ENVIRONMENTAL QUALITY SERIES

Lake Kathlyn Water Quality

Assessment Report (1985 to 2015)

March 2021

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Acknowledgements

This report builds on a considerable volume of work that has been done on Lake Kathlyn over the years by volunteers of the Lake Kathlyn Protection Society and staff of the British Columbia Ministry of Environment and Climate Change Strategy. As such, it was not intended to be a critical review of this work; rather, the goal was to use what others have done to assess water quality against the existing objectives for Lake Kathlyn water quality and current guidelines to help with long-term lake management. Jeremy Roscoe summarized historical data in a draft report, Norm Zirnhelt expanded on the draft report, and Lisa Torunski added recent water quality data to complete the final report.

EXECUTIVE SUMMARY

This document presents a summary of the ambient water quality of Lake Kathlyn, British Columbia (B.C.) from 1985 to 2015 and compares these data to the B.C. water quality guidelines (WQG) and the 1985 water quality objectives (WQOs) designed to protect existing and future water uses. The lake water quality assessment and an evaluation of the watershed form the basis for this report.

The Lake Kathlyn watershed, with an area of 39.52 km^2, is located approximately five kilometres northwest of the town of Smithers in north-central B.C., within Wet'suwet'en territory. The water uses to be protected in Lake Kathlyn include private domestic use, recreation, irrigation, aquatic life, and wildlife.

WQOs for Lake Kathlyn were originally established in 1985 as part of an assessment of lakes in the Smithers area (Tyhee, Kathlyn, Seymour, and Round lakes). Objective levels derived from B.C.'s ambient water quality guidelines were established for eight parameters (water temperature, dissolved oxygen, turbidity, true colour, total organic carbon, total phosphorus, *E. coli* and chlorophyll *a*) related to potential sources of contamination. Objective level attainment reports for the Smithers lakes were completed in 1996 and 2004.

The following conclusions were drawn from the water quality data assessment.

Summer surface water temperatures exceeded the aquatic life guideline of 16°C for Coastal Cutthroat Trout, the most temperature-sensitive species in Lake Kathlyn. For this reason, water temperatures should not exceed 16°C at any depth below three metres. At times, summer temperatures between water depths of three and six metres exceed 16°C and are therefore a concern.

Summer dissolved oxygen profiles show that only the upper four to five metres of the water column are well oxygenated and dissolved oxygen level declines rapidly below six metres, reaching anoxia (<0.5 mg/L) in the bottom waters. To protect aquatic life, dissolved oxygen concentrations in the upper six metres of the water column should remain above 5 mg/L at all times of the year.

Elevated concentrations of total organic carbon near guideline limits suggest that to protect the health of domestic water users, the maximum TOC concentration in all grab samples should be less than 4 mg/L.

Managing for increased lake productivity as it relates to drinking water concerns and recreational water uses should include assessing total phosphorus, *Escherichia coli* (*E. coli*) bacteria and chlorophyll *a* to B.C water quality guidelines or existing water quality objectives. Phosphorus concentrations in the lake may be declining compared to historic concentrations; however, to continue to manage for algal growth the current objective of ≤ 15 µg/L should be applied to management and restoration efforts in Lake Kathlyn. Combining phosphorus and summer chlorophyll *a* monitoring should help to identify changes to the relatively high productivity of the lake. Finally, *E. coli* sampling near drinking water intakes and established bathing beaches will support the protection of recreational lake users.

Except for dissolved copper, metal concentrations are currently not a concern at Lake Kathlyn. All dissolved copper concentrations exceed the 2019 B.C. Bio Ligand Model (B.C. BLM) long-term water quality guideline for copper. The average 2010 spring concentrations were two times higher than the guideline value. The long-term guideline for dissolved copper is meant to be applied to a mean calculated from five samples collected in 30-days; however, the current data set includes only single monthly samples; therefore, the assessment of potential impact of copper is inconclusive and requires more frequent monitoring during spring overturn.

The report concludes with recommendations for future monitoring.

CONTENTS

EXECUTIVE SUMMARY IV
1. INTRODUCTION 1
2. WATERSHED PROFILE AND HYDROLOGY 1
   2.1 General Landscape and Features 1
   2.2 Hydrology and Precipitation 1
3. WATER USES 2
   3.1 Water Licenses 2
   3.2 Fisheries 2
   3.3 Recreation 2
   3.4 Wildlife 3
   3.5 Designated Water Uses 3
4. INFLUENCES ON WATER QUALITY 3
   4.1 Land Ownership 3
   4.2 Basin Profile 4
   4.3 Licensed Water Withdrawals 7
   4.4 Forest Harvesting and Forest Roads 7
   4.5 Wildlife 7
   4.6 Recreation 7
   4.7 Mining 7
   4.8 Aquatic Plant Harvesting 8
5. STUDY DETAILS 9
6. WATER QUALITY ASSESSMENT 10
   6.1 Limnological Characteristics 11
      6.1.1 Temperature Stratification 11
      6.1.2 Dissolved Oxygen 13
      6.1.3 Water Clarity 14
   6.2 Water Chemistry 14
      6.2.1 pH 14
      6.2.2 Turbidity 15
      6.2.3 Colour and Total Organic Carbon 16
      6.2.4 Specific Conductance 17
      6.2.5 Nutrients (Nitrate, Nitrite, and Phosphorus) 18
      6.2.6 Metals 20
   6.3 Biological Analysis 22
      6.3.1 Coliform Bacteria 22
      6.3.2 Phytoplankton and Chlorophyll *a* 24
   6.4 Sediment Chemistry 25
7. CONCLUSIONS 25
8. MONITORING RECOMMENDATIONS 26
REFERENCES 28
APPENDIX A: SUMMARY OF WATER QUALITY DATA 30

