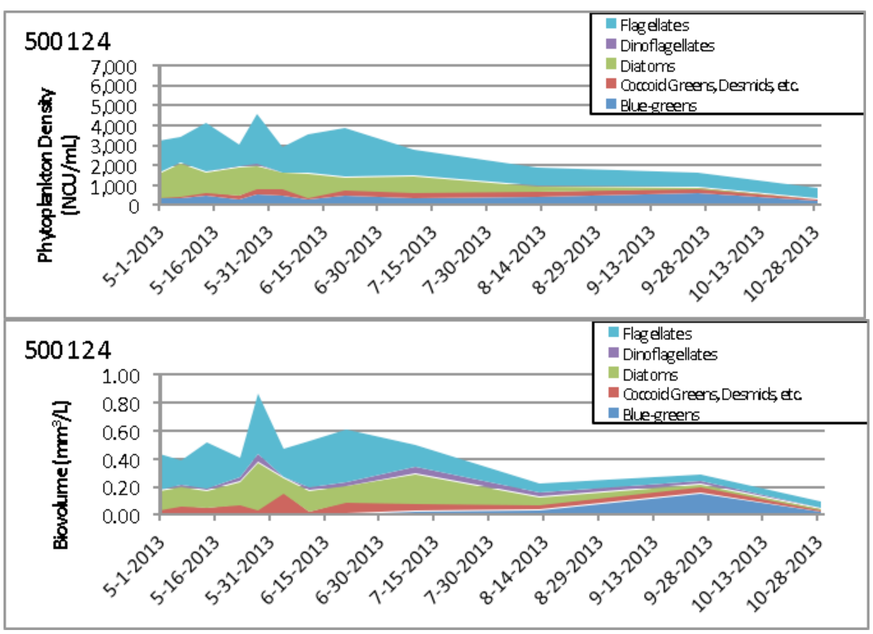


Figure 6: Phytoplankton density and bio-volume from May to October 2013 in Shuswap Lake off Marble Point from Stockner et al. 2014.

[9] Photograph of *Ochromonas* sp. bloom in Shuswap Lake, June 2008.

3.6 Ecosystems and Wildlife Habitat

The Shuswap Lake watershed is located primarily within four biogeoclimatic zones. The Interior Cedar-Hemlock (ICH) occupies the area surrounding the Sicamous Reach (Salmon Arm) and extends northwest to the Main Arm (MOF 1998). Interior Douglas-fir (IDF) extends from Sorrento Reach (Main Arm) south to Salmon Arm, including Little Shuswap Reach (ENV 2015f). Engelmann Spruce – Subalpine Fir (ESSF) is found at higher elevations, below patches of Interior Mountain Heather – Alpine (IMA) (MOF 1998).

The watershed supports a wide range of wildlife species, including deer, elk, moose, mountain goats, bears, wolves, cougars, beavers, small mammals, amphibians, and reptiles. Many of the wildlife species make use of the riparian areas along watercourses and lakes, including numerous birds such as western grebe and osprey (Ecoscape 2009). These riparian areas also have positive effects on water quality. The potential number of B.C. red-listed (endangered or threatened) and blue-listed (special concern) species within the watershed are provided in Table 16.

Table 16: Number of potential red-listed and blue-listed vertebrate and vascular plant species within the Shuswap Lake watershed

Class	Red-Listed[1]	Blue-Listed[2]
Vertebrate Animals[3]		
Birds	13	27
Amphibians	2	2
Mammals	4	14
Reptiles	1	4
Turtles	0	1
Ray-Finned Fish	1	5
Vascular Plants[3]		
Grasses, some herbaceous plants (monocots)	15	19
Legumes, herbaceous/woody plants (dicots)	36	43
Conifers	0	1
Ferns	3	1
Quillworts	1	1

Notes:
1. Red-listed species are extirpated, endangered, or threatened in BC.
2. Blue-listed species are of special concern (formerly vulnerable) in BC.
3. The search criteria used within the CDC database (ENV 2015f) was restricted to the following:
    - BEC Zones: ICH, IDF, ESSF, and IMA
    - Okanagan Shuswap Forest District

3.7 Invasive Species (Aquatic and Riparian)

Several invasive aquatic species have been identified in the Shuswap Lake watershed. One of the primary invasive species of concern is Eurasian water milfoil (*Myriophyllum spicatum L.*), first identified as a non-native aquatic plant in 1981 (CSRD 2015b). Eurasian water milfoil has colonized large parts of Shuswap Lake, with Salmon Arm Bay the most affected area. The CSRD and the Ministry of Environment, Lands and Parks entered into a joint control program (CSRD 2013) in 1981 that involves survey, treatment, and prevention measures to help control the spread of Eurasian Water Milfoil within the Shuswap Lake system.

In 1989, a new rototilling vessel was commissioned to remove Eurasian Water Milfoil during the fall and early winter (CSRD 2015b). Ongoing work includes further research into biological controls and advancing mechanical treatment methods.

Other invasive aquatic species of concern include zebra/quagga mussels and yellow flag iris (CSISS 2015), and fish species, such as largemouth bass and perch (FFSBC 2016). Although no infestations have been confirmed in B.C., zebra/quagga mussels have the potential to cause millions of dollars of damage to infrastructure and negatively impact ecosystems and recreational activities within the Shuswap watershed (CSISS 2015). Yellow flag iris, native to Europe, central Asia, and northwest Africa, has been found in shallow areas around the shores of lakes within the Shuswap region (CSISS 2015). Perch were found in Adams Lake in 2009 (thought to be "drop-downs" from Forest Lake), and several lakes in the Shuswap highlands have since been treated to control largemouth bass and perch (FBC 2016). No perch have been found in Adams Lake since the control and rehabilitation projects were undertaken (Andrew Klassen, personal communication).

To reduce the spread of invasive plants and organisms throughout B.C. waters, including the Shuswap Lake system, the Invasive Species Council of B.C. (ISC) has implemented the *'Clean, Drain and Dry'* campaign throughout the Southern Interior of BC, encouraging boat users to 'clean drain and dry' all boats and equipment before transporting between waterbodies (ISC 2015).

4 INFLUENCES ON WATER

Increased development throughout the Shuswap watershed has led to concerns about the water quality and the formation of the Shuswap Lake Integrated Planning Process in 2006 (SLIPP 2014). These concerns peaked during the algal blooms on Shuswap and Mara Lakes in June of 2008 (NHC 2014b). Later that year, SLIPP released a Strategic Plan that included recommendations to implement a long-term water quality monitoring program on Shuswap and Mara Lakes and the surrounding tributaries to augment existing monitoring conducted by ENV (NHC 2014b). In addition, several studies examining the influences of human activity on water quality within the Shuswap watershed have been completed in recent years and are discussed below.

4.1 Coliform Bacteria

4.1.1 Background

Health authorities may sample the water quality of recreational beaches or create reports on recreational water quality concerns to help inform of any public health risks. Based on these sampling results, the Interior Health Authority may decide to close beaches, issue public advisories, or post warning signs until the water samples indicate that it is safe to resume swimming in these waters.

Interior Health Authority routinely monitors the following beaches in the Shuswap region:

- Lions Park Beach (Main Arm)
- Canoe Park Beach (Salmon Arm)
- Herald Park Beach, Sunnybrae (Salmon Arm)
- Sunnybrae Park Beach (Salmon Arm)
- Shuswap Lake Provincial Park Beach, Scotch Creek

- Sicamous Park Beach, Sicamous

Interior Health Authority applies the Health Canada coliform bacteria guidelines for their beach condition reports. For fresh recreational waters used for primary contact activities, the Health Canada guideline values for coliform bacteria are as follows:

- Geometric mean concentration (minimum of five samples): ≤ 200 *E. coli* per100 ml
- Single-sample maximum concentration: ≤ 400 *E. coli* per100 ml

Guidelines also exist for drinking water and vary depending on how much treatment the water receives prior to consumption. For water that receives no treatment, no bacteriological indicators can be present at any concentration. Drinking water that receives disinfection is permitted to have a 90th percentile of 10 CFU/100 mL of *E. coli*, and a 90th percentile of 3 CFU/100 mL of *Enterococci* (Health Canada, 2014).

4.1.2 Commentary

The Health Canada criteria are set at protective levels that should not be compromised.10 Since pathogens associated with E. coli bacteria have the potential to impact human health, the objectives should remain the same as the established guidelines. Coliform bacteria should be monitored by Interior Health Authority near beaches and other recreation areas. A minimum of five samples should be collected within a 30-day period, preferably during mid-summer when the beaches are at their busiest. Water samples can also be collected on the same schedule near water intakes to determine if the drinking water guideline is being met.

4.2 Summary of Nutrient Loading to Shuswap Lake by Source

The results of the SLIPP 2011-2013 tributary monitoring program indicated water quality in the Shuswap Lake system was generally good. However, elevated nutrients, including nitrogen and phosphorus, were found in the Salmon, Shuswap, and Eagle Rivers compared to other tributaries (SLIPP 2014, McDougall 2014), prompting nutrient loading to be identified as a major water quality issue. The portion of the Shuswap River watershed located between Mabel and Mara Lakes was determined to be the dominant source of total phosphorus and total nitrogen to Shuswap Lake, with the Salmon and Eagle Rivers being the second and third largest contributors, respectively (NHC (2014b).

In 2014, SLIPP commissioned Tri-Star to identify sources of nutrients within the Shuswap Lake watershed and estimate phosphorus and nitrogen loading from various sources. While they found generally good water quality, extensive nutrient loading existed in some areas (Tri-Star 2014). Furthermore, results indicated that point sources (for example, authorized discharges to lake and ground- and wastewater treatment plants) comprised a small percentage (5.6% and 5.7%, respectively) of total phosphorus and nitrogen loading (Table 17). Instead, the largest potential nutrient sources were agricultural operations in the watershed (Tri-Star 2014).

The Shuswap Watershed Council (SWC)11 engaged UBC Okanagan to compared total phosphorus (TP), and total dissolved phosphorus (TDP) contributions to Shuswap Lake from three different sources: ungauged

[10] http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/guide_water-2012-guide_eau/index-eng.php

[11] The SWC was created in 2015 following the end of SLIPP.

incremental flow in sub-watersheds (IFSW), gauged tributaries, and the upper reaches of both the Salmon and Shuswap Rivers (Ludwig 2018). The ungauged IFSW, which includes water that drains into tributaries such as groundwater, seasonal streams and agricultural ditches, contributed the greatest estimated contributions of TP and TDP (Ludwig 2018). Ludwig (2018) estimated that anthropogenic contributions of TP and TDP, which were mostly associated with agriculture and urban development, could be seven to 66 times higher than the amounts expected from undisturbed forested areas. These studies indicate non-point (diffuse) sources (for example, agriculture and private on-site wastewater systems) likely contribute more phosphorus and nitrogen to Shuswap Lake than point sources.

Table 17: Summary of total phosphorus and nitrogen loading to Shuswap Lake

Nutrient Source	Phosphorus		Nitrogen	
	Total Phosphorus (kg/year)	Percentage of Total (%)	Total Nitrogen (kg/year)	Percentage of Total (%)
Direct Discharges to Shuswap Lake				
Tributary inflows	56,525	92.1%	1,171,934	96.4%
Spawning salmon[12]	1,186	1.9%	8,892	0.7%
Houseboat Greywater	352	0.6%	211	0.0002%
Private on-site Wastewater Systems	762	1.2%	1,252	0.1%
Salmon Arm WWTP	1,088	1.8%	>26,337	2.2%
Other authorized operations discharging to Lake	538	0.9%	5,763	0.5%
Authorized Operations discharging to Ground	903	1.5%	1,216	0.1%
Sources in Tributary Watershed to Shuswap Lake				
Stormwater - Agriculture	36,290	8.6%	235,021	13.4%
Stormwater – Agricultural / Residential	3,539	0.8%	3,539	0.2%
Stormwater - Forest Harvesting	86	0.02%	403,703	23.1%
Stormwater - Rangeland	1,814	0.4%	18,109	1.0%
Stormwater - Urban	2,650	0.6%	20,443	1.2%
Stormwater - Forest Fires	170	0.03%	172,531	9.9%
Livestock on Private Land	361,782	85.3%	807,386	46.2%
Cattle on Tenure Land	11,992	2.8%	37,011	2.1%
Sicamous WWTP	414	0.1%	13,050	0.7%
Enderby WWTP	5,336	1.3%	37,602	2.2%

Source: Tri-Star (2014).

[12] Nutrients brought into the lake by migrating salmon that are released after the fish spawn, die, and decompose.

4.3 Permitted Discharges (Point Sources)

4.3.1 Discharges to Surface Water

Table 18 lists the maximum permitted flow and contaminants associated with the 10 active permitted discharges to surface waters within the Shuswap Lake watershed (B.C. Government 2015). The details of these authorizations, including the maximum authorized concentrations of the regulated parameters, are available on the GeoBC data centre.[13]

Table 18: Summary of active permitted discharges to surface water within the Shuswap Lake watershed

Effluent source	Permit number	Authorized discharge location	Maximum permitted flow (m^3/d)	Parameters with specified limits under the authorization
Sewage outfall Gateway Lakeview Estates Inc.	17070	Shuswap Lake – Main Arm-Sorrento Reach (near Scotch Creek)	230	TSS ≤ 10 mg/L, BOD ≤ 10 mg/L TP ≤ 1 mg/L, PO_4 ≤ 0.5 mg/L
Saratoga Marine and Resort 2002 Ltd.	17270	Shuswap Lake – Main Arm-Sorrento Reach (near Scotch Creek)	17.01	TSS ≤ 10 mg/L, BOD ≤ 10 mg/L fecal coliforms ≤ 2.2 CFU/100 mL median, ≤ 14 CFU/100 mL max
Shuswap Lake Resort (PE 11194) sewage outfall	17794	Shuswap Lake - Main Arm-Sorrento Reach (near Scotch Creek)	102.1	TSS ≤ 10 mg/L, BOD ≤ 10 mg/L fecal coliforms ≤ 2.2 CFU/100 mL median
Owners, Strata Plan KAS3536	17796	Shuswap Lake – Main Arm-Sorrento Reach (near Readman Point)	107	TSS ≤ 10 mg/L, BOD ≤ 10 mg/L fecal coliforms ≤ 2.2 CFU/100 mL median, TP ≤ 1 mg/L
District of Salmon Arm aerobic digester effluent	1251	Shuswap Lake – Salmon Arm Bay	4.5	-
District of Salmon Arm wastewater treatment facility			8200	TSS ≤ 20 mg/L, BOD ≤ 15 mg/L fecal coliforms ≤ 200 CFU/100 mL max, TP ≤ 1 mg/L
Enderby wastewater treatment facility discharge to Shuswap River	203	Shuswap River (Enderby)	3400	TSS ≤ 45 mg/L, BOD ≤ 45 mg/L *E. coli* ≤ 50 MPN/100 mL max
NORD back wash water discharge from Water Treatment Plant	15263	Shuswap River (actual discharge is to ground; about 1 km from Duteau Creek)	7	Chlorine ≤ 0.01 mg/L, TSS ≤ 10 mg/L, temp ≤ 5°C above receiving water temp, temp ≤ 23°C, Al-D ≤ 20% above ambient conditions, DO ≤ 10% from ambient conditions
Remediation Facility (Lumby, B.C.)	12481	Discharge to ground with overflow to Bessette Creek	500	chlorophenols ≤ 1 µg/L, pH 6.8 – 8.5, dioxins and furans ≤ 15 pg/L, phenanthrene ≤ 0.3 µg/L, benzo(a)anthracene ≤ 0.1 µg/L, benzo(a)pyrene ≤ 0.01 µg/L, anthracene ≤ 0.1 µg/L, acenaphthene ≤ 6.0 µg/L, pH, dioxins, fluorene ≤ 12 µg/L, fluoranthene ≤

[13] http://geobc.gov.bc.ca/

				0.2 µg/L, naphthalene ≤ 1.0 µg/L, acridine ≤ 0.05 µg/L, pyrene ≤ 0.02 µg/L
District of Sicamous wastewater treatment facility	13644	Discharge to ground with (via rapid infiltration basins)	1135	Ground - TSS ≤ 30 mg/L, BOD ≤ 30 mg/L TP ≤ 1 mg/L

Source: B.C. Government (2015).
Note: BOD = biological oxygen demand and TSS = total suspended solids

4.3.2 Discharges to Ground

Currently, 69 active permits allow for discharge to ground within the Shuswap Lake Watershed (B.C. Government 2015). Table 19 summarizes the number of permits by discharge type and the permitted contaminants associated with each type. Private on-site wastewater (septic) systems, which also discharge to ground, do not require individual authorizations and therefore are not summarized below. For further discussion on septic systems, see Section 4.3.2. For more information on individual permits and maximum permitted concentrations, refer to GeoBC data centre.14

Table 19: Summary of active authorized discharges to ground within the Shuswap Lake watershed

Discharge type	Number of Authorizations	Contaminant(s) with Permitted Limits[1]
Ditch or Culvert	1	-
In Plant	1	-
Irrigation Spray/Sludge	10	TSS, BOD, fecal coliforms
Landfill	9	-
Outfall	1	TSS, BOD
Seepage or Seepage Pools	3	TSS, BOD, total phosphorus, pH
Storm sewer	1	Oil & Grease
Well	1	TSS, BOD
Infiltration Pond	9	TSS, BOD, total phosphorus, soluble phosphate, pH, total nitrogen, fecal coliforms
Tile Field	30	TSS, BOD, total phosphorus, nitrate plus nitrite (as N)
Septic Tank	3	TSS, BOD

Source: B.C. Government (2015)
Notes:
1. Includes general contaminants for each discharge type that have permitted limits. Not all permits authorize discharges of all contaminants in each list.

4.4 Non-Point (Diffuse) Sources of Nutrients

As described in Section 4.1, studies that have examined nutrient inputs indicate that non-point sources contribute significantly more nutrients to Shuswap Lake than point sources (Ludwig 2018, Tri-Star 2014). Major sources of non-point pollution include agriculture, septic systems, stormwater, transportation and utilities corridors, and recreation. These are discussed in the sections below.

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[14] http://geobc.gov.bc.ca/

4.4.1 Agriculture

The largest source of nutrient loading to Shuswap Lake occurs via the main tributaries (Table 17). In the tributaries, agriculture was likely the largest contributor of phosphorus and an important source of nitrogen (Tri-Star 2014). McDougall (2014) provided a comprehensive overview of agriculture in the Shuswap area, the perceived impacts of nutrient inputs to water quality, and the current state of phosphorus management knowledge in watersheds. Table 20 summarizes the key agriculture-related findings of these two studies.

Table 20: Key reports and findings relating to nutrient loading and agricultural impacts

Report	Citation	Key findings
SLIPP Water Quality Report: Sources of Nutrients 2014	Tri-Star 2014	• Over 90% of the phosphorus loading to Shuswap and Mara Lakes comes from the tributaries, rather than direct discharges to the lakes. • According to the author, the highest contributor of phosphorus to these tributaries was believed to be agriculture operations. • Shuswap River contributes the highest amount of phosphorus to Shuswap Lake, followed by Salmon River and Eagle River. • The best way to reduce the level of nutrients entering Shuswap Lake is to reduce the amount of nutrients entering water from agricultural operations, (specifically in the Shuswap River, Eagle River, and Salmon River watersheds).
Agricultural Nutrient Management in the Shuswap Watershed for Maintaining and Improving Water Quality: Literature Review and Nutrient Management Strategies	McDougall 2014	• Elevated phosphorus is primarily found in spring (snow melt) and late spring/early summer (high water period). • The main agriculture-caused sources of phosphorus include phosphorus-rich fertilizer and the application of manure to fields. • The transportation mechanisms of nutrients to water include erosion of phosphorus-rich soil, surface runoff, and subsurface flow. • Soil erosion contributes primarily particulate phosphorus, whereas surface and subsurface flow contribute primarily dissolved phosphorus which is biologically available to organisms and thus has a greater effect on water quality. • The primary pathway of phosphorus into the Shuswap tributaries is surface runoff during snow melt and subsurface flow during freshet.

Ludwig (2018) found that anthropogenic land uses (urban and agricultural) contributed between seven and 66 times as much TP and TDP as undisturbed forest. As well, although flow contributions from IFSW were generally small and often ephemeral, TP and TDP fluxes were larger in these than in tributary watersheds and upper reaches. TP and TDP concentrations were approximately twice as high in the IFSW compared to the tributaries. TP and TDP contributions were correlated with flow, with the highest contributions occurring during spring freshet and during the fall after heavy rain events.

4.4.2 Septic Systems

In 2009, the CSRD commissioned the development of several Liquid Waste Management Plans for communities located within the regional district boundaries. A concern often identified in these plans was the potential impact of private septic systems to surface and groundwater quality (EarthTech 2009, Focus Corporation 2009, Urban Systems 2009a, b). In the Shuswap Lake Area, the majority of wastewater disposal is via onsite disposal systems, such as septic tanks with in-ground disposal fields.