FIGURES

Figure 1: Lake Kathlyn and Surrounding Area. 5
Figure 2 Lake Kathlyn Bathymetric Map (FIDQ, 2015)..6
Figure 3 Sample sites on Lake Kathlyn. Image source: Google Earth. 9
Figure 4 Lake Kathlyn deep station temperature profiles 12
Figure 5. Dissolved oxygen profiles for Lake Kathlyn – April and August 2016 and 2017........................13
Figure 6. Average annual Secchi depth readings for Lake Kathlyn from 2002 to 2017. 14
Figure 7. Lake Kathlyn surface and bottom-water turbidity (NTU) values from 1985 to 2014..................16
Figure 8. Lake Kathlyn total phosphorus at spring overturn from 1985 to 2010. 20
Figure 9. Lake Kathlyn 2018 dominant phytoplankton species. 24

TABLES

Table 1: Summary of water licensing for the Lake Kathlyn waterbody..2
Table 2: Summary of Morphometric Data (Boyd et al., 1985)..4
Table 3: 1985 water quality objectives for Lake Kathlyn 11
Table 4: Lake Kathlyn Turbidity Data, 1985 to 2014..15
Table 5: Summary of colour concentrations at Lake Kathlyn, 1985 to 2014...17
Table 6: Summary of field measured specific conductance (µS/cm) data for 2014 at Lake Kathlyn. 18
Table 7: Summary of Lake Kathlyn spring overturn phosphorus concentrations.....................................19
Table 8: Summary of deep station dissolved copper concentrations (µg/L), 1992-2010. 22
Table 9: Summary of fecal coliform sampling at Lake Kathlyn from 1988 to 2007. 23
Table 10: Summary of E. coli sampling at Lake Kathlyn between 2001 and 2014....................................23
Table 11: Proposed schedule for future water quality monitoring of Lake Kathlyn. 26

Table A 1: Water chemistry summary, Lake Kathlyn's deep station (EMS 1131007), 1985 to 2010. 30
Table A 2: Water chemistry summary from sites Kathlyn Lk #1 through #4). 33
Table A 3: Kathlyn Lk deep station phytoplankton resulting (August 30, 2018)..33

1. INTRODUCTION

Objective levels for the water quality of Smithers area lakes (Tyhee, Kathlyn, Seymour and Round lakes) were initially prepared by Boyd et. al. in 1985 and are based on historic water quality data and applicable water quality guidelines. The primary water uses that these objectives are intended to protect are raw drinking water supply and recreation.

This report presents the results of water quality monitoring completed at Lake Kathlyn from 1985 to 2015. These results are assessed against the existing water quality objectives for the lake and current B.C. water quality guidelines.

Since 2016, water quality in Lake Kathlyn has been routinely monitored as part of the B.C. Lake Monitoring Network[1]. The results of this monitoring are not included in this report as they are beyond the scope of the original assessment.

2. WATERSHED PROFILE AND HYDROLOGY

2.1 General Landscape and Features

Lake Kathlyn is located approximately five kilometres northwest of the town of Smithers in north-central B.C. Smithers and the surrounding area are located within the Bulkley Ranges ecoregion, which is a narrow mountainous corridor leeward of the rounded Kitimat Ranges. The landscape is dominated by the broad Bulkley River valley and nearby mountains. Low coastal passes allow moist Pacific air to influence the region year-round (Demarchi, 1996). The resulting climate is generally cool and moist with average daily temperatures ranging from -8.9°C in January to 15°C in July with an annual average temperature of 3.9°C. The average total annual precipitation is 512.7 millimetres with 204 millimetres (water equivalent) falling as snow. Late winter and early spring (February – May) are notably drier than the rest of the year and only account for approximately 20% of the annual total precipitation (Climate Normals 1971 – 2000).

2.2 Hydrology and Precipitation

Maximum daily discharge and water level values from Environment Canada hydrometric stations on the Bulkley River near Smithers, Kathlyn Creek upstream of the confluence with Simpson Creek, and Lake Kathlyn, suggest that watersheds in the area are strongly influenced by springtime snowmelt. Peak flows and maximum water levels at these three sites typically occur in late May or early June (Water Survey of Canada 2019). May is a relatively dry month in the area with an annual average total precipitation of 36 millimetres (Climate Normals 1971 – 2000), which suggests that the high flows and lake levels are largely due to melting snow and the associated surface runoff.

Stream flows and lake levels typically decrease throughout the summer, with summertime low flows typically occurring in early to mid-September. September and October are the two rainiest months in the Smithers area (Climate Normals 1971 – 2000). Stream flows and lake levels typically rise during this period, peak in late October or early November, and then drop rapidly as rain is replaced with snow and winter freeze-up begins. Annual low flow conditions typically occur in late winter immediately prior to springtime snowmelt (Water Survey of Canada).

A conditional water license issued in November 1988 authorizes the Regional District of Bulkley Nechako to divert water (no more than 12 cubic feet per second) from Glacier Gulch into Lake Kathlyn via Club Creek during the spring and summer peak flow period only. The diversion of summer flow has been

[1] B.C. Lake Monitoring Network internet link: https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/lake-monitoring/bc-lake-monitoring-network

ongoing since 1994. The primary purpose of the diversion structure is to prevent flooding from Glacier Gulch Creek to Club Creek and Lake Kathlyn. Secondly, the structure provides a summer seasonal flow in the order of six cubic feet per second to Lake Kathlyn. This is the largest single contribution to the lake and represents about 22% of the lake volume. The diversion of glacial water into the lake provides vital seasonal flow necessary to keep summer temperatures from getting too warm and dissolved oxygen concentrations from getting too low.

The Ministry of Environment and Climate Change Strategy (ENV) has been collecting water quality data for Lake Kathlyn from 1985 to the present. It is difficult to determine if the diversion specifically has influenced lake water quality. The data shows nutrient concentrations (i.e. ammonia and total phosphorus) were higher pre-1994 than post. However, most of the data collected after 1994 comes three years after Lake Kathlyn Protection Society volunteers began a summer aquatic macrophyte or "weed" harvesting program on the lake (Section 4.8). This program's purpose is to reduce nutrient inputs, improve water clarity, and enhance recreational activities.