To address this concern, water quality monitoring programs were implemented by CSRD to assess the potential impacts on groundwater quality in Anglemont (Summit 2014a), Blind Bay/Sorrento (Summit 2014b), Celista/Magna Bay (Summit 2014c), Sunnybrae (Summit 2014d), and Seymour Arm (Summit 2013). The purpose of these monitoring programs was to assess potential septic impacts to lake and groundwater quality to help evaluate the need for a community sewer system. During the annual monitoring programs, water quality samples were collected from networks of groundwater monitoring wells, water supply wells, foreshore locations, and surface water locations (Summit 2014a, b, c, d). Generally, study results suggested septic systems may be locally impacting groundwater in some communities (Summit 2014a, b, c, d). However, Tri-Star (2014) estimated that septic systems contribute only 1% of the phosphorus loading to Shuswap and Mara Lakes, which suggests that although in-ground septic systems may be contributing to localized effects such as algal growth, they are unlikely to be having a measurable effect on overall nutrients levels in Shuswap Lake (Tri-Star 2014).

4.4.3 Stormwater Discharges

Tributaries provide over 90% of the phosphorus and nitrogen to Shuswap Lake (Table 17), and within tributaries, nutrient loading from stormwater inputs account for approximately 10% and 49% of total phosphorus and nitrogen loading, respectively (Table 17, Tri-Star 2014).

4.4.4 Transportation and Utility Corridors

Roadways (paved and unpaved), railways, and the vehicles that use them, are often important sources of pollutants to surface and groundwater. In addition to phosphorous and nitrogen, transportation activities can be the source of hydrocarbons, metals, and other contaminants. The Trans-Canada Highway (Highway 1), which traverses the southern shoreline of Shuswap Lake, provides a large area of impervious material that likely increases runoff into Shuswap Lake, either directly or via groundwater. The forested areas in the watershed contain numerous resource roads, as well as Forest Service Roads near Shuswap Lake (ENV 2015e). The Canadian Pacific main Trans-Canada railway line runs from Sicamous south to Salmon Arm, west towards Sorrento Reach, and along the southern shore of Little Shuswap Lake (ENV 2015e).

4.4.5 Recreation

Recreational impacts are likely greatest during the summer months when most lake-based activities occur (PPA 2012). PPA (2012) broadly examined the potential impacts of various types of recreational activities occurring on Shuswap Lake (Table 21), they did not address the direct contributions of individual contaminants from these activities. However, the potential impacts of houseboat greywater, which is discharged directly to Shuswap Lake, have been examined (NHC 2010b). Greywater contains nutrients, pathogens, and detergents and may contain personal care products and other chemicals including endocrine disruptors (NHC 2010b), but in general, *E. coli* and fecal coliforms (pathogens) levels remained below recreational levels.

Several recreation management plans were completed under SLIPP, including a backgrounder, situation analysis report, and survey result reports (SLIPP 2014). These reports discussed issues impacting the user experience on the lake, including noise, infrastructure, economics, and so forth, with brief sections on water quality. A summary of the findings of these reports appears in Table 21 and in Appendix A.

Table 21: Summary of potential impacts to water quality and aquatic life habitat from recreation activities

Recreation-associated structure or activity	Potential impacts to water quality and/or aquatic life habitat
Boat launches	• Boat launches and associated vehicle access can impact vegetation and lake habitat (PPA 2012). A total of 200 concrete boat launches were noted along the shoreline of Shuswap and Mara Lakes during the FIM study (Ecoscape 2009). • Roughly estimated, at least 2,500 m^2 of habitat has been lost around the lakes due to the presence of boat launches (PPA 2012).
Docks	• Over 2,700 docks were noted along the shoreline of Shuswap and Mara Lakes during the FIM study (Ecoscape 2009). The results of that study indicated most docks were not built-in accordance with best management practices (PPA 2012). • Docks may limit access to spawning areas for fish (PPA 2012). Abandoned docks may also present a problem (PPA 2012).
Beaches	• Emergent aquatic vegetation and habitat has been lost by the creation of beaches (PPA 2012). • Heavy use of beaches may also cause anthropogenic impacts.
Houseboats	• Shuswap Lake supports the largest houseboat industry in the province and possibly in Canada (NHC 2010b). Greywater, which is discharged directly to Shuswap Lake, contains nutrients, pathogens, and detergents, (NHC 2010b). and may contain personal care products and other chemicals including endocrine disruptors. The problem may be exacerbated due to the tendency of boats to congregate near popular beaches (NHC 2010b). • In 2009, ENV released a report on the risk of houseboat greywater discharge to recreational users on Shuswap Lake beaches (NHC 2010b). The results indicated that although *E. coli* and fecal coliforms levels generally remained below recreational levels, there was an association between number of houseboats and the detection of human-host fecal bacteria near houseboats (NHC 2010b).
Motorized (non-house) boats/marinas	• A total of 51 marinas were noted along the shoreline of Shuswap and Mara Lakes during the FIM study (Ecoscape 2009). Impacts from marinas and other motorized boats may include discharge of pollutants (such as gasoline leaks or spills or boat cleaning chemicals). Specific impacts from marinas may also include stormwater runoff from parking lots and alteration of the shoreline (Environment Canada 2001). Erosion from boat wake-generated waves may impact shorelines (PPA 2012).
Parks/ campgrounds	• Heavy use of parks can create issues such as littering, vandalism, garbage dumping, and disturbing vegetation/aquatic life. High boat use at parks may lead to contamination (see Houseboating for further details).

Sources: PPA (2012), ENV (2009), Ecoscape (2009), Environment Canada (2001).

5 WATER QUALITY MONITORING

5.1 History of Water Quality Monitoring in Shuswap Lake

The water quality of Shuswap Lake has been monitored since the 1970s and although the monitoring schedules have varied over the years, the sampling locations have remained constant. The need for a systematic monitoring program culminated in the development and implementation of an integrated water quality monitoring plan (NHC 2010a). This five-year water quality monitoring plan has served as a guiding framework for the development of various annual water quality monitoring programs by SLIPP partners since 2010.

The monitoring plan included a historical review of lake water quality and a discussion of previous and current monitoring programs, trends in water quality, and concerns surrounding existing and emerging threats to water quality in the Shuswap Lake system. Possible nutrient sources and loadings were identified and a comprehensive program to monitor the known and emerging threats to drinking water quality and ecosystem health in the lakes and tributaries in the Shuswap watershed was developed (NHC 2010a). Results have been summarized in the various SLIPP reports (for example, NHC 2013, 2014a, b, Tri-Star 2014, SLIPP 2014) for a variety of monitoring sites, which were selected to meet specific monitoring goals. These sites included:

- “Deep” stations (“mid-lake” or pelagic areas)
- “Shallow” stations (littoral areas)
- Sites influenced by specific activities or land uses, including point-source discharges
- Targeted tributaries

The SLIPP annual reports on water quality up to 2013 provided a summary of monitoring results at the above-listed sites (NCH 2014b). The many reports produced under the SLIPP program further described in detail the historical water quality data.

5.2 Sampling Methods, Data Management and Parameter Selection

5.2.1 Sample Collection

Over the years, water quality monitoring has taken place through a combination of efforts from provincial government, consultants, and volunteer stewardship groups. Laboratory detection limits have improved over the years so variability in results occurred at very low concentrations of nutrients. However, sampling methods consistently followed the protocols described in the British Columbia Field Sampling Manual, Parts A and E (ENV 2013), which allowed for comparison of data over the years.

All water sampling data used for this assessment were analyzed in an accredited laboratory. Samples were collected from the mid-lake or pelagic locations monthly during the growing season stratified period (May to October) and twice in the winter and early spring, when the lake was isothermal (not stratified). Additional supplemental weekly sampling was also conducted on Shuswap Lake between April 1st and June 30th following the *Ochromonas* algae bloom in Mara Lake in May 2010, to aid in predicting future bloom conditions. At each mid-lake station, a multi-parameter sonde was used to collect temperature and dissolved oxygen readings along vertical profiles, and these data were used to identify appropriate sample depths for collecting water chemistry. Composite water samples were collected from three epilimnetic (upper depths) and three hypolimnetic (lower depths) at each site using a van Dorn or Kemmerer sampler. Water transparency was measured with a 20-centimeter diameter Secchi disk to determine the depth of light penetration and to estimate the photic zone. Samples for chlorophyll *a* concentrations and phytoplankton taxonomy were collected from a composite of three depths within the photic zone.

5.2.2 Spatial Units for Assessing Water Quality (lake reaches)

As a large lake, Shuswap Lake has considerable variation in natural biophysical properties and land use activities that influence its water quality. To address this variability, water sampling has been conducted within specific reaches of the four arms of the lake. Reaches were selected to capture the differing limnological characteristics associated with variations in morphometry, land uses, biophysical properties, climatic zones, and watershed discharges. For consistency, the lake reach definitions identified in the 2014 Secchi disk study (Grace and Sidney 2014) have been used to delineate the lake reaches. To ensure the appropriate sampling locations within a reach were chosen for this report, an initial review of water quality data was conducted. Four reaches encompassed most of the stations with substantial historical water quality data from Shuswap Lake (Figure 7):

1. Salmon Arm Reach – from the Salmon River inflow to Canoe Point near Sicamous
2. Sicamous Reach (in Salmon Arm) – from Sicamous to the east side of Cinnemousun Narrows
3. Main Arm Reach– from the west side of Cinnemousun Narrows to McBride Point
4. Sorrento Reach (in Main Arm) - from McBride Point to Squilax

While previous monitored has been conducted in Seymour and Anstey Arms, they were not selected for this report because fewer human impacts to water quality were expected in these arms due to less development along the shorelines and within the watersheds. A qualitative evaluation of water quality data from these arms and other existing reports (for example, reports produced for SLIPP) confirmed both arms are currently less affected by point and non-point source inputs. However, data examined in the addendum to this report (Appendix B). indicate that some impacts may be occurring in these arms. Ongoing monitoring of these reaches is recommended to track water quality with respect to BC water quality guidelines and to identify any trends (see Section 8).

Priority in this assessment has been given to assessing water quality parameters that would best demonstrate changes from the ambient (background) water quality that could be a result of human activities, such as nutrients, in the watershed. Therefore, one long-term monitoring station within each reach was selected for detailed data analysis.

Each of the four sampling sites is an existing mid-lake [15] or offshore pelagic sampling station located at or near the maximum depths of the reach (Table 22, Figure 7). Sandy Point is a long-term sampling station off the mouth of the Salmon River at Salmon Arm and has one of the most comprehensive data sets available for Lake Shuswap. Marble Point is also a long-term sampling station located in Sicamous Reach, mid-way between the District of Sicamous and the Cinnemousun Narrows. Armstrong Point is in the eastern portion of the Main Arm Reach, west of Cinnemousun Narrows. The final sampling station is located near the Shuswap Lake outflow, at the west end of the Sorento Reach.

[15] Often called "deep" stations in SLIPP reports.

Table 22: Station names, codes and sampling periods used for water quality objectives

Station Name	Station Code	Start of Sampling	Most Recent Sample
Salmon Arm Reach - off Sandy Point TB#5	E206771	Sep 1986	March 2015
Sicamous Reach - opposite Marble Point	0500124	Jun 1971	March 2015
Main Arm Reach - off Armstrong Point	E208723	Jul 1990	March 2007
Sorrento Reach - west of Sorrento	0500123	May 1971	March 2015

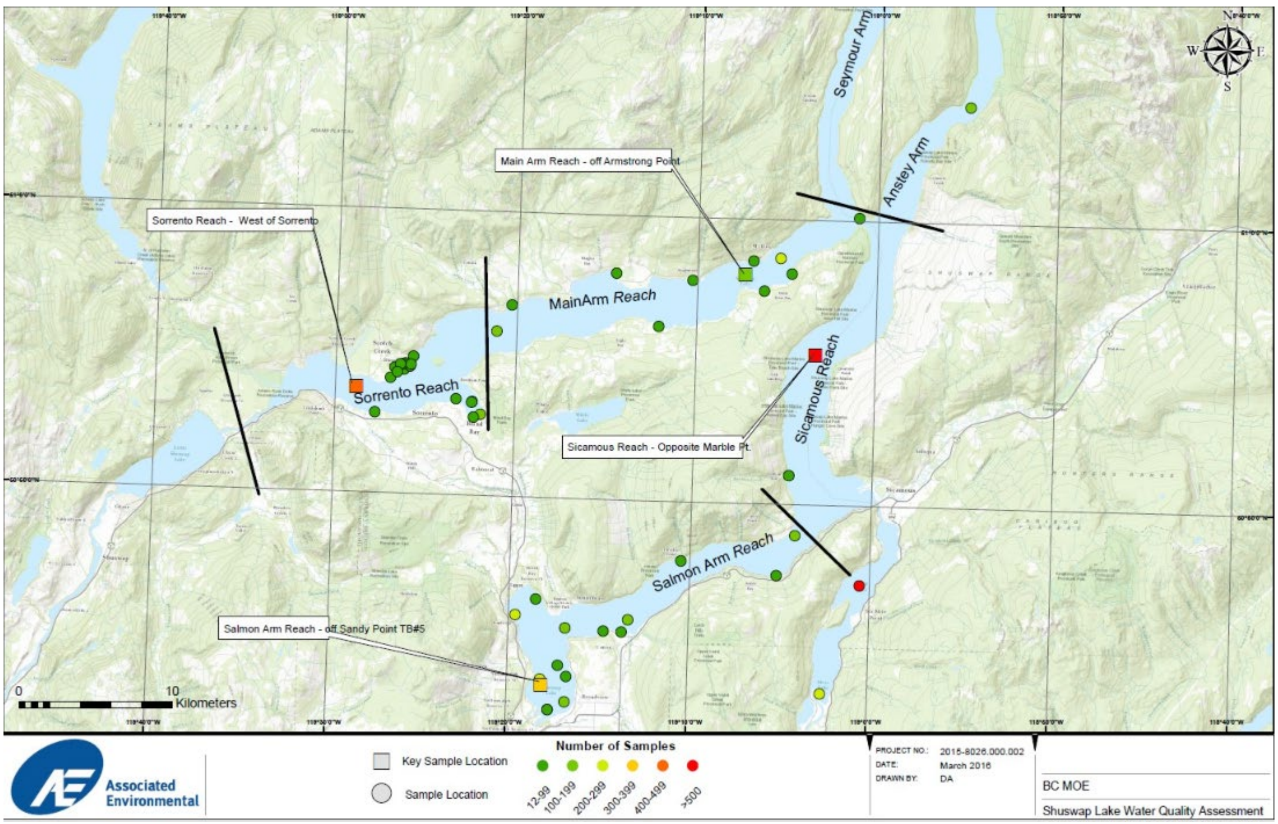

Figure 7: Map indicating key water quality sampling stations and Reach locations in Shuswap Lake

5.2.3 Data Retrieval, Tabulation and Analyses

Data used to assess water quality were retrieved from the Environmental Monitoring System (EMS) database (B.C. ENV2015g) and from the Ministry of Environment electronic files.

Values in this assessment were calculated using recently collected data, so each metric may reflect some level of point and non-point source inputs. Consequently, any baseline values determined in this assessment should not be considered to indicate pristine or pre-development water quality with respect to the chosen parameter, but rather represent the current state of the lake.

Vertical lake profiles of temperature measured between 2003 and 2015 were used to estimate when the lake becomes thermally stratified and when it de-stratifies. The data suggests that the Shuswap Lake typically stratifies in May or June and is de-stratified from November to March.

Analytical data were assigned to the stratified (summer) or unstratified (winter) periods, and mean, median and the 5th and 95th percentile concentrations of each parameter were calculated and interpreted as the baseline condition for assessing water quality. For results that were below detection limits, results were evaluated at the detection limit for a conservative approach to the analyses.

Nutrient data from each station was segregated by the 'growing season' (May – October, inclusive) or the non-growing season (November – April), consistent with the protocol used by ENV to assess water quality. The importance of the growing season is specific to water quality parameters related to primary productivity, including phosphorus, chlorophyll *a*, and Secchi depth.

5.2.4 Water Quality Parameter Selection

Water quality parameters were selected as they relate to the more sensitive designated uses of the lake. Aquatic life is typically the most sensitive use affected by changes in water quality, followed by domestic source water and aesthetic/recreational uses. The parameters most relevant to the sensitive uses were identified and ranked in order of priority based on a review of the compiled water quality data, issues raised by stakeholders (SLIPP) and with consideration of First Nations values. Concerns about nutrient loading and algal blooms resulted in a parameter list headed by nutrients and chlorophyll *a*, but also included parameters that were likely to be influenced by the primary land use activities in the watershed (see Section 4). These key parameters, in approximate order of priority, include:

- total phosphorus (TP)
- chlorophyll *a*
- total nitrogen
- dissolved oxygen (DO)
- water temperature
- water transparency (measured as Secchi depth)
- total organic carbon

6 WATER QUALITY ASSESSMENT

6.1 Approach to Assessing Water Quality Data

Each of the selected water quality variables listed in Section 5.2.4 was assessed for each of the four priority reaches of Shuswap Lake by comparing sampling results to BC water quality guidelines (WQGs) as well as to historical data to examine general trends in water quality over time. As WQGs can differ slightly between designated water uses (for example, aquatic life or primary-contact recreation), it is possible for water quality to be impact for some uses, but not others.

Water samples have been collected in each of the reaches since the early 1970's; however, this report will focus on data collected between 2000 and 2014. The greater the number of sampling events in a year, the better the assessment of annual limnological processes in the lake. When reasonable, historical data prior to 2000, was examined to evaluate identified trends in later data.

6.2 Phosphorus

6.2.1 Background

Phosphorus (P) has been measured in Shuswap Lake as total phosphorus (TP), dissolved inorganic orthophosphate (PO_4^{3-}), also called ortho-P or soluble reactive P, and total dissolved phosphorus (TDP). Total P consists of all the PO_4^{3-}, TDP and the particulate P that is >0.45 µm in size. The TDP fraction consists of all the P that passes through a 0.45 µm filter and is comprised of PO_4^{3-} and a fraction of dissolved organic P from the breakdown of biotic material and polyphosphates (Nordin, 1985).

In the trophic status classification system, lakes with average spring TP concentrations below 10 µg/L, are classified as nutrient poor or oligotrophic and lakes with TP <4 µg/L are classified as ultra-oligotrophic (CCME 2004). In general, those with TP concentrations ≥35 µg/L are classified as nutrient rich or eutrophic, and TP values in between are classified as having moderate productivity or mesotrophic. The BC water quality guideline for the protection of source water for drinking and recreational use of lakes is 10 µg/L TP while a range from 5 to 15 µg/L is considered protective of aquatic life (Nordin 1985). The WQGs are conservative because phosphorus at higher concentrations promotes more primary productivity and could lead to algal blooms (CCME 2004) and a degradation of the local aquatic ecosystem.

The ENV technical document supporting the nutrient BC WQG recommends that phosphorus concentrations in lakes be measured at spring overturn if the epilimnetic water residence time is greater than six months (ENV 2001). The timing of spring overturn across provincial lakes can vary considerably, as well as differ on an individual lake from year to year. In Shuswap Lake, the water residence time is greater than six months (Table 2-1), but analysis of historical spring overturn nutrient levels suggest that spring TP may not to be truly representative of nutrients available for primary production during the growing season (D. Einarson, pers. comm.). As a result of this uncertainty, the growing season mean phosphorus concentration was calculated by averaging across the samples collected from the mid-lake sites monthly between May and October, the summer growing period.

6.2.2 Assessment

The growing season mean concentrations of TP in the Sicamous, Main Arm and Sorrento Reaches were low, ranging from 3.4 µg/L at Sorrento to 4.6 µg/L in the Sicamous Arm (Figure 8). In contrast, TP concentrations in the Salmon Arm Reach were higher, with a mean concentration of 10.2 µg/L over the same time period. After a review of the data, the growing season TP measurements (Figure 6-1) were considered representative of summer stratified conditions at these mid-lake stations in the four reaches in Shuswap Lake. Few differences were noted between TP concentrations in the surface and deep[16] samples, except in the Salmon Arm.

[16] Usually called "epilimnion" or "hypolimnion" in data sheets.

6.2.2.1 Comparison to Water Quality Guidelines

Concentrations of TP were below the BC WQG level of 10 µg/L for drinking water and recreation at three of the four reaches, and indicated the lake was generally oligotrophic. However, TP exceeded this BC WQG of 10 µg/L in the Salmon Arm Bay from 2000 to 2002 and again from 2012 to 2014 (Figure 8), elevating the long-term average TP concentration to 10.3 µg/L, which remains within the acceptable limits of the BC WQG for aquatic life (5 to 15 µg/L).

The higher concentrations of TP in the Salmon Arm Bay Reach during these years likely reflected contributions from the local tributaries, which serve as the primary source of phosphorus (Tri-Star 2014; Ludwig 2018). Although the Salmon Arm Wastewater Treatment Plant discharges into Salmon Arm, it represents a comparatively small contribution, and likely has only a localized effect on water quality and aquatic life (Tri-Star 2014). Significant loadings of phosphorus to the tributaries of Shuswap Lake have been attributed to agriculture and urban development (Table 17). TP levels in 2012 were very high, likely due, in part, to the extreme flood event that occurred that year, and which extended the high-water level period usually only associated with spring freshet, into late July and early August. During this extended flood period, turbidity in Shuswap Lake and the Salmon River was high, suggesting that most TP was associated with sediment from the river inflows.