3. WATER USES

3.1 Water Licenses

Licensed withdrawals from Lake Kathlyn have declined slightly since WQOs were originally established. Table 1 summarizes licensed withdrawals from Lake Kathlyn from 1985 to 2020.

Table 1: Summary of water licensing for the Lake Kathlyn waterbody.

Use Description	1985	1996	2002	2010	2020(1)
Domestic	50.3 m^3/d	45.5 m^3/d	45.5 m^3/d	40.914 m^3/d	31.78 m^3/d
Irrigation	1700 m^3/y	495 m^3/y	493 m^3/y	493 m^3/y	493 m^3/y
Industrial	478 m^3/d	22.8 m^3/d	0 m^3/d	0 m^3/d	500 m^3/y (2)
Stock Watering	0 m^3/d	0 m^3/d	2.27 m^3/d	0 m^3/d	0 m^3/d

1 Source: B.C. Northwest Water Tool (NWWT) (FLNROD, 2020)
2 Short term use approval expires: May 2022

3.2 Fisheries

Fish species in Lake Kathlyn include Coastal Cutthroat Trout, Rainbow Trout, Northern Pikeminnow, Prickly Sculpin, Redside Shiner, Longnose Dace, White Sucker, and steelhead (Habitat Wizard, 2015). In the 1950s, the lake was stocked with Rainbow Trout and in the 1990s it was stocked with Coastal Cutthroat Trout (Habitat Wizard, 2015). Coho Salmon are known to spawn in lower Kathlyn Creek and have been observed in upper Kathlyn Creek (RDBN, 2009). Pink Salmon have also been observed in upper Kathlyn Creek (RDBN, 2009). Coastal Cutthroat Trout use the lake during various stages of their life cycle; in particular, rearing in all shallow areas and spawning in the lake inlet and outlet. Salmon species listed were confirmed with the Department of Fisheries and Oceans.

3.3 Recreation

Lake Kathlyn is a popular recreation area with high swimming and non-motorized boating activity. Algal blooms and increased aquatic plant growth in the lake diminished these values for a time (RDBN, 2009); however, the water diversion and macrophyte harvesting programs have had a dramatic effect of increasing the amount of recreational use of the lake (Lake Kathlyn Protection Society, 2015).

3.4 Wildlife

Wildlife at Lake Kathlyn includes moose, deer, black bear, otter, muskrat, and beaver. A variety of eagles, osprey, hawks, and owls are also a part of the lake ecosystem. Loons, Canada geese, mallards, goldeneyes, mergansers, grebes, and teal nest at the lake. Sandhill cranes use the lake for staging in the spring and fall (RDBN, 2009).

3.5 Designated Water Uses

Designated water uses at Lake Kathlyn have not changed significantly since WQOs were set in 1985. Current uses include drinking, recreation, irrigation, livestock, aquatic life, and wildlife. The primary water uses that the Lake Kathlyn objectives are intended to protect are raw drinking water supply and recreation.

4. INFLUENCES ON WATER QUALITY

4.1 Land Ownership

Much of the land surrounding Lake Kathlyn is comprised of privately owned rural residential lots. There are approximately 40 private residences located on the shores of Lake Kathlyn. A significant portion of these residences are inhabited year-round. None of the residences on Lake Kathlyn are served by municipal storm or sanitary sewers or drinking water except for the Watson's Landing properties (see below). The potential for non-point source contamination in the form of leaching from aging septic systems and overland runoff is therefore quite high, as most residences rely on septic fields to dispose of liquid wastes, have extensive driveways, and large lawns which often extend to the water's edge.

There is a relatively small parcel of rural agricultural land located along the eastern shore of Lake Kathlyn. Most of this land is used to grow hay. The remaining portion of the land is used to support a small hobby farm. Horses and other livestock are penned well away from the lake. Potential impacts to the lake associated with overland runoff of manure and sediments are relatively low.

Development of a residential subdivision containing 29 lots, Watson's Landing, began in 2008 immediately south of the agricultural land noted previously. Avoiding impacts to the lake was a major consideration in the design and approval processes of the subdivision. The developer has limited potential impacts by placing restrictions on pesticide and fertilizer use, installing stormwater filtration equipment, and servicing each lot with access to municipal sanitary sewer and drinking water infrastructure. An environmental impact assessment report prepared by Triton Environmental Consultants Ltd. noted that a Riparian Revegetation Plan was developed to satisfy a request from ENV, Skeena Region (Hartman, 2008). The Riparian Revegetation Plan has not been carried out and there is no information concerning the implementation of this plan. Also unavailable were stormwater discharge quality or quantity results.

Canadian National Railway's right-of-way passes through the area immediately west of Lake Kathlyn and crosses all tributaries which flow into the lake. Contaminants associated with railway ties and airborne dust and debris from passing trains could potentially impact the lake. A derailment in this area could have devastating effects on the lake if toxic chemicals were released into the environment.

The Highway 16 corridor is located within 200 metres of the eastern shore of Lake Kathlyn. The highway crosses numerous drainage ditches and associated culverts in the vicinity of the lake. Surface runoff from the highway and other residential roads in the area could potentially impact the lake through the delivery of suspended sediment and other contaminants associated with roads and vehicle traffic (dust controlling agents, hydrocarbons, tire wear products, antifreeze, etc.).

4.2 Basin Profile

Lake Kathlyn is contained within the Kathlyn Creek watershed on the eastern slopes of Hudson Bay Mountain. Hudson Bay Mountain rises approximately 2,100 metres above the lake. The watershed is 3,952 hectares in area and includes the Club and Simpson creek watersheds (Figure 1). Table 2 summarizes morphometric data for Lake Kathlyn. Figure 2 is a bathymetric map of Lake Kathlyn showing the depths within the lake basin.

Table 2: Summary of Morphometric Data (Boyd et al., 1985).