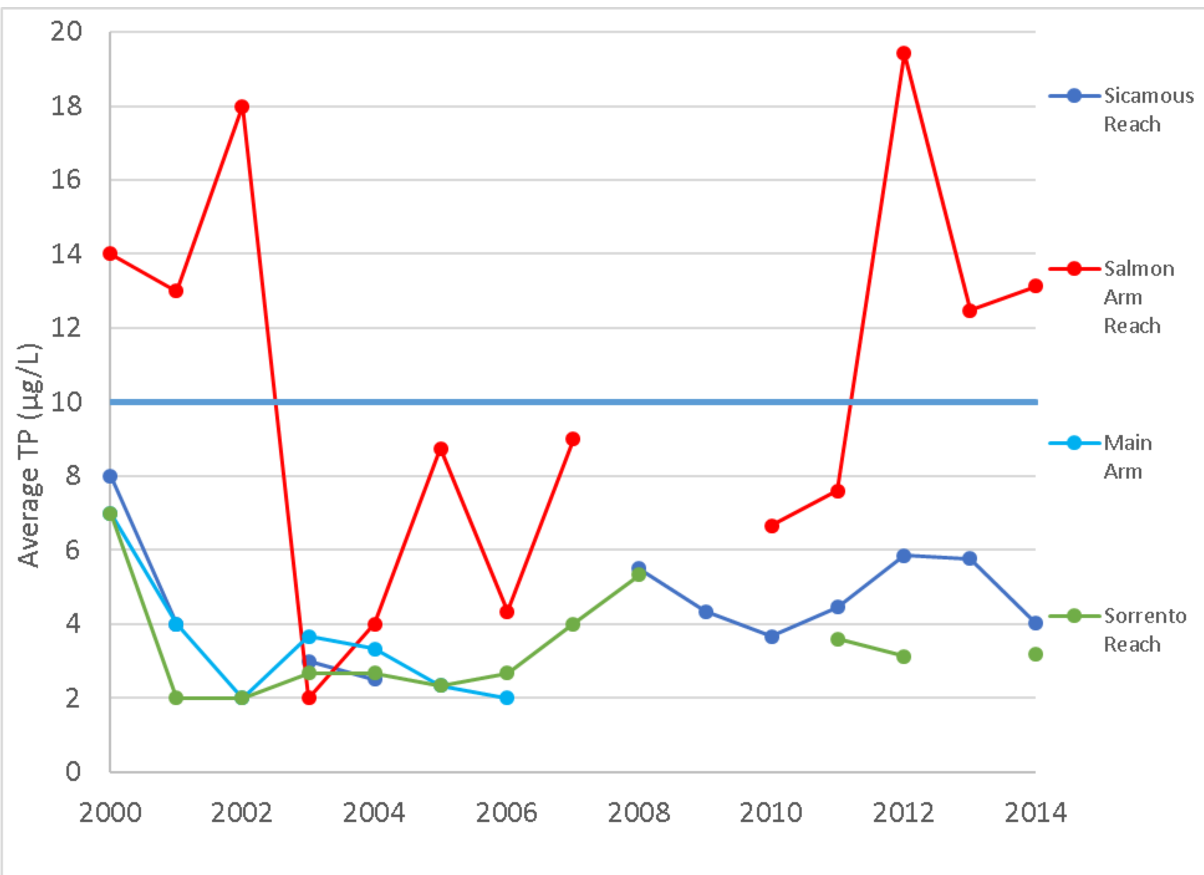

Figure 8: Comparison of mean epilimnion TP concentrations in each of the four Shuswap Lake reaches during the growing season (May-October, inclusive) from 2000-2014. Recreational guideline for TP of 10 µg/L is included.

6.3 Chlorophyll *a*

6.3.1 Background

Chlorophyll *a* is one of the pigment groups responsible for photosynthesis in algae (Nordin 2005). The measurement of chlorophyll *a* is used as a measure of the quantity of planktonic algae present in the surface water, that is, it serves as a surrogate for phytoplankton biomass. In general, chlorophyll *a* has a positive statistical relationship with TP, so as TP increase, so does the quantity of planktonic algae (as measured by chlorophyll *a*). After documenting the positive relationship between TP and algal growth in Shuswap Lake (NHC 2014b), the SLIPP noted that measurement of both parameters was "essential in defining the present conditions in the lake and setting a baseline by which future measurements can be evaluated."

Algal blooms, especially those that have occurred in Salmon Arm, have become a significant issue for the Shuswap Lake system (NHC 2014b). These blooms are most often a problem during the growing season, when days are long and water temperatures are high, and are usually composed of Cyanobacteria (blue-green algae), which can produce cyanotoxins . However, the 2008 and 2010 algal blooms in Shuswap Lake were Chrysophyte algae, which typically occur during the early part of the growing season and do not produce toxins. Regardless of the type of algal observed, chlorophyll *a* measured during the growing season is a priority parameter for ongoing monitoring.

6.3.1.1 Trophic Status

The BC ENV has not established chlorophyll *a* water quality guideline for lakes, the following are the generally accepted trophic classification values based on trigger ranges referred to by Nordin (1985):

- Oligotrophic: <2.0 µg/L
- Mesotrophic: 2.0 to 7.0 µg/L
- Eutrophic: >7.0 µg/L

6.3.2 Assessment

Chlorophyll *a* concentrations in surface samples have been relatively low during the growing season in Shuswap Lake, except for the Salmon Arm Reach (Figure 9). The growing season mean chlorophyll *a* concentration in the Sorrento Reach was <2 µg/L between 2000 and 2014. Likewise, chlorophyll *a* concentrations in Main Arm Reach were also below 2 µg/L between 2000 and 2006, the period for which data were available. These mean values were consistent with Shuswap Lake's oligotrophic classification. The growing season mean concentrations within Sicamous Reach were below 2 µg/L until the algal blooms of 2008 and 2010. During those blooms, the chlorophyll *a* concentrations for the growing season mean increased to a high of 3.32 µg/L in 2010 but declined over the next four years to 1.39 µg/L in 2014. The growing season mean chlorophyll *a* concentrations in Salmon Arm Reach were higher than the other areas of the lake. Prior to 2005, the growing season mean at the Sandy Point sampling site had high variability (Figure 9). After 2004, the growing season mean concentration remained between 2 and 4 µg/L with an average of 3.4 µg/L. These values reflect a mesotrophic chlorophyll a range that is consistent with the range observed in the data prior to 2000 (NHC 2014b).

For the Salmon Arm Reach both chlorophyll *a*nd TP are higher than in the other reaches, which is consistent with the relationship that often occurs between the two variables. The SLIPP report found the growing season TP concentration exceeded 10 µg/L from 2012 to 2014 which resulted in growing season means of chlorophyll-*a* at or above 3 µg/L (NHC 2014a, b). The growing season long-term chlorophyll *a* data was variable but an increasing trend in the Salmon Arm Reach was not visually observed. Analysis of the data would be needed to determine if the Sicamous and Sorrento Reaches were seeing increasing chlorophyll *a* concentrations after 2008 (Figure 9). For information on chlorophyll *a* prior to 2000, refer to the SLIPP reports (NHC 2013, 2014a, b).

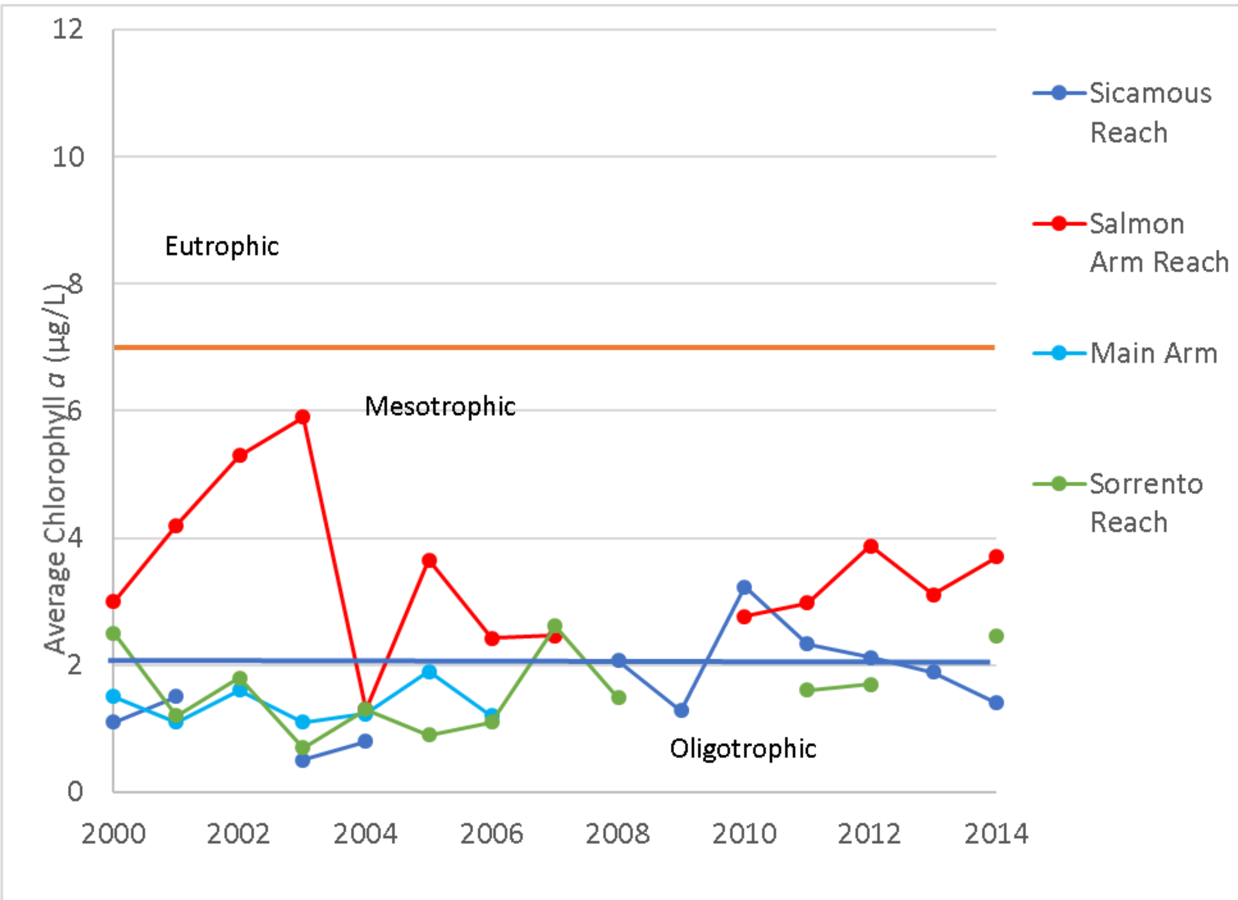

Figure 9: Growing-season mean of chlorophyll-a concentrations in Shuswap Lake (May-October) from 2000-2014. Eutrophic value for chlorophyll-a of 7 µg/L is included.

6.4 Nitrogen

6.4.1 Background

Nitrogen is an essential plant nutrient and occurs in lakes and other freshwater systems in several forms, including dissolved molecular N_2, organic compounds (amino acids, amines, humic compounds, and so forth), ammonia (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-) (Wetzel 2001). Ammonia is the reduced inorganic form of nitrogen, and nitrate is the oxidized inorganic fraction. Kjeldahl nitrogen (TKN) is the sum of the ammonia and organic forms of nitrogen. While ammonia is a relatively small component of the total nitrogen (TN), it, along with, nitrate is important due to its direct availability to algae, plants, and phytoplankton (Nordin 2005). Figure 6-3 shows the complex nitrogen cycle that occurs within lakes, including the oxidation and reduction processes that occur in the presence (oxic) or absence (anoxic) of oxygen.[17] Natural, undisturbed waters typically have ammonia concentrations <0.1 mg/L, and excessive concentrations of ammonia, along with other nitrogen compounds, may contribute to eutrophication of water bodies. A general description of the various forms of nitrogen found in Shuswap Lake can be found in the SLIPP reports, including measurements made of TN, total organic nitrogen, TKN, dissolved ammonia, and combined nitrate + nitrite.

Sources of nitrogen for lakes may include direct precipitation, nitrogen fixation (in water and sediments), and inflows from surface and groundwater drainage. Losses can be via outflows, reduction of nitrate to N_2 by bacterial denitrification (Figure 10), or permanent sedimentation of nitrogen-containing compounds to the sediments at the lake bottom.

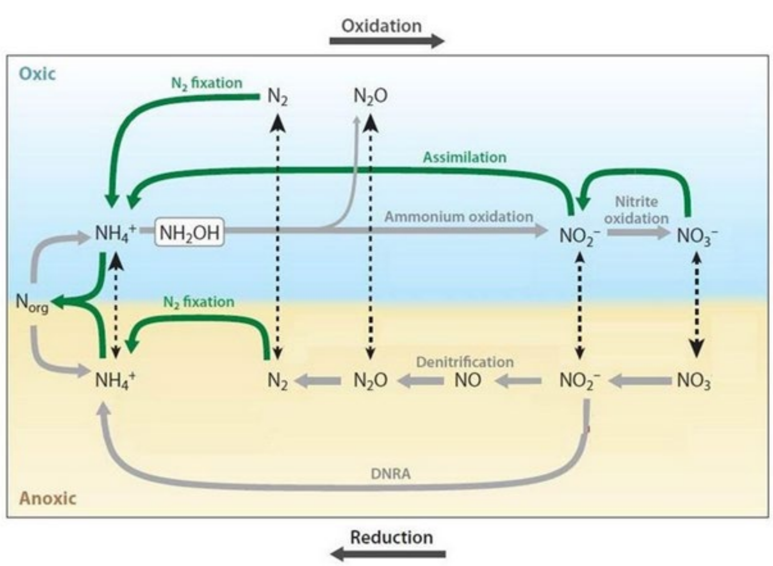

Figure 10: The aquatic life nitrogen cycle (modified from Thamdrup 2012)

6.4.2 Assessment

Total nitrogen concentrations have been generally low during the growing season in the surface waters of Shuswap Lake (Table 23). With the exception of samples from October 2012, total nitrogen measurements were all below 0.4 mg/L, and the medians and means in all reaches never exceeded 0.20 mg/L with the 95th percentiles always below 0.35 mg/L. Visually comparing data collected prior to 2000, the recent years appear to have higher concentrations of total nitrogen in the Salmon Arm, as well as the Sicamous, and

[17] Figure from planetgeogblog website

Sorrento Reaches (Figure 11, Figure 12, Figure 14). Alternatively, concentrations of total nitrogen in the Main Arm Reach appear relatively consistent (Figure 13).

Like TN, the key bio-available nitrogen species (ammonia and nitrate + nitrite) have consistently been below laboratory detection limits in surface water (epilimnetic) samples (Table 24 and Table 25). Long-term records indicate growing season surface concentrations have not exceeded BC WQGs for nitrate, nitrite, and ammonia (Table 26).

Table 23: Statistics for TN results during the growing season for 1971 to 2014 (surface samples only)

Station name	Sample size (n)	Median (mg/L)	Mean* (mg/L)	5th percentile (mg/L)	95th percentile (mg/L)
Salmon Arm Reach - off Sandy Point TB#5	74	0.18	0.19	0.10	0.33
Sicamous Reach - opposite Marble Point	80	0.14	0.15	0.06	0.25
Main Arm Reach – off Armstrong Point	26	0.09	0.10	0.08	0.16
Sorrento Reach – west of Sorrento	67	0.11	0.12	0.06	0.24

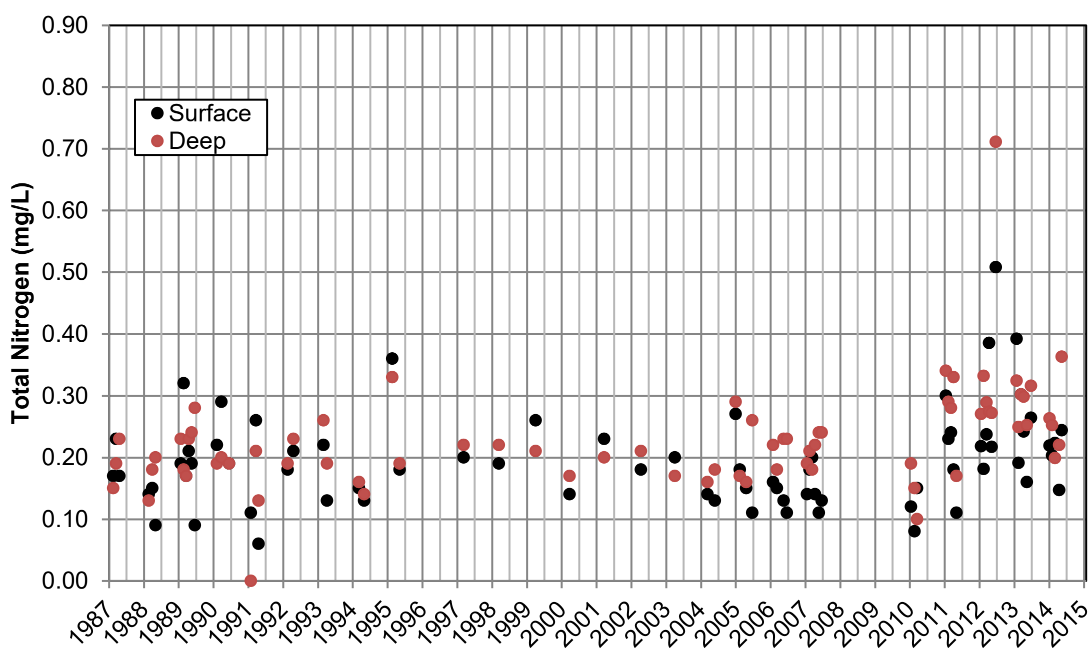

Figure 11: Growing season TN in the Salmon Arm Reach (off Sandy Point TB#5) from 1987-2014

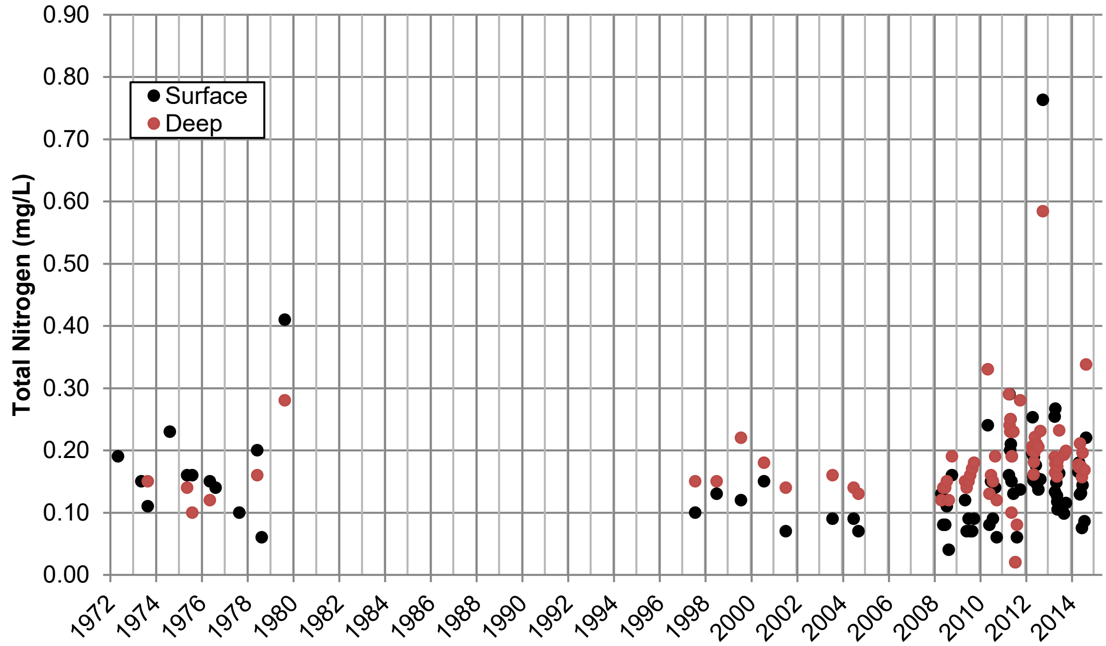

Figure 12: Growing season TN in the Sicamous Reach (opposite Marble Point) from 1972-2014

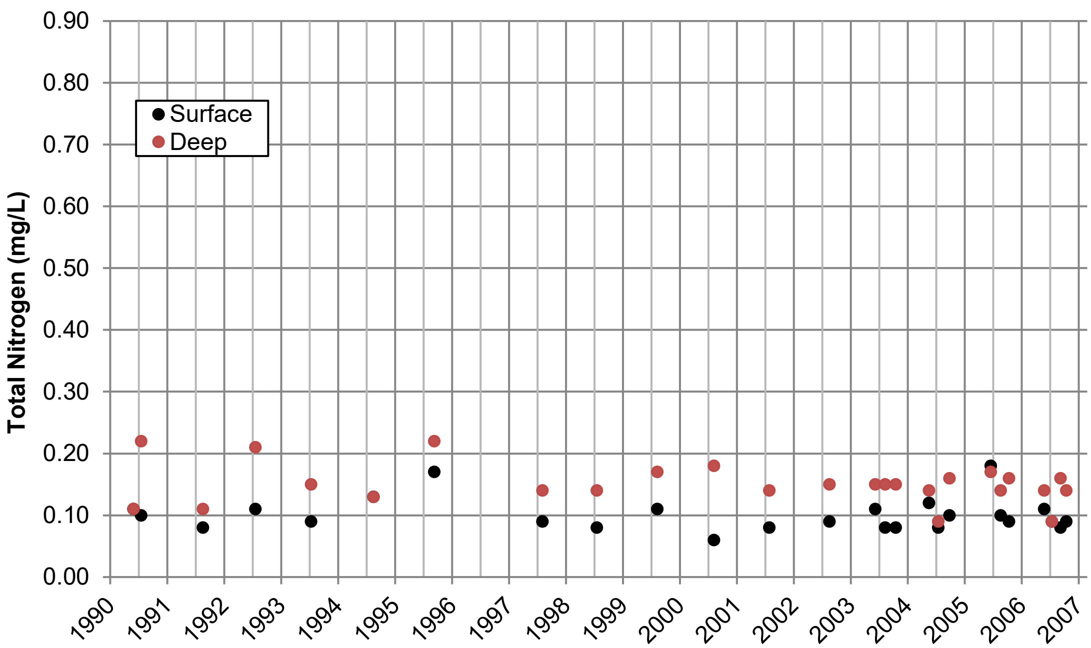

Figure 13: Growing season TN in the Main Arm Reach (off Armstrong Point) from 1990-2006

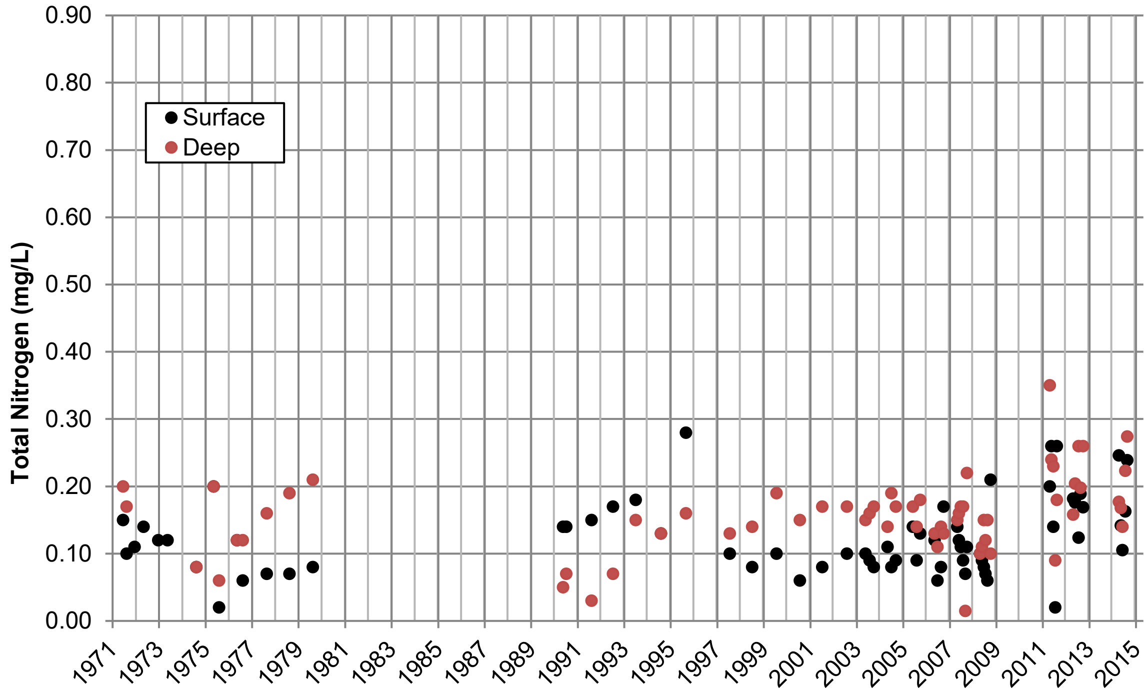

Figure 14: Growing season TN in the Sorrento Reach (west of Sorrento) from 1971-2014

Table 24: Statistics for dissolved nitrate + nitrite results during the growing season for 1971 to 2014 (surface samples only)

Station name	*Sample size (n)*	Median TN (mg/L)	Mean (mg/L)	5th percentile (mg/L)	95th percentile (mg/L)
Salmon Arm Reach - off Sandy Point TB#5	74	0.012	0.015	<0.002	0.033
Sicamous Reach - opposite Marble Point	87	0.014	0.021	<0.002	0.064
Main Arm Reach – off Armstrong Point	26	0.011	0.019	<0.002	0.059
Sorrento Reach – west of Sorrento	64	0.019	0.025	<0.002	0.077

Table 25: Statistics for ammonia results during the growing season for 1971 to 2014 (surface samples only)

Station name	*Sample size (n)*	Median (mg/L)	Mean (mg/L)	5th percentile (mg/L)	95th percentile (mg/L)
Salmon Arm Reach - off Sandy Point TB#5	73	0.006	0.010	<0.005	0.024
Sicamous Reach - opposite Marble Point	84	0.008	0.016	<0.005	0.046
Main Arm Reach – off Armstrong Point	25	0.005	0.008	<0.005	0.017
Sorrento Reach – west of Sorrento	60	0.005	0.008	<0.005	0.022

Table 26: B.C. Nitrogen Water Quality Guidelines

Water use	Nitrate-N (mg/L)	Nitrite-N** (mg/L)	Ammonia-N*** (mg/L)
Aquatic life – long term average (chronic)*	3.0	0.02	<0.102
Aquatic life – short term maximum (acute)	32.8	0.06	<0.681

Source: ENV 2009 (refer to this report for full guideline details).
* based on 5 samples in 30 days.
** when Cl^- ≤2 mg/L; if Cl^- = 2 – 4 mg/L, nitrite guidelines are 0.04 mg/L (chronic) or 0.12 mg/L (acute)
*** values for pH up to 9, and temperature up to 20°C. Shuswap L has never recorded levels as high as this for either.

6.4.3 TN:TP Ratios

The ratio of TN to TP (usually written as TN:TP ratio), can be used to predict the composition of the phytoplankton community (Downing *et al*. 1992) because different phytoplankton groups require nutrients in different, predetermined ratios based on their metabolic machinery. The preferences of the different algal groups range from 7:1 to 68:1, with lower TN:TP ratios favouring the growth of heterocystic cyanobacteria (blue-green algae which can fix atmospheric nitrogen in low TN conditions) (Nordin, 2005). Building on this concept, the TN:TP ratios can use the availability of these essential nutrients to predict the type of algae that may be favoured within a lake (Nordin, 2005).

Using the mass concentration (in mg/L), the TN:TP ratio that defines P limitation in a lake is a ratio greater than 15:1. Conversely, N limitation would occur at TN:TP ratios below 5:1. For the TN:TP ratios between 5:1 and 15:1, the nutrients are co-limiting. The long-term TN:TP ratios in Shuswap Lake, were calculated using the growing season mean concentrations of TN and TP of surface samples. The ratios for the four reaches were:

- Salmon Arm Reach - off Sandy Point TB#5 (n=74 [for TN]; n=71 [for TP]): **18:1**
- Sicamous Reach - opposite Marble Point (n=80 [for TN]; n=87 [for TP]): **28:1**
- Main Arm Reach - off Armstrong Point (n=26 [for TN]; n=25 [for TP]): **29:1**
- Sorrento Reach - west of Sorrento (n=67 [for TN]; n=64 [for TP]): **29:1**

Based on their TN:TP ratios, Sicamous, Main Arm and Sorrento Reaches would be considered "strongly" phosphorus limited, while Salmon Arm Reach would be "weakly" phosphorus limited and could tend towards co-limited at times. The TN:TP ratios are affected by changes in hydrology. Higher ratios would be expected during low run off years, while lower ratios would be expected during high runoff and flood years (Nordin, 2005).

The present ratios of 28-29:1 ratios in the three arms represents a nutrient balance that is not expected to enhance cyanobacteria production, and thus reduce the chances of a cyanobacteria bloom. However, in the Salmon Arm Reach, the TN:TP ratio could be lower during high stream flows and flood years, which could create favourable growing conditions for cyanophytes.

6.5 Dissolved Oxygen and Water Temperature

6.5.1 Background

Oxygen is the most fundamental element in lakes because it is essential for metabolism in aerobic aquatic organisms, making the solubility and dynamics of oxygen in lakes basic to understanding the distribution, behaviour and growth of aquatic organisms (Wetzel 2001). Because oxygen solubility increases as the temperature of water decreases, depth profiles for dissolved oxygen (DO) are usually depicted along with temperature profiles to clearly show this relationship through the seasons.

Oxygen concentrations with depth, and particularly in the deepest parts of a lake, are a key environmental indicator to be monitored. If oxygen was to become depleted, making the bottom waters anoxic, a chemical change at the water-sediment interface would occur. Under anoxic conditions nutrients that are chemically locked into the sediments under "oxidizing conditions" are released under "reducing (anoxic) conditions," a process referred to as internal loading (Wetzel 2001). Released nutrients can then mix with the surface waters and increase the overall nutrients available for algae growth during the next growing season (Wetzel, 2001), and creating a condition that can persist for several years. Therefore, the BC WQG for DO considers aquatic life the most sensitive user and establishes an instantaneous minimum of 5 mg/L and a 30 day mean of 8 mg/L to ensure internal loading conditions are avoided (ENV 1997).

Temperature is the primary influencing factor affecting primary productivity, water density, the thermal stratification patterns (NHC 2013) and concentration of DO in the water column of a lake. Since water temperature affects primary productivity the timing and duration of thermal stratification can impact water chemistry and algal species composition. A longer period of thermal stratification will favour algal species more tolerant to those conditions.

Surface water temperatures in temperate zone, monomictic[18] lakes, such as Shuswap Lake, typically range from 4°C in winter to approximately 25°C in summer. The largest sources of heat are natural, including solar radiation, contact transfer from air, condensation of water vapour at the water surface, evaporation, sediments, precipitation, and inflows from tributaries, surface runoff from lakeshore areas and groundwater (Wetzel 2001). Temperature changes to lake water can also occur with very large discharges from sewage treatment plants, open loop geothermal installations, or other industrial discharges to the

[18] Monomictic lakes are relatively deep, do not freeze over during the winter months, and undergo a single stratification and mixing cycle during the year.

deep lake environment. BC WQG for temperature designates aquatic life as the most sensitive user and call for a maximum of +/- 1°C change from ambient conditions.

The various SLIPP reports provide a historical perspective of DO-temperature profiles in specific years at many locations in the lake. This report discusses measurements collected at four times between March and October 2013 at Sandy Point (TB#5) in the Salmon Arm Reach and Marble Point in Sicamous Reach. The profiles (Figure 15 and Figure 16) are representative of DO and temperature patterns observed in the data collected between 2000 and 2014 at all four mid-lake sampling stations in the Salmon and Main Arms. The historical records indicate that DO concentrations remain at levels adequate to maintain aquatic life (>8 mg/L) during all other times of year.

6.5.2 Assessment

With the occasional exception of Sandy Point, in the Salmon Arm Reach, no evidence of hypolimnetic oxygen depletion or anoxic conditions was found for any time of the year in Shuswap Lake. Since the lake does not completely freeze over in winter, atmospheric transfer of oxygen to surface waters occurs throughout the year, with hypolimnetic mixing through the water column during winter months.

Figure 15 shows that the lake thermally stratifies during the summer, with some DO reductions in the deep waters at Sandy Point (Salmon Arm Reach) by late October. The low DO conditions occurred during early fall before the lake de-stratification and turnover. These low DO levels may restrict fish movements in the zone near the bottom, but do not reach anoxic conditions that would exclude fish and that would result in internal loading of nutrients. At Marble Point (Sicamous Reach), which is less affected by anthropogenic activities and nutrient inflows, the lake stratifies from May through October and DO concentrations remain >9 mg/L throughout the water column (Figure 16). Of note is that the epilimnetic layer is very narrow at this location, indicating the thermal stratification of the epilimnion is weak, which could result in mixing of the surface layer and upper thermocline depth during strong winds. This mixing would move oxygen into the deeper depths even during the stratified summer period.

Surface water temperature profiles in Shuswap Lake (Figure 15 and Figure 16) in 2013 appear to follow the typical pattern found in northern, temperate, monomictic lakes, and are representative of lake conditions found between 2000 and 2014. The timing and length of the stratification may impact water chemistry and algal species composition as a longer period of thermal stratification will likely favour algal species more tolerant of warm water. The temperature profiles shown in Figure 15 and Figure 16 are representative of lake conditions between 2000 and 2014. No changes to seasonal trends or surface temperatures were observed in the temperature data. Long-term trends in changes to the stratification period in Shuswap Lake can not be determined from this data.

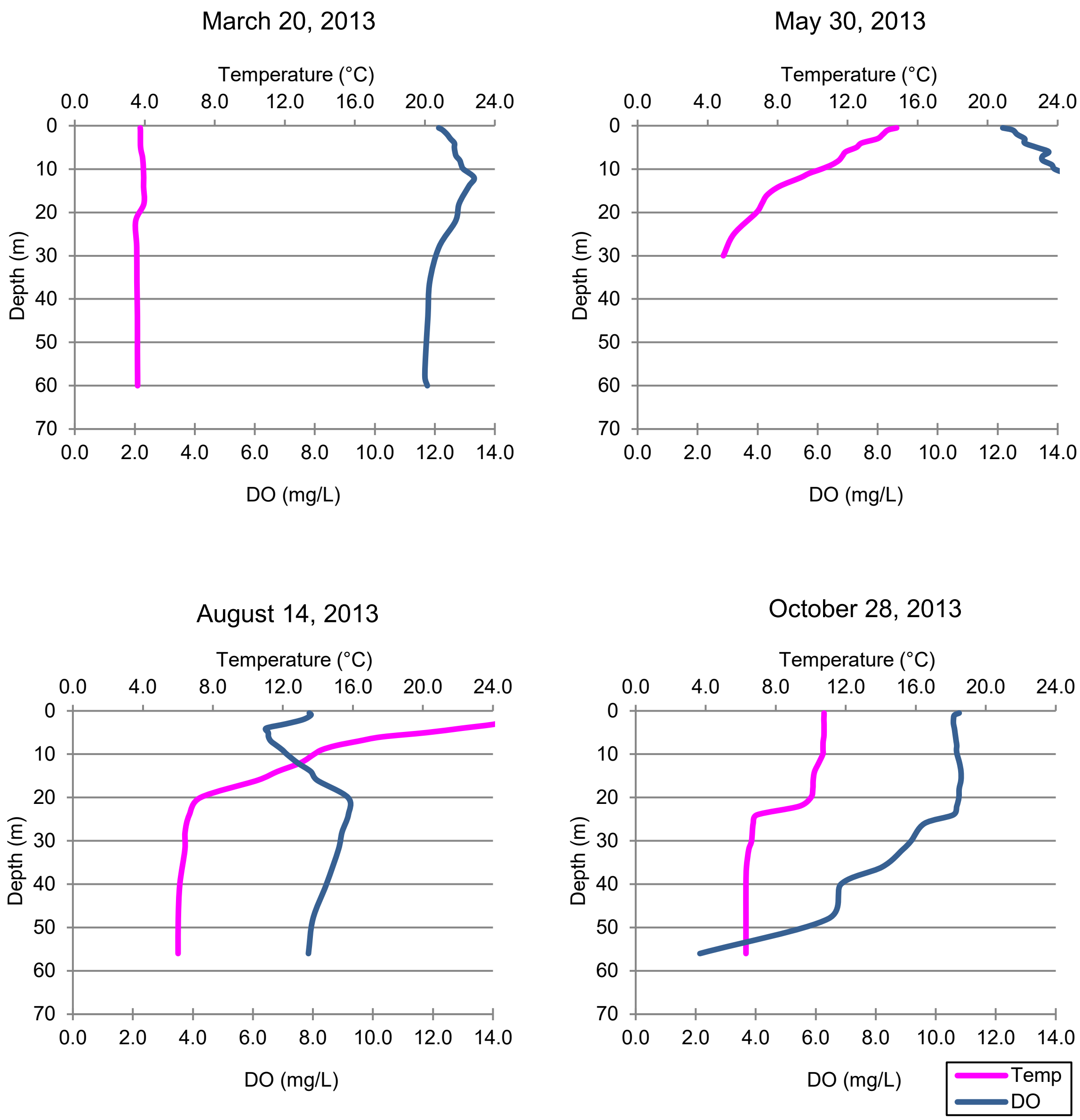

Figure 15: Temperature and DO profiles in the Salmon Arm Reach (off Sandy Point TB#5) in 2013

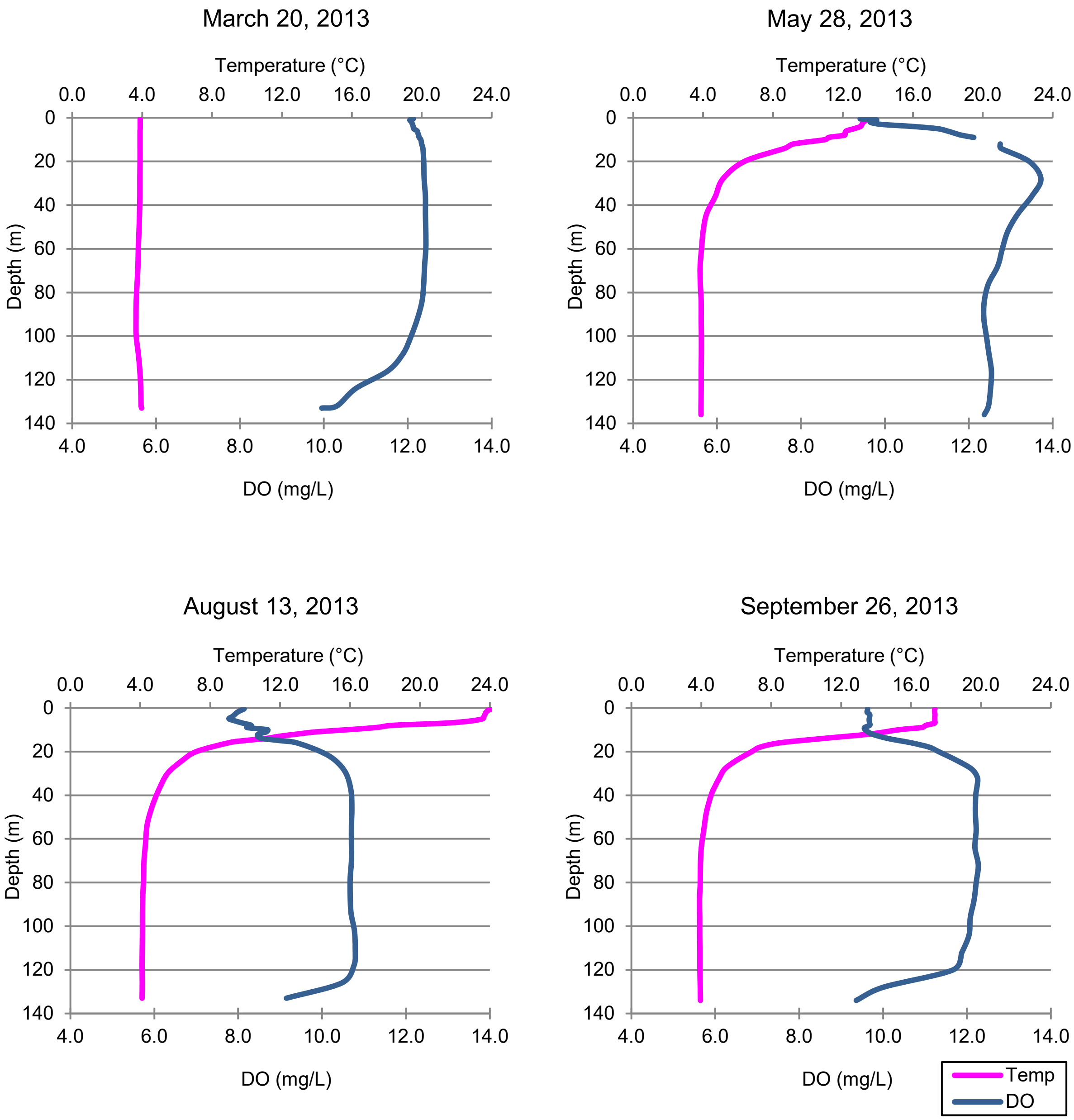

Figure 16: Temperature and DO profiles in the Sicamous Reach (opposite Marble Point) in 2013

6.6 Water Transparency (Secchi Depth)

6.6.1 Background

Generally, lakes with high productivity (eutrophic) tend to have low water transparency, and lakes with low productivity (oligotrophic) tend to have high transparency. The depth of light penetration also determines the depth at which phytoplankton, periphyton and rooted aquatic plants can grow (Wetzel 2001).