Attribute	Value		Units
Elevation	472		metres (m)
Surface area	170		hectares (ha)
Volume	7,780		cubic decametres (dam^3)
Mean Depth	4.6		metres (m)
Littoral Area (<5m)	30		percentage of lake surface area (%)
Maximum Depth	9.5		metres (m)
Perimeter	6,130		metres (m)
Water Retention time	Mean	1.15	years (yr)
Flushing rate	Mean	0.9	years (yr)

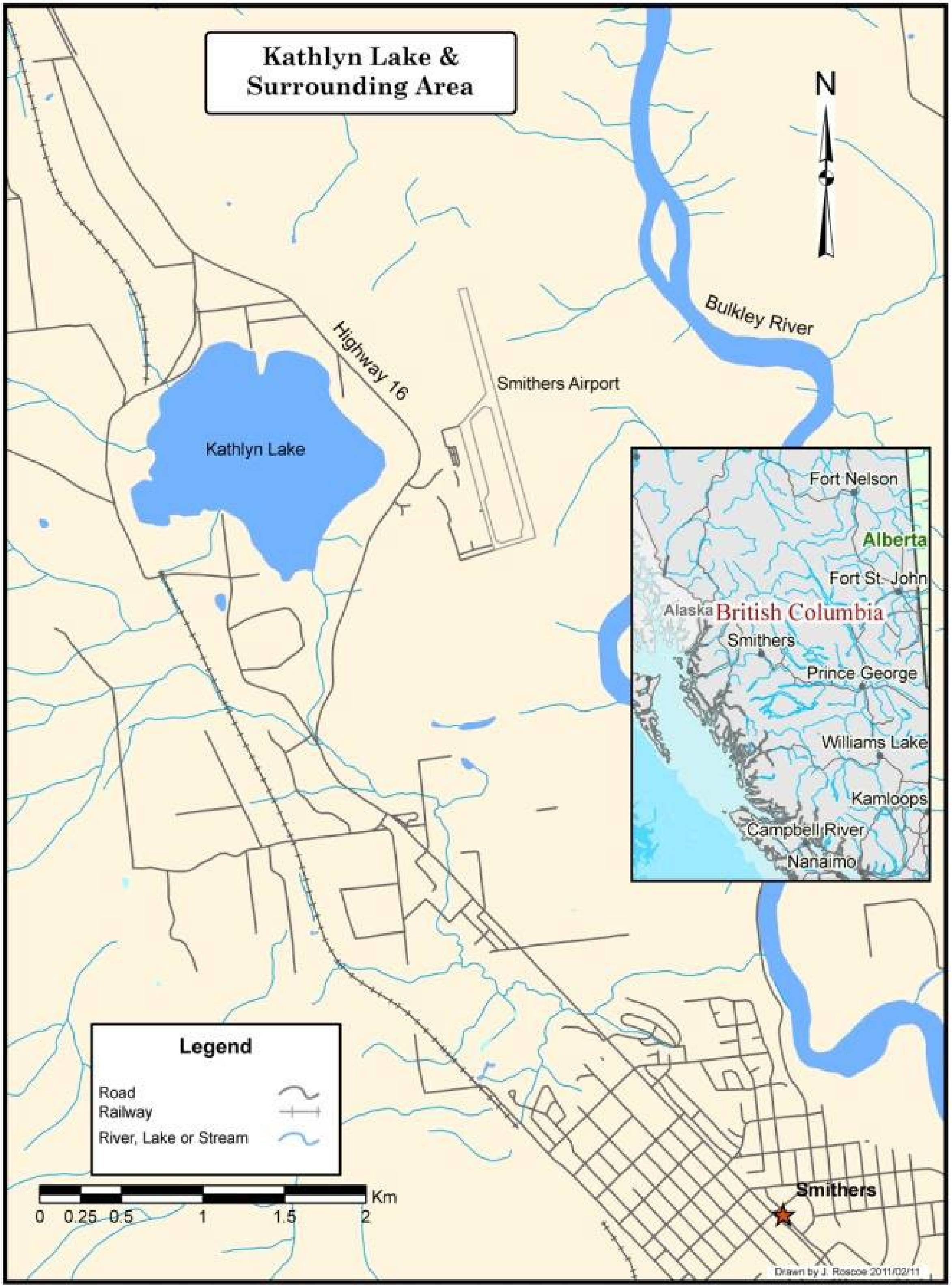
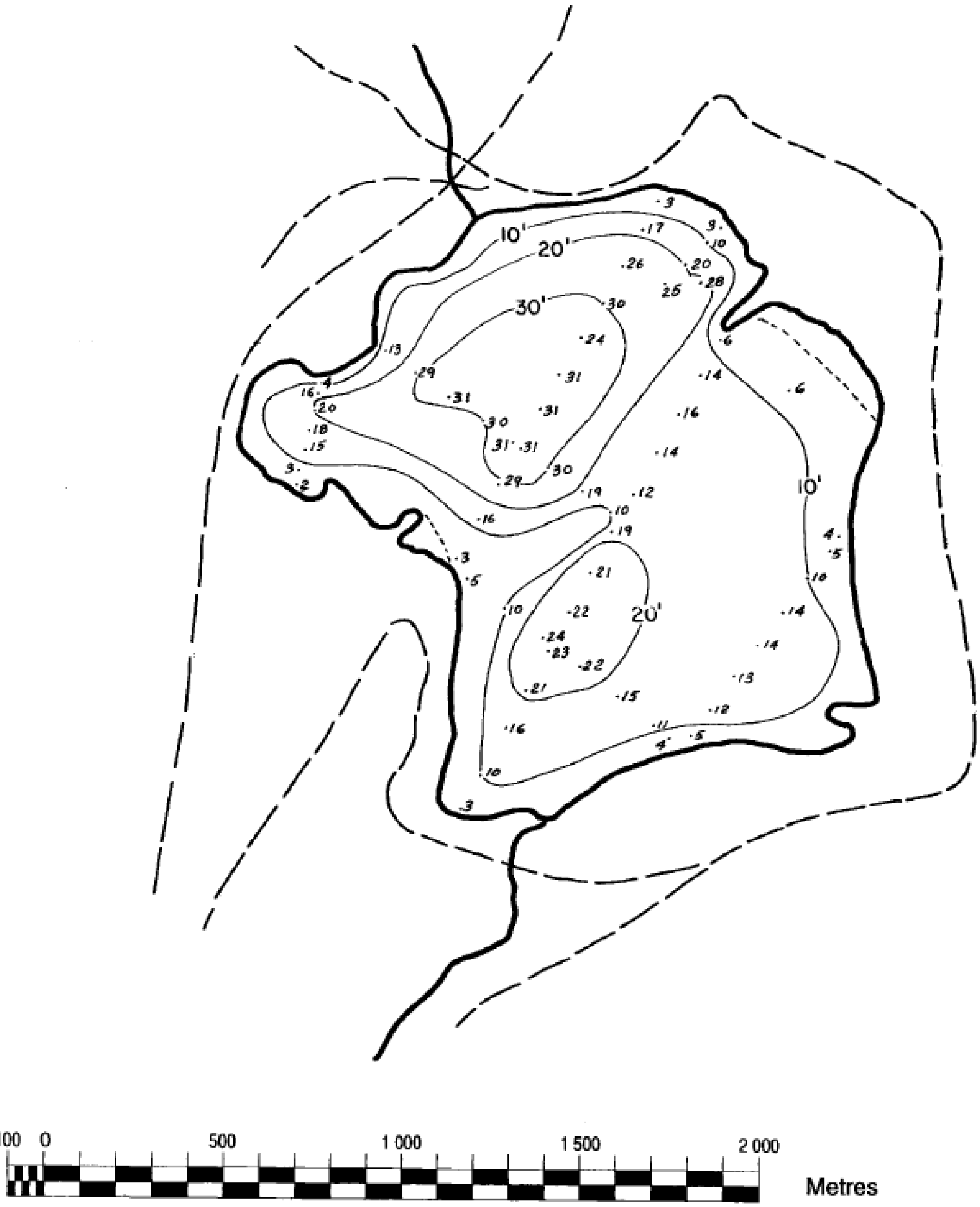