The clarity of the water and depth to which light can penetrate can be estimated using a Secchi disk. The Secchi disk transparency is the average of the depth at which a weighted, black-and-white disk visually disappears when lowered from the shaded side of a vessel, and the depth at which it reappears after raising it again (Wetzel 2001). The relationship between Secchi depth and phytoplankton, measured as chlorophyll *a*, has been well-established, and the simplicity of the Secchi disk method makes it an important monitoring tool.

6.6.2 Assessment

A lake could be considered oligotrophic when the growing season mean Secchi depth is >6 m and mesotrophic when the depth is between 3 to 6 m (Nordin 1985). Secchi depths tended to be lowest during the spring months (when freshet introduces silts and particulate matter to the lake), slightly greater during the mid-summer, and greatest during the winter months.

Except for Salmon Arm Reach, Shuswap Lake has low primary productivity based on historical growing season Secchi depth transparency (Table 27). No long-term trend was determined but transparency may be decreasing (Figure 17). Salmon Arm Reach near the City of Salmon Arm showed reduced water transparency during the summer and had a mean growing season Secchi depth transparency of 3.7 m, which was less than half of that found in the Main Arm Reach (Table 27). Secchi depth for the Main Arm Reach was not monitored between 2006 and 2014 (Figure 17) so it is not possible to say whether transparency has changed after 2006.

Table 27: Descriptive statistics for Secchi Depth readings for the growing season (May-October)

	Sicamous Reach	Salmon Arm Reach	Main Arm Reach	Sorrento Reach	Lake Mean
May	5.6	2.7	6.9	6.7	**5.5**
June	4.9	3.2	7.6	6.8	**5.6**
July	6.7	3.7	8.6	7.5	**6.6**
August	8.2	3.3	9.1	8.1	**7.2**
September	8.6	5.3	9.3	8.2	**7.8**
October	8.9	4.0	8.1	8.0	**7.2**
Seasonal Mean	**7.1**	**3.7**	**8.3**	**7.5**	**6.7**

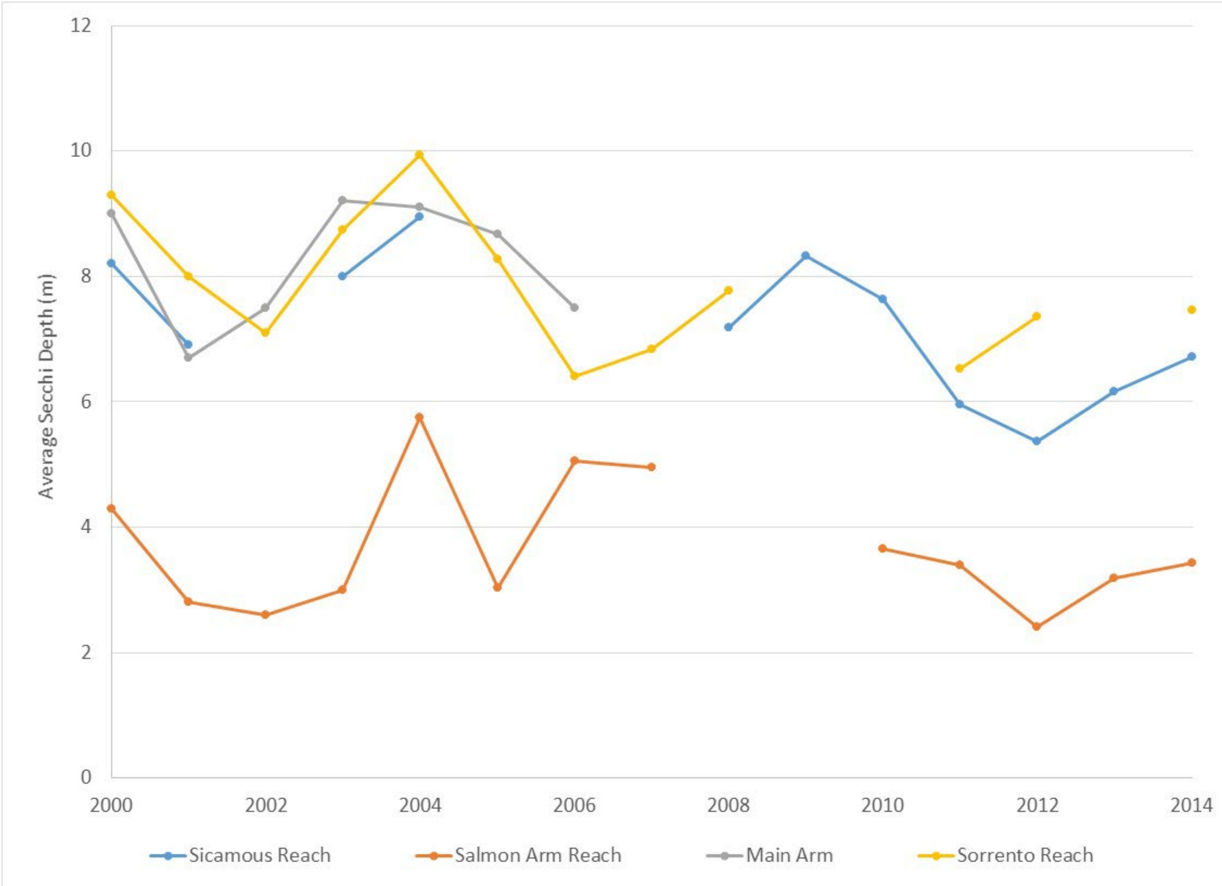

Figure 17: Secchi depth (m) in Shuswap Lake during the growing period (May – October) from 2000-2014.

6.7 Total Organic Carbon

6.7.1 Background

Total organic carbon (TOC) is comprised of the dissolved (DOC) and particulate organic carbon in water. Much of the organic carbon in water is composed of humic substances, which are found in the partially decomposed terrestrial and aquatic plant materials. These humic materials are often resistant to microbial degradation, but some are readily susceptible to further microbial or oxidative breakdown (SLIPP 2014).

Most types of organic carbon found in surface water are naturally occurring, and non-toxic to aquatic life and humans. The primary reason for reducing organic carbon in drinking water is not related to the toxicity of the organic carbon compounds themselves, but rather to prevent the formation of disinfection by-products. Trihalomethanes (THMs) and haloacetic acids (HAAs) can be formed following disinfection by chlorination (Rathbun 1996). The removal of excess organic carbon prior to chlorination will reduce the production of THMs and other substances that bind with humates at low levels.

However, moderate amounts of DOC in surface waters have benefits. DOC has been known to bind to metals and organic contaminants, which reduces the bioavailability and toxicity of these contaminants to aquatic life (Spry and Wiener 1991, Luider *et al.* 2004). Studies have demonstrated that organic matter reduces metal bioavailability in proportion to its concentration in water (Miskimmin *et al.* 1992, De

Schamphelaere *et al.* 2004), a process that must be included in predictive modeling of both contaminant bioavailability and toxicity. The property of DOC complexation is why water quality guidelines and models (for example, the BLM copper model) often incorporate this variable into their calculations.

TOC in natural waters can range from 1 to over 30 mg/L, with the highest values typically associated with sphagnum bogs or other types of wetlands. In concentrations >15 mg/L, organic carbon can impart a brownish hue or tea-like colour to water, but these levels are still not toxic to aquatic life. Higher levels of organic carbon in water may promote the formation of disinfection by-products when exposed to treatment by chlorination.

Water quality guidelines for organic carbon in B.C. were derived based on the potential for by-product formation during disinfection of drinking water. As such, in Shuswap Lake, organic carbon is only of concern around domestic water intakes where chlorination is used in the treatment. The guideline for source water for drinking (prior to treatment) is a maximum of 4 mg/L TOC (ENV, 1998). The depth of each water intake will influence the concentration of TOC in the source water because concentrations often vary with depth. Typically, municipal water intakes are placed in deeper waters because water is likely to be less contaminated and therefore requiring less treatment. For single residential intakes, it is unlikely that many are unable to withdraw water from the below the thermocline. For example, the City of Salmon Arm has their intake depth at approximately 25-30m, but other systems and uses as listed in Table 8 and Table 9 will have intakes at varying depths. As TOC is only a concern when water is chlorinated, and because only the large utilities use chlorination as treatment, TOC concentrations are primarily of concern in deeper waters.

6.7.2 Assessment

TOC concentrations in the deep-water samples from Shuswap Lake are low, with concentrations generally below the B.C. drinking water quality guideline (Table 28). In the Salmon Arm Reach, where organic carbon measurements were started in 2010, TOC concentrations exceeded the guideline in one deep water sample, with a maximum of 4.04 mg/L on May 2014 (Figure 18). At the Sicamous Reach, mean TOC concentrations were like those found in the Salmon Arm Reach, except the guideline was exceeded on five occasions in the deep-water samples, with concentrations ranging from 4.18 mg/L to a maximum of 8.5 mg/L (Figure 19). Exceedances appeared unrelated to seasonality, as they occurred during the months of April, May, August, September, and October, and over several years, and were often preceded and followed by values within the guidelines. For example, the TOC concentrations one month prior to and one month after the maximum value at Sicamous Reach were only 1.4 mg/L. While occasional exceedances of the guideline occur, they appear to be short-lived. Data were also analyzed for annual and monthly trends, but none were noted; mean TOC concentrations were similar between years and between months in both reaches.

Table 28: Descriptive statistics for total organic carbon (TOC) concentrations in all seasons from 2010 - 2014 (deep water)

Station name	*Sample size (n)*	Median (mg/L)	Mean (mg/L)	5th percentile (mg/L)	95th percentile (mg/L)	Maximum (mg/L
Salmon Arm Reach - off Sandy Point TB#5	33	2.6	2.6	1.8	4.0	4.04
Sicamous Reach - opposite Marble Point	62	2.5	2.6	1.3	3.7	8.5

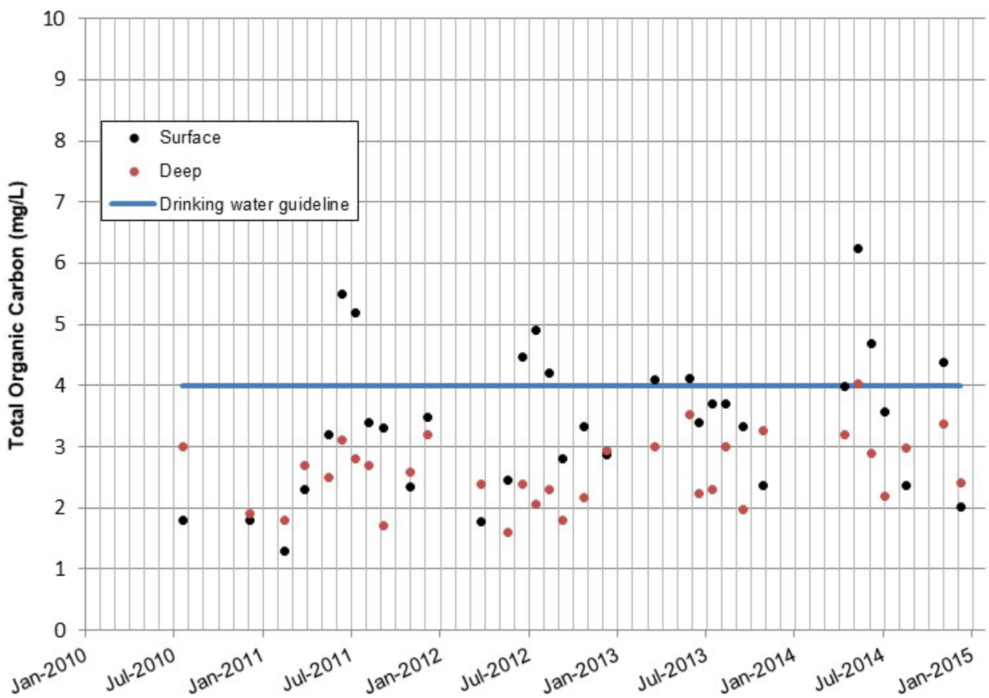

Figure 18: TOC measured in the Salmon Arm Reach (off Sandy Point TB#5) from 2010-2014

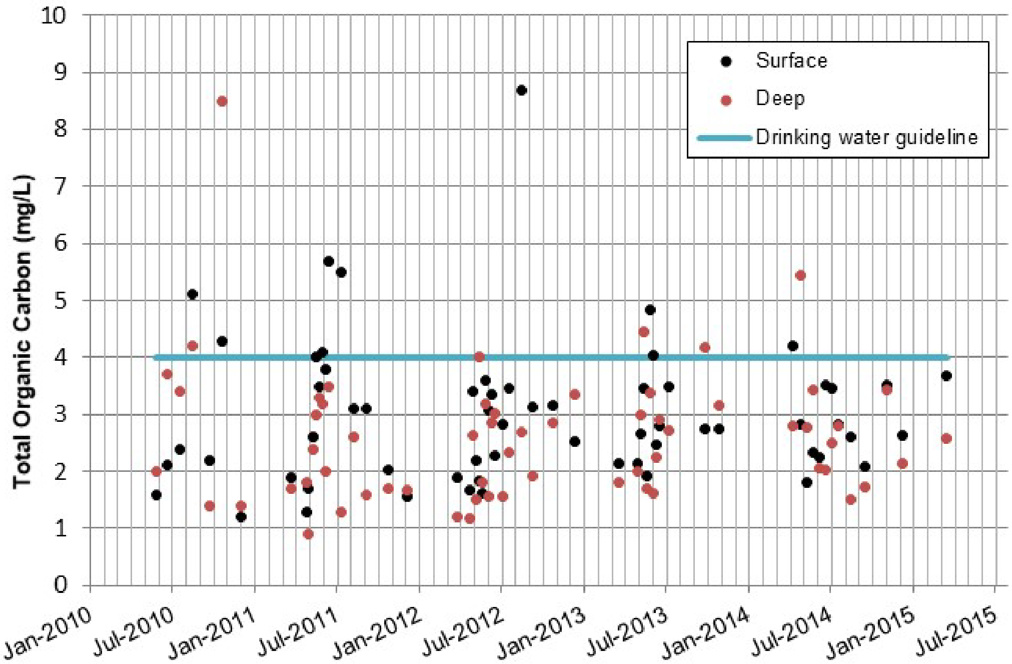

Figure 19: TOC measured in the Sicamous Reach (opposite Marble Point) from 2010-201

7 DISCUSSION

Shuswap Lake is an important resource in the Southern Interior of B.C. In addition to its ecological and First Nations values, the lake supports many tourist and recreational activities that depend on good water quality and a healthy ecosystem. This report provides information on water quality sampling between 2000 and 2014 on Shuswap Lake.

The volume of water contained in the Shuswap Lake is small compared to the total volume of water that flows into it, resulting in a short water residence time of 2.1 years. Water entering via the Shuswap River at Mara Lake and the Salmon River at Salmon Arm, would require the longest time to move through the lake, while inflows from Adams River would have the shortest residence time before flowing out at Little River. This geographical difference is an important consideration when understanding how the lake deals with nutrient inputs, especially from the tributaries.

Nutrient loading from tributaries has been identified as a major water quality issue (SLIPP 2014, Tri-star 2014). The SLIPP tributary monitoring program (2011-2013) identified the Salmon, Shuswap, and Eagle Rivers as important sources of nutrient loading in Shuswap Lake (SLIPP 2014, McDougall 2014), and within the Salmon and Shuswap tributaries, groundwater, seasonal streams, and agricultural runoff contributed the greatest loadings of TP and TDP to the Shuswap Lake system. In contrast, authorized discharges to ground and wastewater discharges to the lake contributed a small percentage of the total phosphorus and nitrogen loading to the lake (Tri-Star 2014).

Other studies found Shuswap Lake generally had good water quality with the Salmon Arm basin considered to be fair (SLIPP 2014). The assessment of water quality results described in this report were consistent with those earlier studies. Based on its chemical and biological conditions, including water transparency, oxygen levels, algal biomass and nutrient concentrations, Shuswap Lake is best described as oligotrophic, and having low biological productivity, clear water, and low nutrient concentrations. However, in the Tappen Bay area of Salmon Arm, higher nutrient levels and more primary productivity has been observed, indicating mesotrophic conditions in this area.

Water quality parameters assessed in this report were selected based on the most sensitive, designated uses of the lake, specifically aquatic life, domestic source water, and aesthetic/recreational uses. The selected parameters were also ones most likely to be influenced by the major land use activities in the watershed. The water quality parameters included:

- total phosphorus (TP)
- chlorophyll *a*
- total nitrogen (TN)
- dissolved oxygen (DO)
- water transparency (measured as Secchi depth)
- total organic carbon

These parameters were assessed within four reaches within the Main and Salmon Arms of Shuswap Lake by comparing them with the BC WQGs, trophic status indices and comparable historical data. In the Main Arm Reach and Sorrento Reach (in the Main Arm), the results show good water quality capable of promoting a healthy aquatic ecosystem. These reaches were classified as oligotrophic due to the low concentrations of nutrients and the good oxygen levels throughout the water column. The conditions in Sicamous Reach (in Salmon Arm) were more variable and appeared to be trending toward poorer water quality in recent years. This reach was classified as primarily oligotrophic, but with occasional periods of mesotrophic conditions due to the slightly higher concentrations of nutrients and primary productivity. The water quality in Salmon Arm Reach was fair, with even higher nutrient concentrations and productivity compared to the other three reaches. Although, conditions in Salmon Arm Reach do not appear to have changed much from earlier studies, and the reach remained classified as mesotrophic.

For most of Shuswap Lake, TP was below the BC WQG level of 10 µg/L for drinking water and recreation which supported the lake's designation as oligotrophic. However, TP concentrations in the Salmon Arm Reach had a mean concentration of 10.2 µg/L, which exceeded the source water for drinking and recreation guidelines of 10 µg/L from 2000 to 2002 and again from 2012 to 2014. The higher concentrations of TP in the Salmon Arm Bay Reach during these years likely reflected contributions from the local tributaries, a primary source of phosphorus to the lake (Tri-Star 2014; Ludwig 2018), and contributions from the Salmon Arm Wastewater Treatment Plant were considered minor.

Chlorophyll *a* concentrations in surface samples have generally been low during the growing season throughout Shuswap Lake. As with TP, chlorophyll *a* in the Salmon Arm Reach was higher than in the rest of the lake with a mean growing season concentration of 3.4 µg/L. The chlorophyll *a* concentrations in the Salmon Arm Reach do not appear to be increasing. While still low, the Sicamous and Sorrento Reaches had chlorophyll *a* concentrations appear to be increasing in recent years.

More sampling of TN has occurred after 2000 and the concentrations appear to be higher in more recent years in the Salmon Arm, Sicamous, and Sorrento Reaches, whereas concentrations of TN in the Main Arm Reach seemed to be relatively consistent. Ammonia and nitrate + nitrite, which are key bio-available forms of nitrogen, have often been below laboratory detection limits in surface water samples, and the growing season mean concentrations have not exceeded BC WQGs.

Water transparency based on Secchi depth supported the other observations of the low primary productivity found in Shuswap Lake. A long-term trend for Secchi depth was not calculated. Salmon Arm Reach near the City of Salmon Arm showed reduced water transparency during the summer and had a mean growing season Secchi depth transparency of 3.7 m, which was half of what was measured in the other reaches.

Currently water quality in Shuswap Lake is considered good as it has low concentrations of nutrients and low biological productivity. Variability in the water quality of Shuswap Lake is strongly influenced by stream flow, precipitation, and groundwater infiltration as nutrients enter the lake through tributaries, flooding, and infiltration from nearby land use. Climate change may alter this balance, which could have long-term implications for water quality and the environmental conditions of Shuswap Lake. The PCIC climate models predict warmer weather on average in 30 years, resulting in more evaporation from lake. The annual precipitation is expected to increase, resulting in less snowfall and more rain in the winter and spring and more evaporation in the summer. This combination of greater evaporation from the lake and changes in precipitation patterns could affect water temperature, water quality and eventually biological processes in the lake. Therefore, water quality in Shuswap Lake should be maintained to prevent degradation from both anthropological and climate change influences.

Given that this report only went to 2014, water quality sampling done after 2014 has been graphed in Appendix B. These additional data have been analyzed for observational trends and compared to earlier findings to determine if the water quality in Shuswap Lake changed after 2014. Please see Appendix B for more information.

8 MONITORING RECOMMENDATIONS

Table 8-1 provides a recommended monitoring schedule based on previous monitoring. Periodic reviews and analysis of trends should be done to determine if water quality is changing and to make changes to the schedule if needed.

For nutrients, chlorophyll *a*, dissolved oxygen, and Secchi depth, it is recommended that sampling be carried out at least monthly from May through October (Table 29). Additional sampling outside of the lake stratification period, in months such as March, April, and November, is also recommended. Monitoring priorities should focus on the Salmon Arm Reach from May through October, rather than on the reaches that have been less affected by anthropogenic inputs.

In addition to the parameter's indicative of nutrient inputs to the lake, the sampling program should include measurements of physical characteristics such pH and turbidity (Table 29) to support data interpretation and provide a comprehensive record of water quality trends over time.

Spring and fall sampling in all four reaches is recommended for long-term trend monitoring within the lake. Secchi depth, along with temperature and dissolved oxygen profiles at all sites, provides valuable seasonal and year-to-year information about stratification, productivity, and the environmental conditions of the lake.

Periodic monitoring in the Seymour and Anstey Arms would be beneficial to confirm water quality remains good.

Table 29: Recommendations for Future Monitoring

Parameter	Frequency and timing	Site Locations	Depths
Phosphorus **TP, TDP, and ortho-P**	Monthly during growing season (May to October)	All four reaches	**Surface, mid-depth and deep samples**
Chlorophyll-*a*	Monthly during growing season (May to October)	All four reaches	**Photic zone (near surface zone of light penetration)**
Nitrogen **TN, ammonia, nitrate, nitrite**	Monthly during growing season (May to October)	All four reaches	**Surface, mid-depth and deep samples**
Dissolved oxygen[1] **(profile with temperature)**	Monthly during growing season (May to October)	Focus on Salmon Arm Reach	**1 m intervals at a mid-basin deep site**
Secchi depth	Monthly during growing season (May to October)	All four reaches	**Mid-basin deep sites**
Total and dissolved organic carbon	According to municipal water source requirements	Near any drinking water intakes that use chlorination for treatment (see Table 3-2)	**Depth near intakes**
Coliform bacteria	According to Health Canada or Interior Health Authority (IHA) requirements	At beaches and primary contact water use areas.	**IHA monitors appropriate locations and frequency**
Chloride	Seasonal	All four reaches, plus near shore samples in potential wastewater influenced zones.	**Surface, mid-depth and deep samples**

Additional routine parameters: **pH, specific conductivity, water temperature, turbidity, TSS, true colour, hardness, sulphate, and alkalinity**	**Monthly during growing season (May to October)**	**All four reaches**	**Surface and deep samples**

Note:

[1] Dissolved oxygen and temperature should be measured at 1 m intervals to the bottom using field instruments at each site at the time of sampling to create a profile.

Table 30: Recommended benchmarks for growing season mean concentrations in Shuswap Lake.

Parameter	Salmon Arm Bay and Tappen Bay	Other Lake Locations
Total Phosphorus (µg/L) growing season mean (max) in surface water	10 (15)	5 (10)
Chlorophyll a (µg/L) growing season mean (max) in surface water	4 (7)	2 (4)
Total Nitrogen (mg/L) growing season max in surface water	0.15	0.08

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APPENDIX A - SUMMARY OF PREVIOUS REPORTS

	2011, 2012, 2013 SLIPP Water Quality Reports Shuswap, Little Shuswap and Mara Lakes	**SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Libr ary/TR_SLIPP/SLIPP_NHC_Water_Quality_Report_detailed_2013.pdf**	**Annual reports on the results of SLIPP's annual water quality monitoring program for Shuswap, Little Shuswap and Mara Lakes.**	**Northwest Hydraulic Consultants**	**July 2013 February 2014 March 2014**
	Summary: 2011 - 2013 Water Quality Monitoring Results	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_Water_Quality_Summary_2011_2013.pdf	Summary of the key findings of the 2011-2013 SLIPP water quality monitoring program.	SLIPP	**2014**
General water quality studies	Shuswap Lake Integrated Planning Process Final Report	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_Final_Report_web.pdf	Summary of the work and accomplishments of SLIPP from April 2011 - March 2014.	SLIPP	**2014**
	Water Clarity Trends in Shuswap, Mara and Gardom Lakes: A Comparison of Secchi Disk Readings between 1986 and 2009 /2010	B.C. ENV website: http://www.env.gov.bc.ca/wat/wq/trendsWQS/secchi-depth-report.pdf	An evaluation of water clarity between 1986 and 2009 /2010 (based on Secchi disk readings) in Shuswap, Mara, and Gardom Lakes.	ENV	**May 2014**
	SLIPP Water Quality Report: Sources of Nutrients 2014	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_TriStarEnv_Sources_of_Nutrients_Report.pd f	Estimate of nutrient loading from various sources and their effects on the water quality of Shuswap and Mara Lakes.	Tri-Star Environmental Consultants Ltd.	**March 2014**
Nutrients	**Agricultural Nutrient Management in the Shuswap Watershed for Maintaining and Improving Water Quality: Literature Review and Nutrient Management Strategies**	**Fraser Basin website: http://www.fraserbasin.bc.ca/_Libr ary/TR/swc_report_nutrient_management_August_2014_web.pdf**	**Summary of the current water quality and the impact of agriculture in the Shuswap watershed and the state of knowledge of phosphorus-based nutrient management.**	**Ruth McDougal l**	**August 2014**

Category	Report Title	Location	Report Purpose	Author	Date
	Recreation Management Plan Report - Situational Analysis	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_RMP_Situation_Analysis_Report_Jul2012.pdf	Summary of the current recreational trends and patterns, the physical assets that support recreation on the lake, and current policies in recreation management in other jurisdictions.	Peak Planning Associates	**July 2012**
	Recreation Management Plan - Best Practices - Lake Based Recreation Management	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_RMP_Best_Practices_Lake_Based_Recreation_Management_Report_Sept2013.pdf	Supplemental report to the Situational Analysis Report including a summary of lake-based recreation management plans in other jurisdictions to help inform the process for Shuswap/Mara Lakes.	Peak Planning Associates	**September 2012**
Recreation	Recreation Management Plan Intercept Survey Results Final Report	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_RMP_Intercept_Survey_Report_Apr2013.pdf	Information from recreational users about their knowledge of recreational management and their attitudes and values concerning recreation use.	Peak Planning Associates	**April 2013**
	Draft Recreation Management Plan: Shuswap, Little Shuswap, Mara and Adams Lakes	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_Recreation_Management_Plan_Final_Draft_Mar2014.pdf	Addresses management of lake-based recreation in the Shuswap region, considering both the physical and social wellbeing of residents and visitors and the overall social, economic, and environmental health of the region.	Peak Planning Associates	**March 2014**
	Evaluation of Risk from Houseboat Greywater discharges to Recreational Water Users on Shuswap Lake Beaches	**http://www.csrd.bc.ca/sites/default/files/liquid-waste-management/Septic-Smart/ResourceLibrary/Evaluation-of-risk-from-Houseboat-greywater.pdf**	**Identifies whether water quality guidelines are exceeded near BC Parks Beaches at which houseboats overnight frequently, and whether these exceedances are likely due to boat greywater discharges adjacent to the**	**ENV**	**December 2009**

Category	Report Title	Location	Report Purpose	Author	Date
			beaches.		
	Review of Greywater Management Strategies to Improve Public Health and Water Quality in Shuswap Lake	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_NHC_Greywater_Report_July2010.pdf	Assesses potential impacts to Shuswap and Mara Lakes that may result from discharged greywater, compares the magnitude of potential impacts with those from other discharges, and recommends discharge standards that would be appropriate for the Shuswap System.	Northwest Hydraulic Consultants	**July 2010**
	Shoreline Management Guidelines for Fish and Fish Habitat: Shuswap, Mara and Little Shuswap Lakes	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_Shoreline_Mgmt_Guidelines_Shuswap_Mara_Lakes.pdf	Provides risk-based management guidelines for fish habitat on shorelines of Shuswap, Mara and Little Shuswap Lakes.	Ecoscape Environmental Consultants Ltd.	**June 2009**
Aquatic life	Nearshore Habitat Utilization by Spawning Lake Char and Rearing Rainbow Trout in Shuswap, Little Shuswap and Mara Lakes	SLIPP Resource Archive: http://www.fraserbasin.bc.ca/_Library/TR_SLIPP/SLIPP_Trout_Char_Habitat_Report_Rosenau_2014. pdf	Examines nearshore habitats of spawning lake char (also commonly known as lake trout) and rainbow trout in Shuswap, Little Shuswap and Mara Lakes	British Columbia Institute of Technology Fish Wildlife and Recreation Program & Rivers Institute BCIT (M.L. Rosenau)	**2014**
	Final Working Draft: Shuswap Watershed Mapping Project Shuswap Lake, Mara Lake, Little Shuswap Lake and Little River	CSRD Report Archive: http://www.csrd.bc.ca/node/870	Inventories and analyses to help protect important shoreline resources around Shuswap Lake.	Ecoscape Environmental Consultants	**June 2009**

Category	Report Title	Location	Report Purpose	Author	Date
	Results from a 7-year limnological study of Shuswap Lake: Part 1- physics, chemistry, bacteria, phytoplankton	http://publications.gc.ca/collections/collection_2013/mpo-dfo/Fs97-13-993-eng.pdf	Describe fisheries and limnology of the lake. Part II report is on Zooplankton.	Fisheries & Oceans Canada (Nidle & Shortreed)	**1996**
	CSRD Liquid Waste Management Plan (LWMP) Area C Stage 3 Report	CSRD Report Archive: http://www.csrd.bc.ca/node/918	Three-stage exercise to investigate sewage-related problems, identify possible solutions with associated costs and selected preferred options for the various areas based on input received from the public and technical advisory committees.	Earth Tech / AECOM	**January 2009**
	CSRD LWMP Final Stage 3 Report [North Shuswap)	CSRD Report Archive: http://www.csrd.bc.ca/node/920		Focus Corporation	**July 2009**
	Final Report for the CSRD: LWMP Electoral Area E Stage 3 Report	CSRD Report Archive: http://www.csrd.bc.ca/node/919		Urban Systems	**September 2009**
Liquid Waste Management	Final Report for the CSRD: LWMP Seymour Arm Stage 3 Report	CSRD Report Archive: http://www.csrd.bc.ca/node/922		Urban Systems	**March 2003**

	CSRD Groundwater Monitoring Programs	**CSRD Report Archive:** http://www.csrd.bc.ca/services/liquid-waste-management	Assess the potential impacts of private sewage disposal systems on groundwater quality in ten communities in the Columbia Shuswap Regional District (Blind Bay/Sorrento, Falkland, Nicholson, Sunnybrae, White Lake, Seymour Arm, Celista/Magna Bay, Swansea Point, and Malakwa)	**Summit Environmental Consultants Inc., Western Water Associates Ltd.**	**Reports issued annually for each community from 2009 - 2014**

APPENDIX B: ADDENDUM - SHUSWAP LAKE WATER QUALITY DATA REVIEW 2015 TO 2019

EXECUTIVE SUMMARY

Shuswap Lake is an important water body, located within the traditional territory of Pespeselikwe te Secwépemc and Neskonlith Indian Band, that provides cultural, recreational, environmental, and economic values to the Shuswap region in the Southern Interior of British Columbia. This Addendum evaluates the results of water sampling conducted from 2015 to 2019 in Shuswap Lake and provides a comparison to previous findings in the Assessment Report, as well as to British Columbia Water Quality Guidelines (BC WQG), to identify changes that may have occurred to the Shuswap Lake conditions.

No changes in the overall water quality were found in the Sorrento, Main Arm and Sicamous Reaches; however, changes in Salmon Arm Reach indicate worsening conditions, especially during flood events. The water quality remains good in Shuswap Lake except for the Salmon Arm Reach, where conditions declined slightly between 2015 and 2019.

10 INTRODUCTION

As part of the strategy to protect water quality in Shuswap Lake, and to support the development of Water Quality Objectives (WQO), a Water Quality Assessment was done by the Ministry of Environment and Climate Change Strategy (ENV) for Shuswap Lake using data up to 2014. Additional sampling was undertaken from 2015 to 2019 for the following reasons: to determine if sites that had not been monitored for several years had changed, to confirm if assessed levels were still valid, and to continue collecting the data necessary to examine long-term trends in water quality. This Addendum summarizes the findings of the water quality sampling conducted from 2015 to 2019, primarily through the use figures and tables, and is intended to augment the Water Quality Assessment with current, relevant information.

Sampling protocols, frequency, and locations were the same as those used in the assessment (see Section 5.2 of the main report), with some modifications. The monthly sampling conducted during the growing season (May to October) occurred only during 2015 and 2019. During all years between 2015 and 2019, a spring and fall sampling program was completed. Monthly sampling was conducted in 2015 and 2019 because these years followed the dominant sockeye salmon spawning period, when the maximum nutrient loading was expected to occur the Shuswap Lake system.

Sampling locations included one mid-lake site in four reaches within the Main and Salmon Arms of Shuswap Lake, including: Salmon Arm and Sicamous Reaches (both in Salmon Arm), and Main Arm and Sorrento Reaches (both in Main Arm).

11 WATERSHED PROFILE

11.1 Hydrology

Shuswap Lake water levels are monitored at a Water Survey of Canada (WSC) station at Salmon Arm (08LE070; Figure 21). In typical years, the highest lake water levels occur in June and July, following spring freshet, while the lowest lake water levels occur in March and April before freshet occurs. The summer maximum water levels and the lower fall dry period levels in 2015 were well below average; however, the spring levels in 2015 were well above average due to a cool, wet spring. In 2016, the lake level was near average during the spring and summer but had high water levels in November with a peak of 346.6 metres (m) due to heavy fall rains. Water levels in both 2017 and 2018 had typical spring and fall lake levels but showed very high summer water levels that were above the critical lake elevation of 349.0 m for flood control. In 2019 spring water levels in the lake were lower than normal but above average fall levels followed a cool, wet fall.

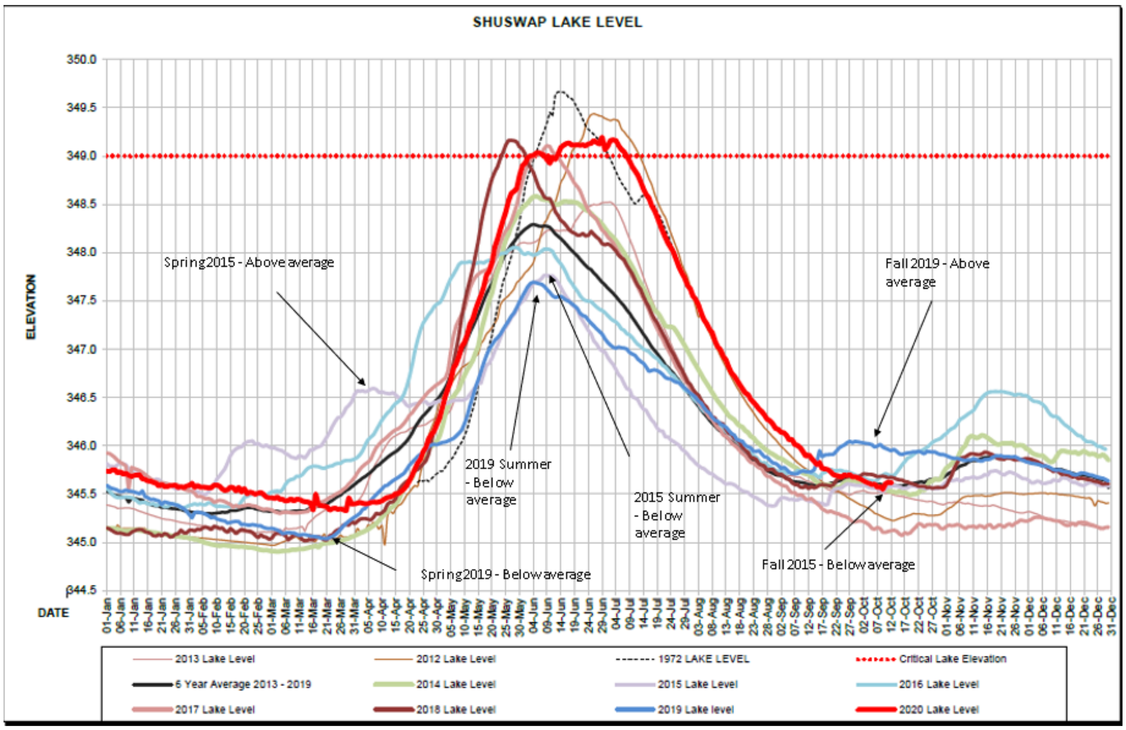


Figure 20: Shuswap Lake Water Levels 2012 to 2020 (graph by the City of Salmon Arm).

12 WATER QUALITY ASSESSMENT

12.1 Approach to Assessing Water Quality Data

Each variable was assessed for the four priority reaches of Shuswap Lake by comparing them to the British Columbia Water Quality Guidelines (BC WQGs), where applicable, and to historical data from the main report. While water samples have been collected in each of the reaches since the early 1970's, this addendum focuses on data collected between 2015 and 2019 but considers data back to 2000 to provide historical context and to examine recent trends or changes in water quality.

Additional monitoring by the Ministry of Environment and Climate Change Strategy occurred at Shuswap Lake off Encounter Point (EMS E208722), Shuswap Lake off Broken Point (EMS E208721), and Shuswap Lake off Canoe Point (EMS E208718) between 2015 and 2019 (Figure 21). The results from that sampling are discussed briefly in each section to provide a broader perspective on the water quality of Shuswap Lake.

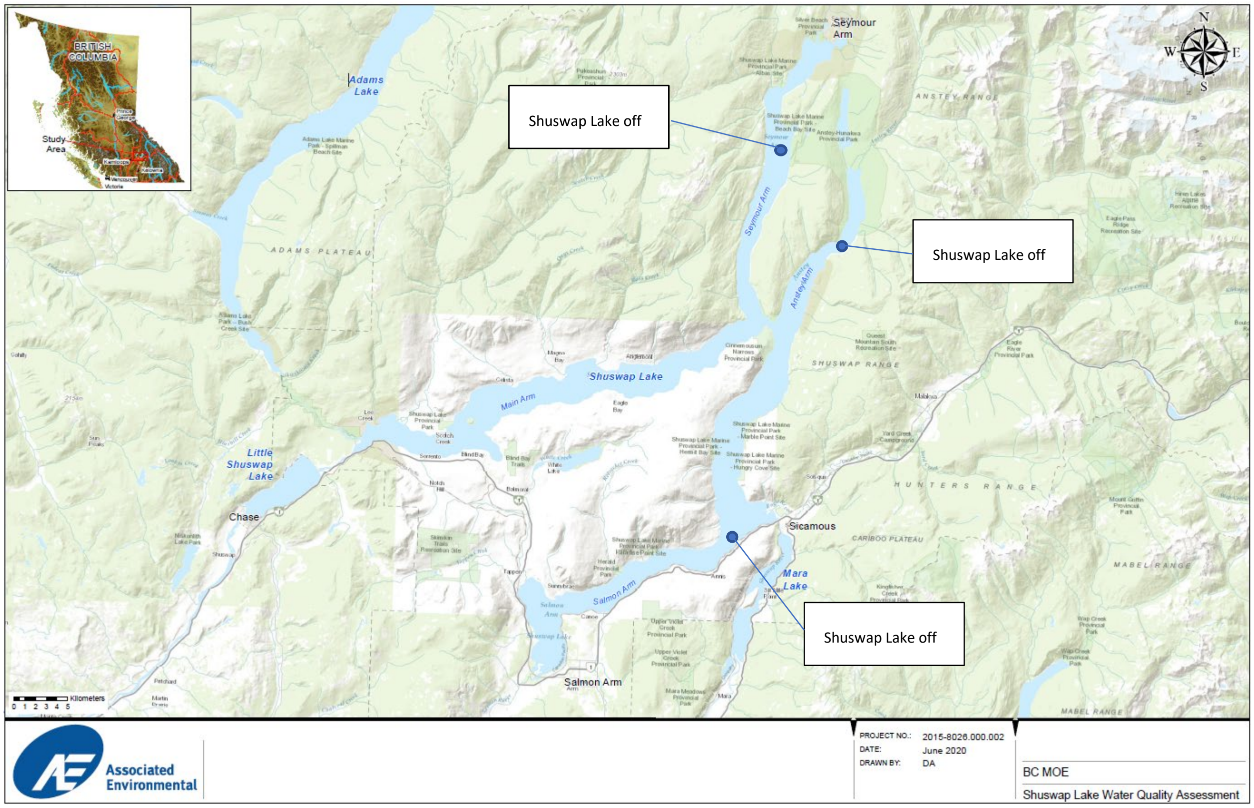


Figure 21: Map showing Broken Point, Encounter Point, and Canoe Point monitoring sites.