Figure 1: Lake Kathlyn and Surrounding Area.



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

Figure 2 Lake Kathlyn Bathymetric Map (FIDQ, 2015)

4.3 Licensed Water Withdrawals

Water withdrawals can affect flows downstream from the point of diversion, especially during periods of lower flows, if licensed withdrawals are large relative to the volume of water in the system. This can have significant impacts on the success of spawning salmon, as well as the survival of juvenile salmonids. However, this does not appear to be of concern in the Lake Kathlyn watershed as licensed withdrawals from Lake Kathlyn have declined slightly since objectives were originally established (Table 1).

4.4 Forest Harvesting and Forest Roads

There is no active forest harvesting occurring in the watershed surrounding Lake Kathlyn. Historically there is evidence of land clearing for agricultural, residential and infrastructure purposes but not forestry. Impacts on water quality from forest harvesting are not likely in the watershed

4.5 Wildlife

Warm-blooded animals can have a negative influence on water quality since they can carry pathogens such as *Giardia lamblia* and *Cryptosporidium* oocysts, which can cause gastrointestinal disease in humans (Epps and Phippen, 2011). Warm-blooded animals also excrete fecal coliforms in their feces, which can lead to elevated levels in samples collected from contaminated water. Without performing detailed source tracking, it is impossible to know if the observed indicators are associated with fecal contamination from animals or humans, and all necessary precautions must be adhered to while treating water for human consumption (Epps and Phippen, 2011).

Lake Kathlyn is frequented by large numbers of waterfowl and terrestrial wildlife. Loons, ducks, and Canadian geese nest in the vicinity of the lake, sandhill cranes use the lake as a staging ground in the spring and fall, and moose, deer, black bears otter, muskrat and beaver depend on the lake and the surrounding area for habitat (Rysavy and Sharpe, 1995). Fecal contamination from waterfowl and wildlife populations is therefore a potential risk.

4.6 Recreation

A small municipal park and public beach are located on the southern shore of the lake. This is a popular recreation site frequented by swimmers, sunbathers, canoeists, and anglers during the summer months. Potential contaminants to the lake associated with the park include fecal coliforms from swimmers (especially infants and toddlers) and pets, re-suspension of bottom sediments as well as debris left by picnickers and other users. There is also a boat launch on the north end of the lake at the end of St. Anne Road. These are popular access points in summer and winter. The use of motorized vessels is not permitted on Lake Kathlyn, so potential contaminants resulting from watercraft use are limited to waste fishing line and other debris.

4.7 Mining

The proposed development of the Davidson (formerly Yorke-Hardy) molybdenum deposit on Hudson Bay Mountain owned by the Thompson Creek Metals (TCM) Company (formerly Blue Pearl Mining Ltd.) represents a source of potential contamination within the Lake Kathlyn watershed. TCM has conducted limited water quality sampling from an existing mine adit located on the lower slopes of Hudson Bay Mountain. Laboratory analysis of samples indicates that the adit discharge contains high concentrations of dissolved molybdenum and arsenic (Rescan Environmental Services Ltd, 2005).

TCM's development proposal was withdrawn in June 2013. If there is renewed interest in this project and the mine goes into production, the historic and continued monitoring of metals concentrations, including molybdenum and arsenic at Lake Kathlyn will help ensure that designated water uses continue to be protected.

4.8 Aquatic Plant Harvesting

Aquatic macrophytes (plants) are the most visible and perhaps most often cited indicator of general lake health. Underwater vegetation is important for several reasons, such as providing oxygen, food, and shelter to a variety of species. These plants help control erosion, and some species can absorb excess nutrients from the water column. The public's negative view of these aquatic plants as weeds and their perceived impairment of recreational and other water uses is often the catalyst that leads to lake rehabilitation efforts. As a result, numerous lakes in B.C. (Kathlyn Lake included) have weed control and management plans in place.