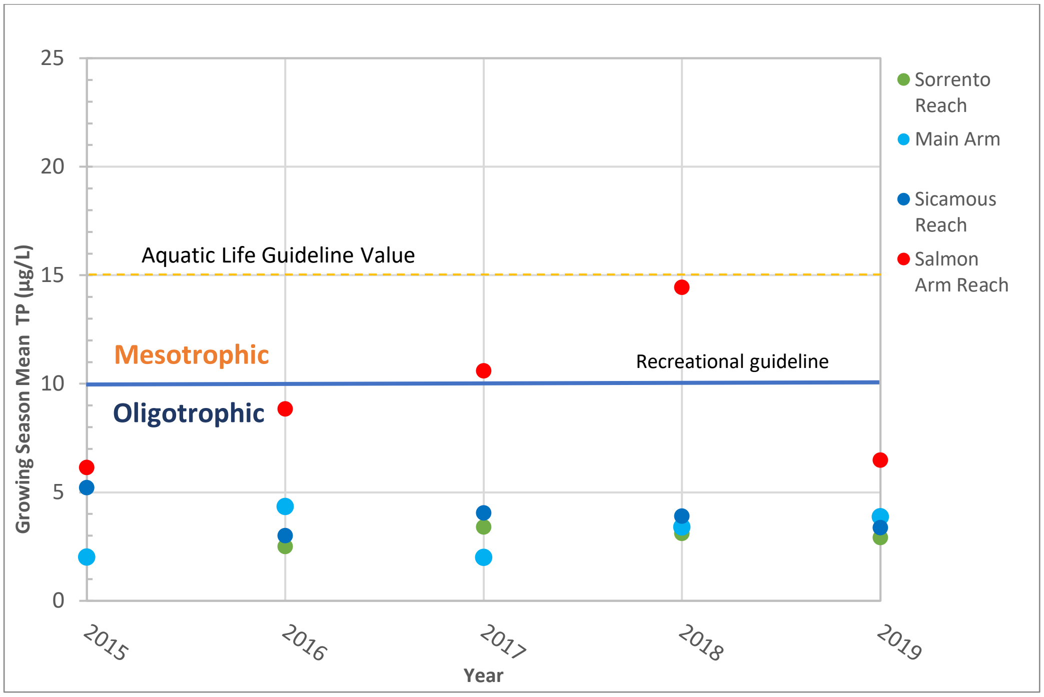
In addition, monthly sampling data collected by the City of Salmon Arm between 2015 and 2019 at Sandy Point in the Salmon Arm Reach have been included in this assessment of growing season means and are included in the tables and figures for chlorophyll a, total phosphorus, and total nitrogen.

12.2 Phosphorus

Growing season means for total phosphorous (TP) were calculated for 2015 and 2019 at all four locations (Table 30 and Figure 22). Using data from the City of Salmon Arm, growing season means for TP were also calculated in the years 2016 to 2018 for the Salmon Arm Reach only. For the other three reaches, average TP was determined for the years of 2016 to 2018 using the spring and fall data.

Table 31: Mean TP concentrations micrograms/litre (µg/L) for 2015 and 2019 in each of the four Shuswap Lake reaches during the growing season (May-October, inclusive).

Location	2015	2019
Main Arm	2.02	3.87
Sicamous Reach	5.22	3.38
Salmon Arm Reach	6.14	6.49
Sorrento Reach	2.00	2.91



Note: All values are growing season means (May-October, inclusive), except 2016-2018 data at Main Arm, Sicamous, and Sorrento Reaches, which are the average of spring and fall TP values.

Figure 22: Comparison of mean TP concentrations (µg/L) from 2015-2019 in each of the four Shuswap Lake reaches.

The growing season means in the Salmon Arm Reach for 2015, 2016, and 2019 are within the oligotrophic range; however, in 2017 and 2018 the means are in the mesotrophic range. The other three reaches have low TP concentrations well within the oligotrophic range.

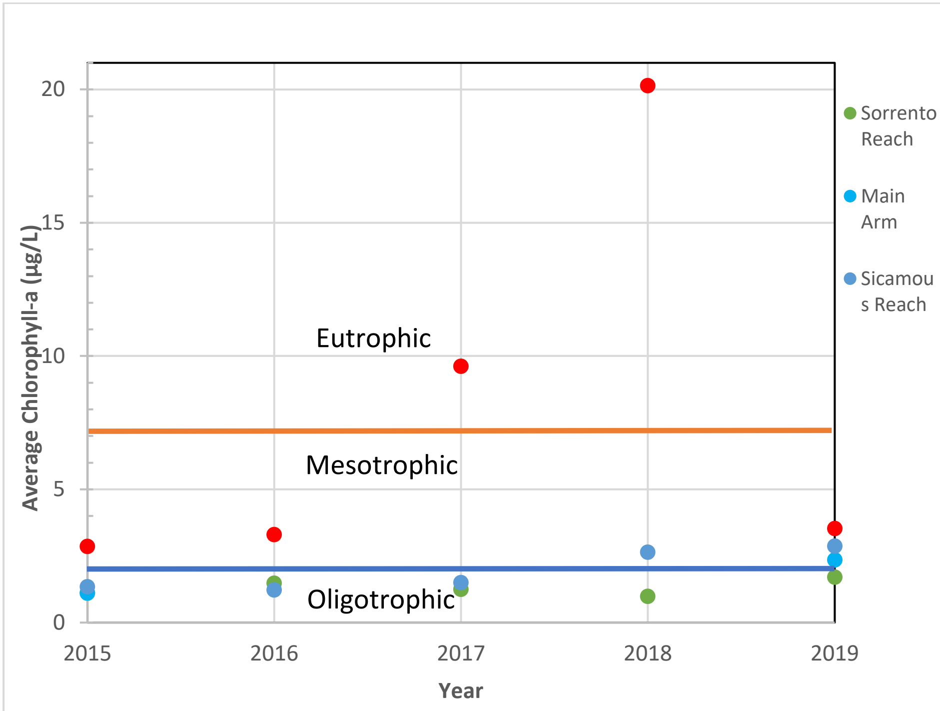
Other sampling locations not included in the main report (Encounter Point, Broken Point and Canoe Point), had TP values with similar levels to four key reaches. These three locations had TP concentrations that generally remained low and within the oligotrophic range.

12.3 Chlorophyll *A*

Trends in chlorophyll *a* provide insight into the potential for algal blooms in Shuswap Lake, particularly in the Salmon Arm Reach, where nutrient levels are often higher. Chlorophyll *a* concentrations in surface samples have generally been low during the growing season in Shuswap Lake, except for the Salmon Arm Reach (Table 31 and Figure 23).

Table 32: Mean chlorophyll a concentrations (µg/L) for 2015 and 2019 in each of the four Shuswap Lake reaches during the growing season (May-October, inclusive).

Location	2015	2019
Main Arm Reach	1.11	2.36
Sicamous Reach	1.35	2.87
Salmon Arm Reach	2.86	3.54
Sorrento Reach	1.12	1.71



Note: All values are growing season means (May-October, inclusive), except 2016-2018 data at Main Arm, Sicamous, and Sorrento Reaches, which are the average of spring and fall chlorophyll *a* values.

Figure 23: Comparison of mean chlorophyll a concentrations (µg/L) from 2015-2019 in each of the four Shuswap Lake reaches.

The Salmon Arm Reach chlorophyll *a* levels were mesotrophic in 2015, 2016, and 2019 which was consistent with values from 2005 to 2014. In 2017 and 2018, the growing season mean of chlorophyll *a* was in the eutrophic range likely because of the increased algae growth in that reach in 2017 and a bloom in 2018. The Sorrento Reach remained in the oligotrophic range with growing season mean chlorophyll *a* levels below 2 µg/L. The Sicamous and Main Arm Reaches had increasing levels of chlorophyll *a* between 2015 and 2019 and were in the mesotrophic range in 2019.

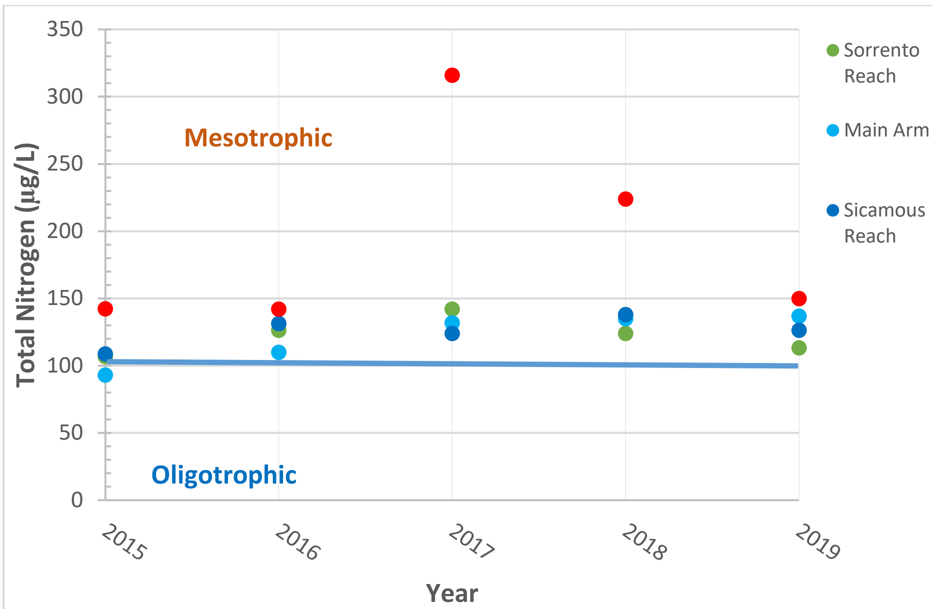
At the locations not included in the main report (Encounter Point, Broken Point and Canoe Point), chlorophyll *a* results were variable, with increases at each site between 2015 and 2019. Chlorophyll *a* at Encounter Point remained in the oligotrophic range while at Canoe Point and Broken Point, the values increased towards the mesotrophic range.

12.4 Nitrogen

In the main report, growing season mean concentrations for total nitrogen (TN) were typically above 100 µg/L for Sicamous, Sorrento and Salmon Arm Reaches. The Main Arm Reach that was generally oligotrophic as the growing season mean was below 100 µg/L. Between 2015 and 2019, all four reaches were in the mesotrophic range except in 2015 when the Main Arm Reach was 93 µg/L.

Table 33: Mean TN concentrations (mg/L) for 2015 and 2019 in each of the four Shuswap Lake reaches during the growing season (May-October, inclusive).

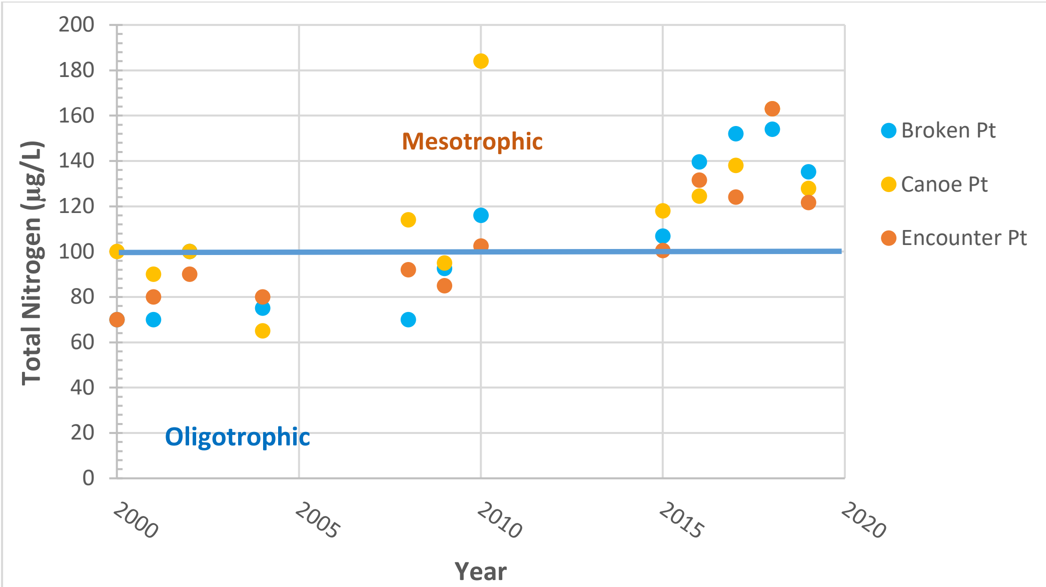
Location	*2015*	*2019*
Main Arm Reach	93.0	136.9
Sicamous Reach	108.8	126.5
Salmon Arm Reach	142.4	150.0
Sorrento Reach	106.8	113.4



Note: All values are growing season means (May-October, inclusive), except 2016-2018 data at Main Arm, Sicamous, and Sorrento Reaches, which are the average of spring and fall TN values.

Figure 24: Comparison of mean TN concentrations (µg/L) from 2015-2019 in each of the four Shuswap Lake reaches.

At the locations not included in the main report (Encounter Point, Broken Point and Canoe Point), TN showed an increasing trend (Figure 25), with all three sites shifting from oligotrophic to mesotrophic in recent years.



Note: All values are the average of spring and fall TN values.

Figure 25: Comparison of mean TN concentrations (µg/L) from 2000-2019 at other sites in Shuswap Lake.

12.4.1 TN:TP Ratios

Ratios of TN and TP are based on the growing season mean for each parameter. A higher total nitrogen to total phosphorus ratio indicates a lake that is phosphorus limited and helps predict the type of phytoplankton community. Nitrogen fixing blue-green algae are favoured in low TN conditions and therefore low TN:TP ratios. Co-limited lakes typically have TN:TP ratios between 5:1 and 15:1. For Shuswap Lake, the mean TN:TP ratios between 2000 and 2014 were between 18:1 and 29:1 (Table 33).

In 2015, the TN:TP ratio for the Main Arm and Sorrento Reaches increased but then decreased again in 2019. In Sicamous Reach, the TN:TP ratio decreased slightly in 2015 and increased in 2019. The Salmon Arm Reach remained low and stable between 2015 and 2019 but appear to still be phosphorus limited.

Table 34: TN:TP ratios for 2000-2014, 2015 and 2019 in each of the four Shuswap Lake reaches during the growing season (May-October, inclusive).

Location	2000-2014	2015	2019
Main Arm Reach	29:1	46:1	35:1
Sicamous Reach	28:1	21:1	37:1
Salmon Arm Reach	18:1	23:1	23:1
Sorrento Reach	29:1	53:1	39:1

At Encounter Point, Broken Point, and Canoe Point, TN:TP ratios for both 2015 and 2019 were above 30:1 Indicating these locations were phosphorous limited.

12.5 Dissolved Oxygen and water temperature

In the main report, low dissolved oxygen (DO) concentrations were identified at Sandy Point in the Salmon Arm Reach in 2013, but no evidence was found indicating hypolimnetic oxygen depletion or anoxic conditions. Figure 26 and Figure 27 show the DO profiles in 2015 and 2019 respectively off Sandy Point in the Salmon Arm Reach. The other three reaches had generally high levels of DO and the location near Marble Point in the Sicamous Reach, shown below in Figure 28 and Figure 29, characterizes the Main Arm and Sorrento Reaches so the graphs have not been included.

For the Salmon Arm Reach, both in 2015 and 2019, DO concentrations from surface to bottom were better than those observed in 2013 as DO remained above 6 milligrams per litre (mg/L) at the bottom.

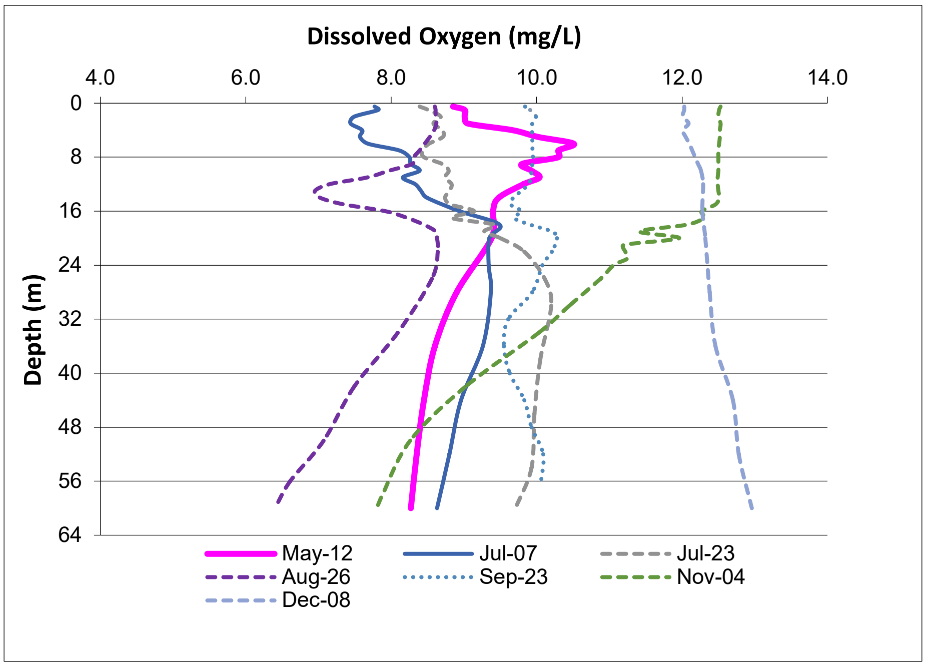


Figure 26: Dissolved oxygen by depth in the Salmon Arm Reach off Sandy Point in 2015.

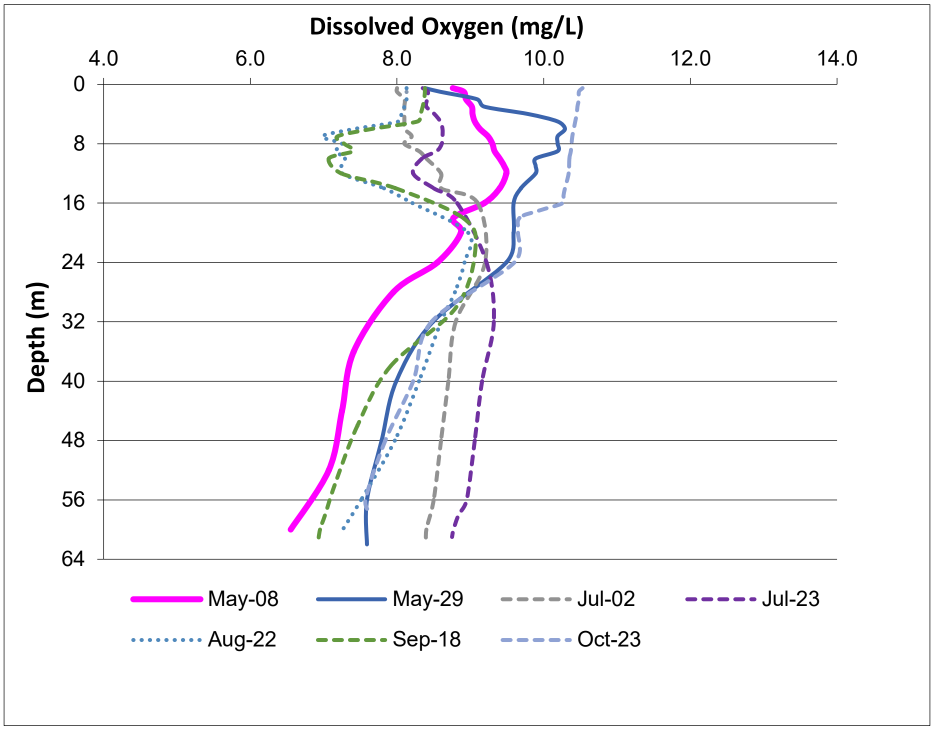


Figure 27: Dissolved oxygen by depth in the Salmon Arm Reach off Sandy Point in 2019.

In the Sicamous Reach, DO concentrations in 2015 and 2019 were high all the way to the bottom and consistent with measurements collected in 2013. The only exception was in July 2015, when DO dropped below 8 mg/L.

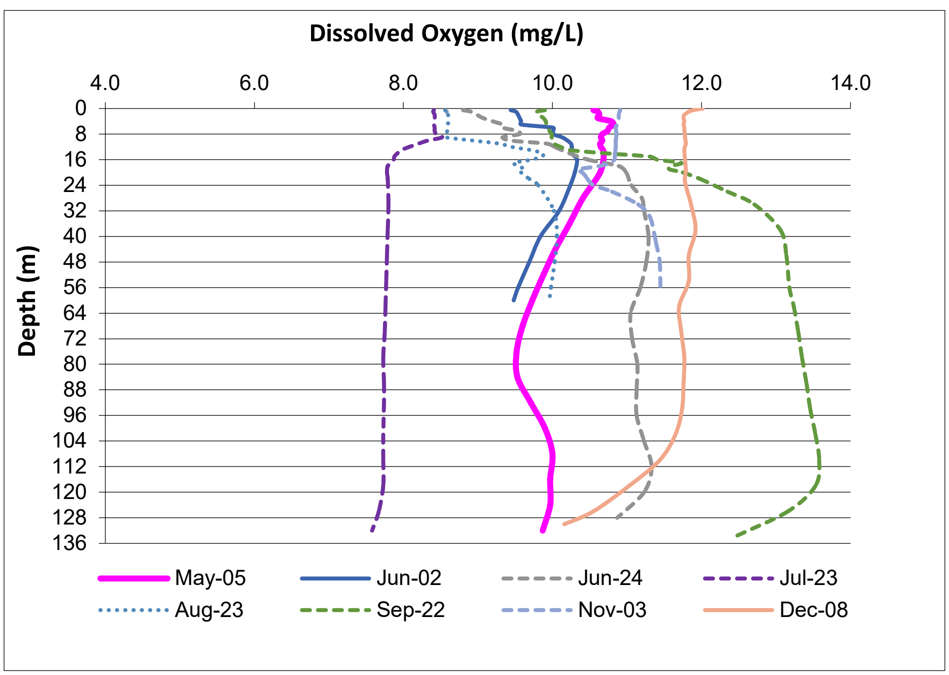


Figure 28: Dissolved oxygen by depth in the Sicamous Reach off Marble Point in 2015.