The Lake Kathlyn Protection Society partnered with ENV and the Regional District of Bulkley-Nechako to develop a weed management plan in response to an outbreak of *Elodea canadensis* (Canadian waterweed or waterweed) in the early 1990s. The Public Conservation Assistance Fund provided a $5,000.00 grant in 2000 and the Lake Kathlyn Protection Society provided over 2,500 hours of volunteer time. The combined efforts resulted in the removal of 2,800 truckloads of weeds from the lake between 1997 and 2006, the ongoing maintenance of a cold-water diversion from Club Creek, and the implementation of a public education program focusing on land use practices and their potential impacts on the lake (Clermont, 2006).

Tabor Lake, located in the Omineca region of B.C., has had an aquatic plant harvesting program in place since 1995, like that for Lake Kathlyn. Calculations of the amount of phosphorus that has been and could be removed from Tabor Lake, compared to the amounts that have been internally loaded, have been reported by Dr. Ellen Petticrew of the University of Northern B.C. Between 1995 and 2002, summer weed harvesting was found to remove between 336 to 760 kg of phosphorus from Tabor Lake each year (Carmichael et al., 2003). This example shows that the removal of aquatic plants can decrease the amount of phosphorus in the lake over time. Further to that, the density and distribution of waterweed in Lake Kathlyn have been significantly reduced and phosphorus concentrations appear to be declining (Clermont, 2006).

The Lake Kathlyn Protection Society received a volunteer award from the British Columbia Lake Stewardship Society in 2002 in recognition of the society's long-term restoration efforts at Lake Kathlyn. In recent years, the society has reduced its plant removal efforts, partially due to the reduced growth of the plants and improved water quality of the lake (Stuart, 2015, Pers. Comm.). From 1997 to 2002, volunteers reported they removed 35 loads from the lake each season, a significant reduction from the several hundred loads removed in the first five years of the project (Stuart, 2015, Pers. Comm.).

The example discussed above demonstrates the importance of aquatic plants in the perceived health of a lake. Unfortunately, attempting to assess species composition and relative density of aquatic plants is challenging and not often attempted. The relationships between water quality and aquatic macrophyte populations are also not well understood. As such, there are currently no provincial water quality guidelines associated with aquatic macrophytes. We suggest monitoring for significant changes to macrophyte species distribution or plant density when other monitoring activities take place at the lake.

5. STUDY DETAILS

Water quality sampling at Lake Kathlyn has been conducted at a deep station site located in the deepest portion of the northwest basin, in the vicinity of three residential water intakes, at the public beach and directly offshore of the recently developed residential subdivision (Figure 3).

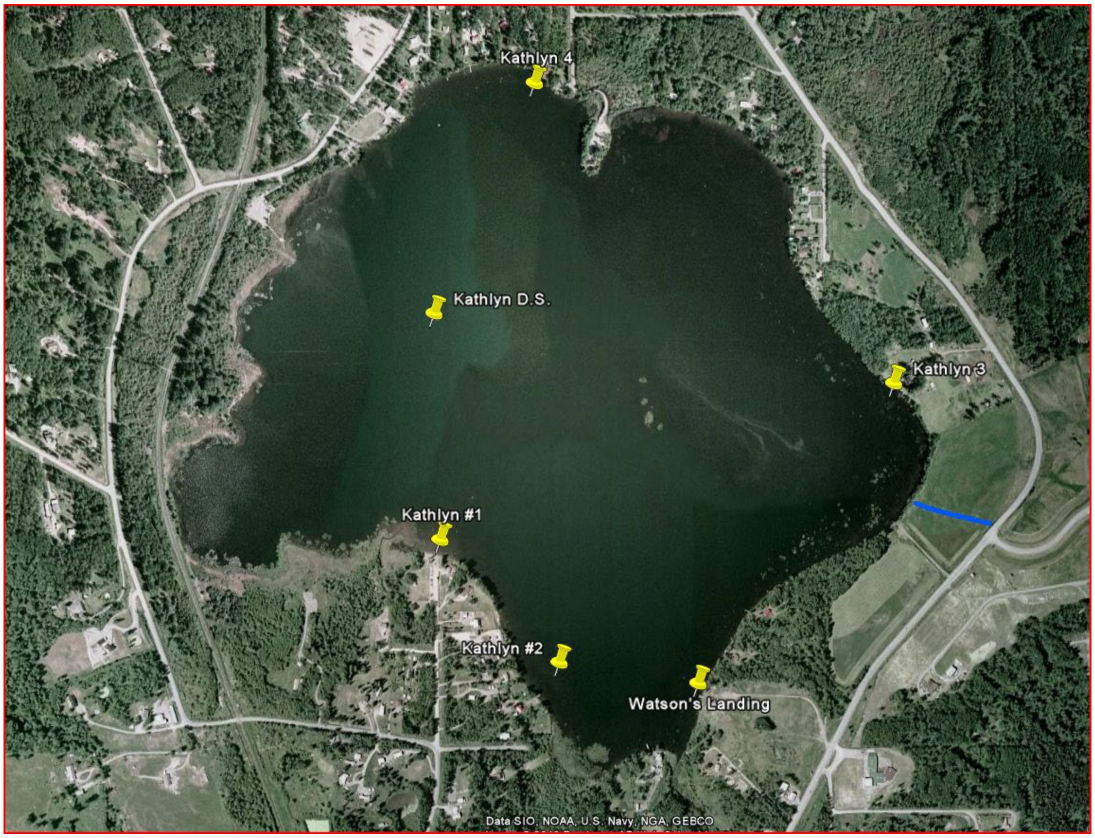


Figure 3 Sample sites on Lake Kathlyn. Image source: Google Earth.

The deep station site (Kathlyn D.S. EMS 1131007) has been sampled 38 times since 1985. Most of these sampling events have occurred at the surface and depths of 4 metres and 9 metres during spring turnover (late April – early May). Notable exceptions to the typical sampling schedule include sampling events in June, July and August of 1992, November 1994, October and November 2000, July and August 2002 and February 2003.

Surface grab samples were collected from the side of the boat. A Van Dorn sampler was used to obtain water samples from the middle and bottom depths. At each depth, the following analyses were typically performed: true colour, pH, specific conductance, turbidity, total and dissolved metals, and various forms of nitrogen and phosphorus. In addition to the general water chemistry noted above, temperature and dissolved oxygen profiles, as well as Secchi depths, were measured 15 times between July 2002 and April 2017.

Three residential water intakes and one site immediately offshore of the public beach (Kathlyn Lk #1 EMS 207548, Kathlyn Lk #2 EMS 207549, Kathlyn Lk #3 EMS 207550, and Kathlyn Lk #4 EMS 207551) have been sampled for various microbiological indicators between three and eleven times since 1988. Each sampling event consisted of five weekly samples collected from each site. Samples were typically collected immediately prior to the fall freshet when bacteria concentrations in the lake are most likely to be elevated. Water quality parameters analyzed during this period included: turbidity, pH, specific conductance, water temperature, total organic carbon, true colour, dissolved oxygen, and microbiological indicators (*E. coli., Enterococci* and *Pseudomonas aeruginosa*).

A surface grab sample was collected at a newly established monitoring location (E283209) immediately offshore of the residential subdivision known as Watson's Landing. This sampling location will provide a means to monitor potential long-term effects to the lake associated with the subdivision.

To check attainment of the established water quality objectives, monitoring was conducted from 2001 to 2003 (Downie and Kokelj, 2004) and in 2014. The 2001 sampling program was limited to the sampling of drinking water intakes around the lake in October. The 2002-03 and 2014 sampling programs included:

- Beach monitoring of microbiological indicators in August 2002 and July, August 2014;
- Drinking water monitoring of colour, turbidity, and microbiological indicators at three intakes in August 2002, October 2002, April 2003 and July, August 2014; and
- Deep station water quality sampling in April 2003.

Analyses of all samples were conducted by ministry-approved laboratories. All samples were collected by ministry staff according to B.C. field sampling manuals for collecting ambient water quality samples and biological samples (ENV 2013a and 2013b).

Biannual water quality sampling for Lake Kathlyn since 2016 has been conducted under the Provincial Lake Monitoring Program. Water quality results from this program are not included in this report, however, result summaries can be accessed from B.C. Lake Monitoring Portal.[2]

6. WATER QUALITY ASSESSMENT

Lake Kathlyn water quality objectives were established in 1985 as part of an assessment of lakes in the Smithers area (Tyhee, Kathlyn, Seymour and Round lakes) for parameters related to potential sources of contamination (Table 3). These included fecal coliforms, turbidity, and total phosphorus (Boyd et al., 1985). Fecal coliforms and colour objectives were set at B.C. water quality guideline levels, while turbidity and total phosphorous were derived from B.C.'s ambient water quality guidelines and set for conditions in Lake Kathlyn. Water quality objectives consistent with B.C. water quality guideline limits were also set for temperature, dissolved oxygen, true colour, total organic carbon and chlorophyll *a*. Water quality objectives attainment reports for the Smithers area lakes were completed in 1996 and 2004.

This report presents a summary of the ambient water quality of Lake Kathlyn from 1985 to 2015 and compares data to B.C. water quality guidelines and water quality objectives.

[2] B.C. Lake Monitoring Portal Kathlyn Lake monitoring results summary link: https://www.nrs.gov.bc.ca/ecms/provlakes/monitoringresultssummary/1131007.html

Table 3: 1985 water quality objectives for Lake Kathlyn

Variable[1]	Objectives
Water temperature	water temperatures should not exceed 16°C at any depth below 3 metres
Dissolved oxygen	DO concentrations in the upper 6 m of the water column should remain above 5 mg/L at all times of the year
Turbidity	≤ 1 NTU (average based on the average of 5 samples collected in 30 days); ≤ 5 NTU (maximum)
True colour	maximum true colour value of 15 TCU in any grab sample collected within 10 metres of a domestic intake
Total organic carbon	maximum TOC concentration of < 4 mg/L in all grab samples
Total Phosphorus	long-term objective: ≤ 15 µg/L (average at spring overturn)
E. coli bacteria	≤10 CFU/100 mL (90th percentile) with a minimum of five weekly samples collected over a 30-days. At beach sites, the geometric mean of a minimum of five weekly samples collected within 30 days must not exceed 77 CFU/100 mL
Chlorophyll a	4.0 µg/L (average of 4 samples collected from 1 metre below the surface at the deep station in May, June, July and August)

1. For all variables above except total phosphorus and turbidity, water quality objectives are the B.C. Water Quality Guidelines.

6.1 Limnological Characteristics

6.1.1 Temperature Stratification

Temperature is important to the quality of drinking water supplies for both health and aesthetic reasons. As water temperature increases, so does the potential for biological growth. Increased biological growth can increase chlorine demand and reduce the effects of the chlorination process. In addition, decaying organics in the water can cause taste and odor problems.

Water temperature is a critical factor for aquatic life. Fish and invertebrate body temperatures are, to a large extent, controlled by their environment. Water temperature directly affects the activity and physiological processes of fish, amphibians, and aquatic invertebrates at all life stages. The capacity for water to carry dissolved oxygen, which is critical to aquatic life, is inversely related to temperature (water at higher temperatures carries less oxygen). Temperature can also affect the toxicity of other parameters, such as ammonia, and increase the solubility of chemical compounds.

Water quality guidelines for temperature have been developed for several water uses (see Oliver and Fidler, 2001, as cited in Epps and Phippen, 2011). For drinking water supplies, it is recommended that water temperature be less than 15°C to protect the aesthetic quality of the water. For the protection of aquatic life in lakes, the allowable change in temperature is +/-1°C from naturally occurring levels. In streams, the optimum temperature ranges for salmonids are based on species and specific life history stages such as incubation, rearing, migration, and spawning.

Lake Kathlyn Protection Society volunteers collected weekly temperature profiles in 2014 between June 11 and September 14 (Figure 4A). The monthly average profiles show a stratified summer water column with water temperatures increasing from June to August, followed by cooler surface water temperatures in September. The June, July, and August surface readings exceeded the drinking water guideline of 15°C.