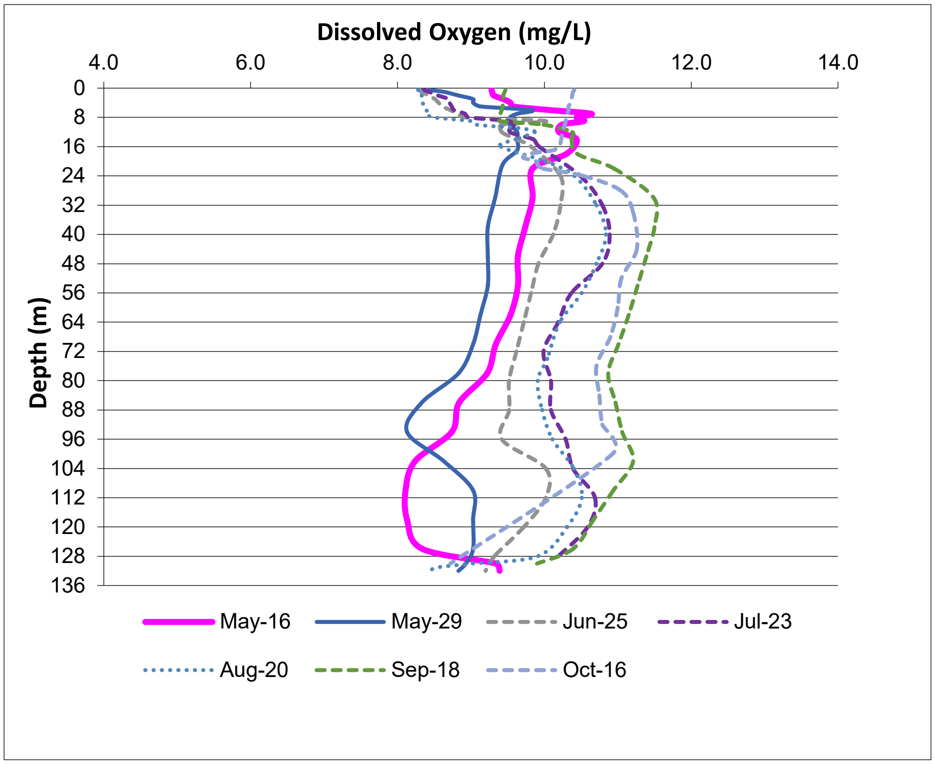


Figure 29: Dissolved oxygen by depth in the Sicamous Reach off Marble Point in 2019.

The 2015 and 2019 temperature profiles for the Salmon Arm Reach showed no change in seasonal trends from the profiles in 2013 and the thermocline was at a similar depth as previous years (Figure 30 and Figure 31).

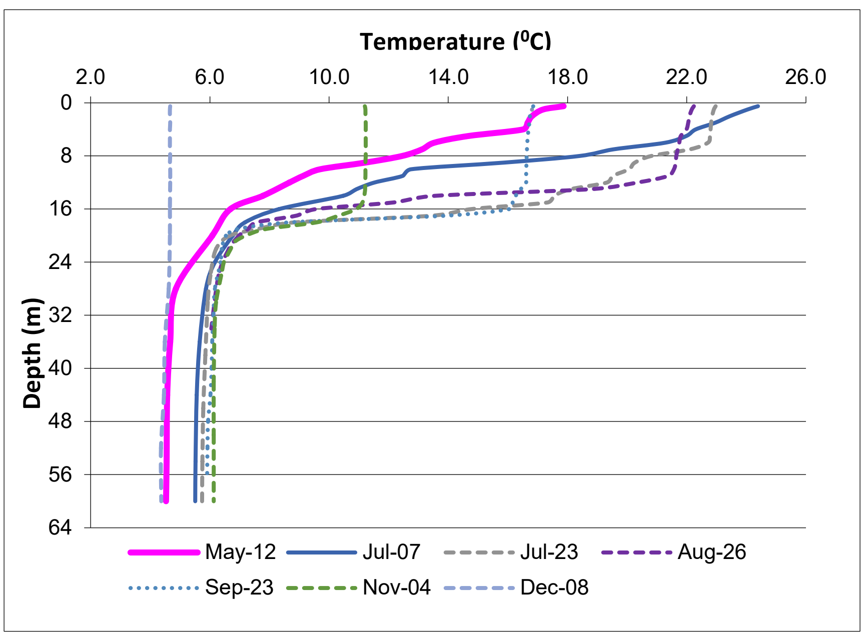


Figure 30: Water temperature by depth in the Salmon Arm Reach off Sandy Point in 2015.

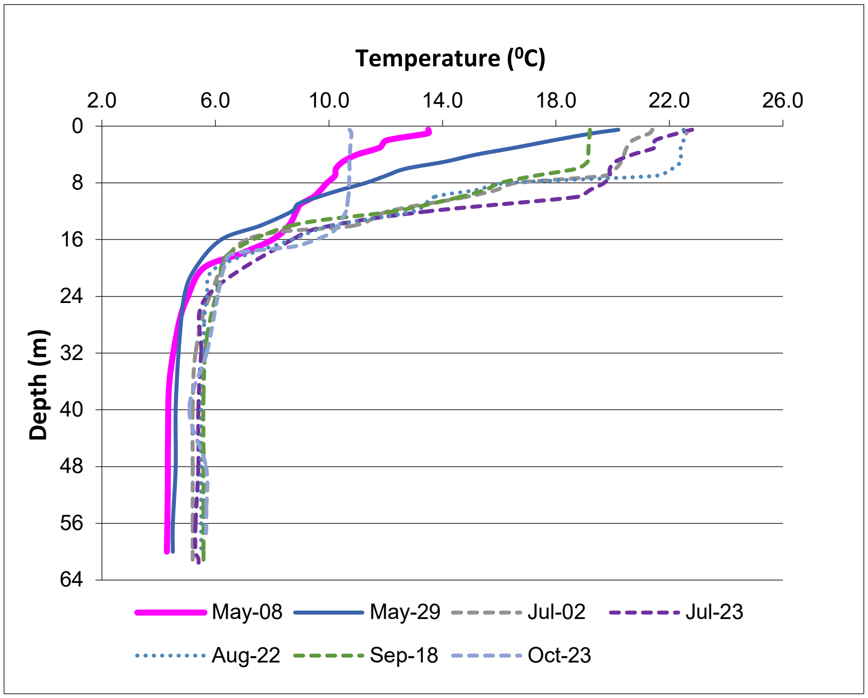


Figure 31: Water temperature by depth in the Salmon Arm Reach off Sandy Point in 2019.

The temperature profiles for 2015 and 2019 in the Sicamous Reach were like the profiles for Salmon Arm Reach and consistent with measurements in 2013.

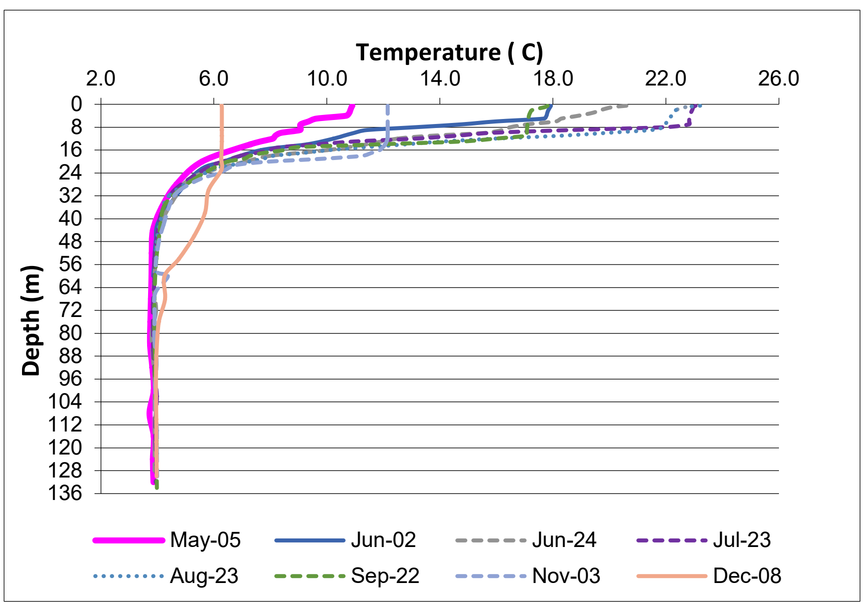


Figure 32: Water temperature by depth in the Sicamous Reach off Marble Point in 2015.

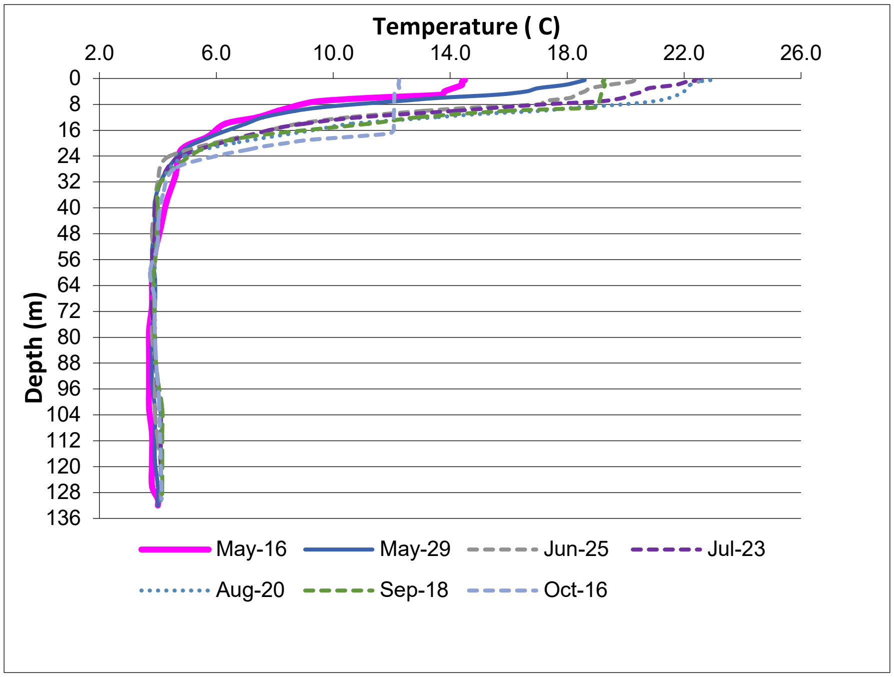


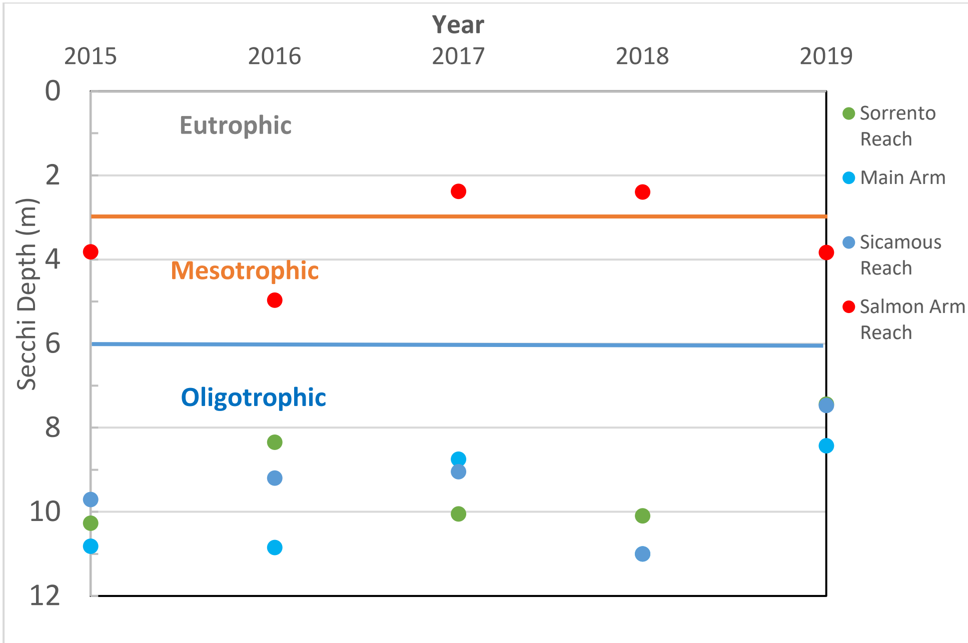
Figure 33: Water temperature by depth in the Sicamous Reach off Marble Point in 2019.

12.6 Water Transparency (Secchi Depth)

Shuswap Lake has low primary productivity shown by the growing season Secchi depth observations greater than 6 metres. Salmon Arm is most productive reach in Shuswap Lake, especially near the City of Salmon Arm. The mean growing season depths in the Salmon Arm Reach of 3.8 m in 2015 and 2019 suggest mesotrophic to slightly eutrophic conditions. The Secchi depth data for the other three reaches in (Table 34 and Figure 34) confirm no discernible long-term increasing or decreasing trend.

Table 35: Mean Secchi Depth (m) for 2015 and 2019 in each of the four Shuswap Lake reaches during the growing season (May-October, inclusive).

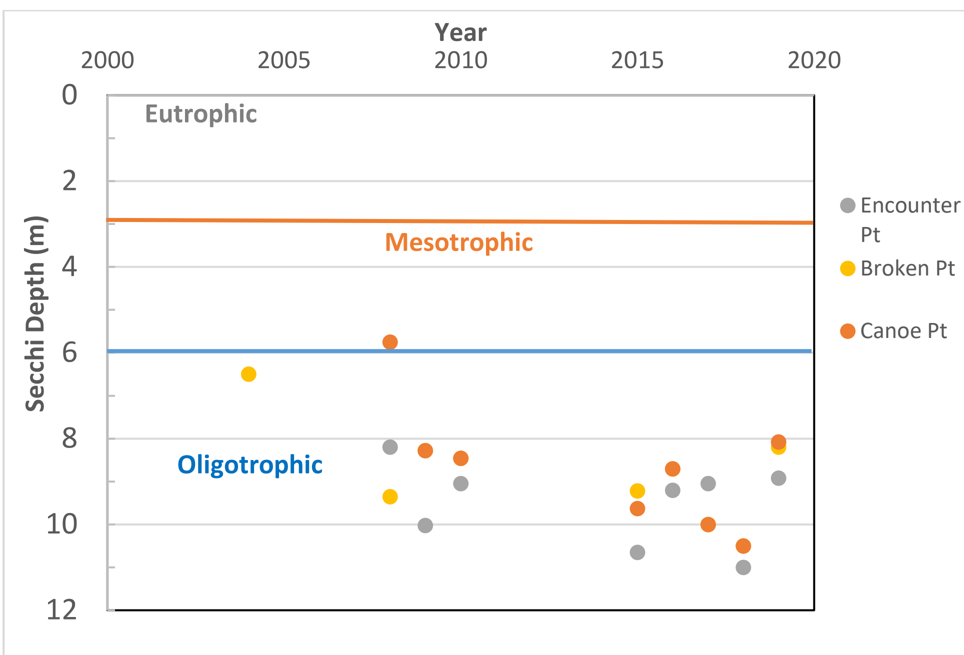
Location	2015	2019
Main Arm Reach	10.4	8.4
Sicamous Reach	9.7	7.5
Salmon Arm Reach	3.8	3.8
Sorrento Reach	10.3	7.5



Note: All values are growing season means (May-October, inclusive), except 2016-2018 data at Main Arm, Sicamous, and Sorrento Reaches, which are the average of spring and fall depth values.

Figure 34: Comparison of mean Secchi depth (m) from 2015-2019 in each of the four Shuswap Lake reaches.

Mean Secchi depths at Encounter Point, Broken Point, and Canoe Point remain in the oligotrophic range and have not decreased in the last five years (Figure 35).

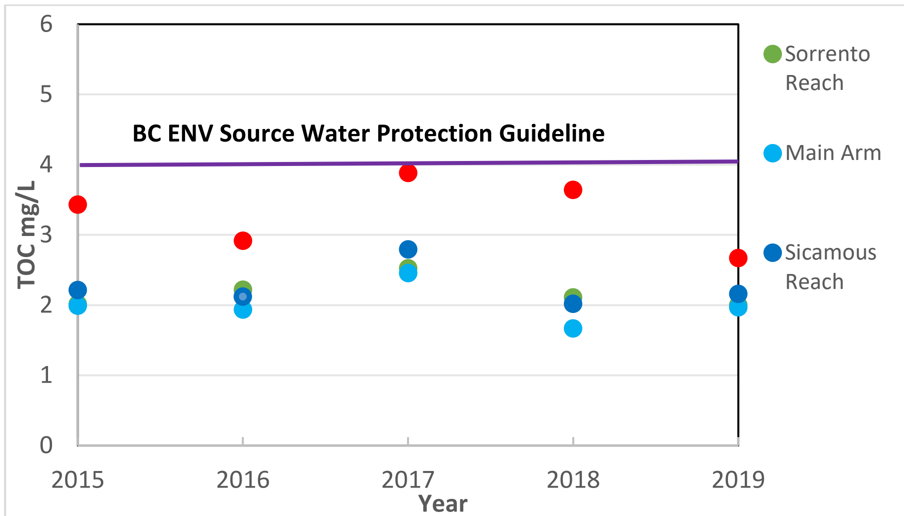


Note: All values are the average of spring and fall depth values.

Figure 35: Comparison of mean Secchi Depth (m) from 2000-2019 at Non-Assessment Sites in Shuswap Lake.

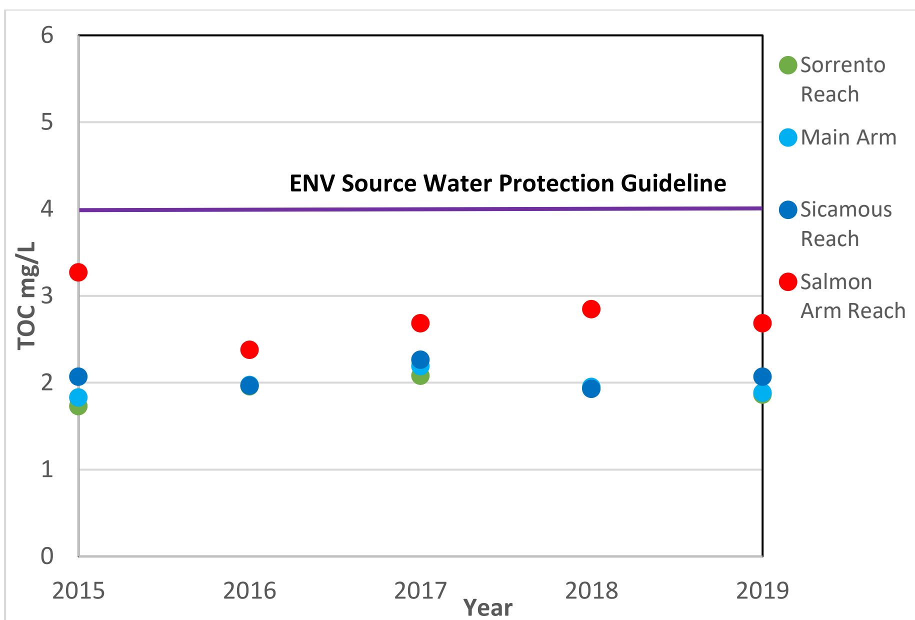
12.7 Total organic carbon

The average annual concentration of total organic carbon (TOC) at the surface (Figure 36) and in deep-water (Figure 37) were below the BC ENV Source Water Protection Guideline for years between 2015 and 2019.



Note: All values are the average of spring and fall TOC values.

Figure 36: Comparison of epilimnetic (surface) total organic carbon (mg/L) from 2000-2019 in each of the four Shuswap Lake reaches.



Note: All values are the average of spring and fall TOC values

Figure 37: Comparison of hypolimnetic (deep water) total organic carbon (mg/L) from 2015-2019 in each of the four Shuswap Lake Reaches.

13 Summary

In the main report, Shuswap Lake was described as primarily oligotrophic based on its water quality, which means it has low biological productivity and low nutrient concentrations which results in clear water. The Salmon Arm Reach, close to the Salmon River, had water quality results that were best described as mesotrophic.

Between 2015 and 2019 water levels in Shuswap Lake were well below the average, such as in 2015, whereas at other times, they were much higher than average, such as in 2017 and 2018. Water levels reflect the critical role hydrology plays in driving nutrient loading and nutrient availability in the surface waters of the lake. For example, inflows from the Shuswap, Eagle and Salmon Rivers have a lot of influence on water quality conditions in the Sicamous and Salmon Arm Reaches.

The Main Arm and Sorrento Reaches had water quality that generally fell within the oligotrophic range. The Sicamous Reach was more variable and showed increasing trends in chlorophyll-a in recent years but remained in the oligotrophic range for water quality. The water quality in Salmon Arm Reach remains consistent for the most part with higher nutrient inputs contributing to higher productivity. Nutrient loadings during flood events appeared to be an important factor in influencing lake conditions in the Salmon Arm Reach. Through the sampling period, the Salmon Arm Reach remained in the mesotrophic range; however, TP, TN, and possibly chlorophyll *a* have been increasing.