Periodically, since 2002, the Ministry has collected temperature and dissolved oxygen profiles in Lake Kathlyn. The most recent profiles were collected once in 2015 and twice (spring and summer) in 2016 and

2017 (Figure 4B). The spring profiles suggest the lake had recently undergone spring overturn, with temperature values ranging from 12°C to 8.3°C on April 27, 2016, and 8°C to 6°C on April 25, 2017. The summer profiles show a stratified water column with temperature values ranging from 20°C to 12°C with depth on August 11, 2016, and 19°C to 9.7°C on August 10, 2017. As with the fall 2014 profile (Figure 4A), the profile collected on September 15, 2015, suggests fall overturn results in a decrease in water column temperatures below 16°C.

Summer surface water temperatures exceeded the aquatic life guideline of 16°C for Cutthroat Trout, the most sensitive species in Lake Kathlyn for this parameter (Oliver et al., 2001). Cutthroat Trout use the lake at various points in their life cycle; in particular, the lotic zone is utilized for spawning and fry rearing. Fish would typically need to stay within the thermocline to avoid physiological stresses associated with elevated water temperatures. For this reason, **water temperatures should not exceed 16°C at any depth below 3 metres. Data from the lake shows that this objective is routinely exceeded during summer months (Figure 4), but that cooler waters below the guideline persist at depth (< 6 m) during peak summer temperatures. Deeper waters may provide refuge for temperature sensitive fish if there is sufficient dissolved oxygen.**

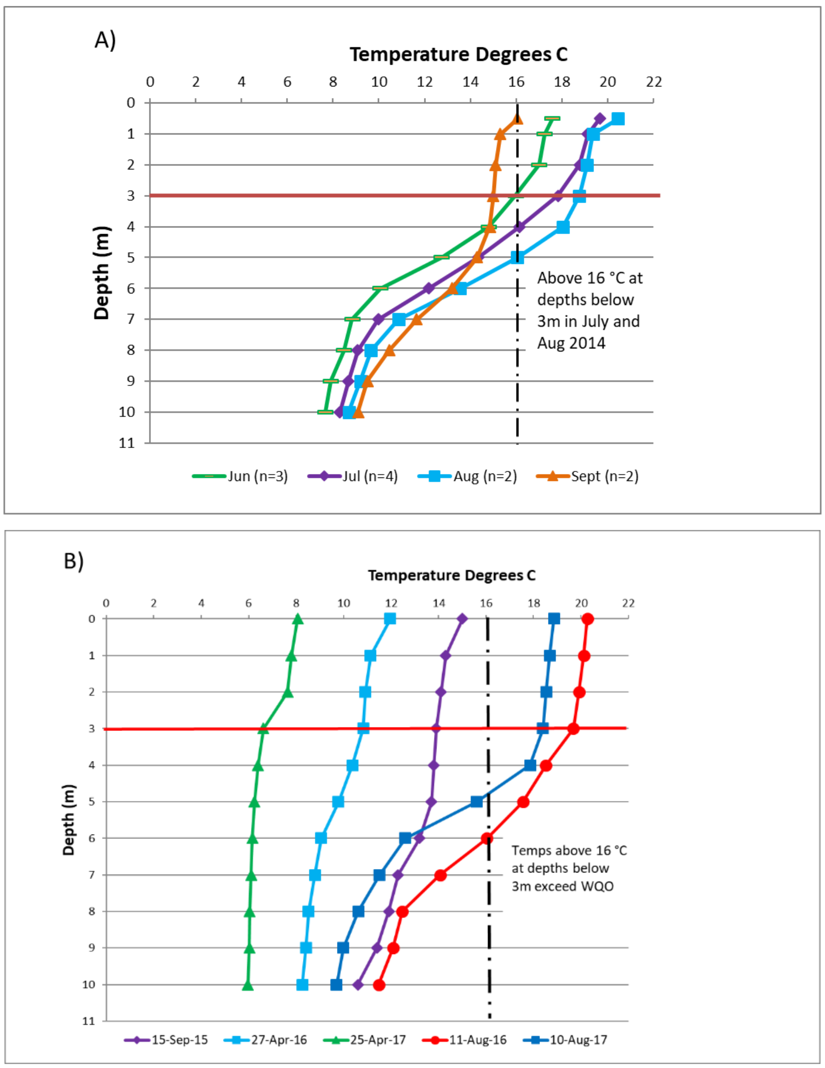


Figure 4 Lake Kathlyn deep station temperature profiles A) 2014 June to September monthly averages and B) spring and late summer profiles between 2015 and 2017

6.1.2 Dissolved Oxygen

Dissolved oxygen (DO) levels are important for the survival of aquatic organisms, especially species sensitive to low oxygen levels such as salmonids. Oxygen becomes dissolved in water on the surface of lakes as a result of diffusion from the atmosphere, as well as from photosynthetic activity from plants and algae. When deeper waters no longer mix with surface waters, due to stratification, concentrations of DO can decrease. This occurs as a result of the decomposition of organic materials, especially in eutrophic lakes (i.e., lakes with high levels of nutrients and therefore high biological productivity). If the euphotic zone (the zone where there is enough light penetration to allow photosynthesis) lies above the thermocline, no photosynthesis occurs in deeper waters, and therefore oxygen depletion from decomposition occurs. The guideline for the minimum instantaneous DO concentration for aquatic life is 5 mg/L (B.C. Ministry of Environment, 1997).

DO profile data collected by ENV in April and August of 2016 and 2017 are shown in figure 5. The August profiles show that the upper four to five metres of the water column are well oxygenated and that DO levels decline rapidly below 6 metres, reaching anoxia (<0.5mg/L) in the bottom waters. Weekly (June to August) profiles collected by volunteers of the Lake Kathlyn Protection Society as recent as 2018 suggest that once the lake stratifies, it remains this way through the summer. Winter profile data are rare; however, data collected under the ice on January 17, 2003, and February 17, 2003, also showed a well oxygenated water column in the upper five metres and declining levels below six metres, reaching anoxia in the bottom waters. April 2016 and 2017 profiles in Figure 5 suggest that the lake mixes at spring overturn, oxygenating the bottom waters.

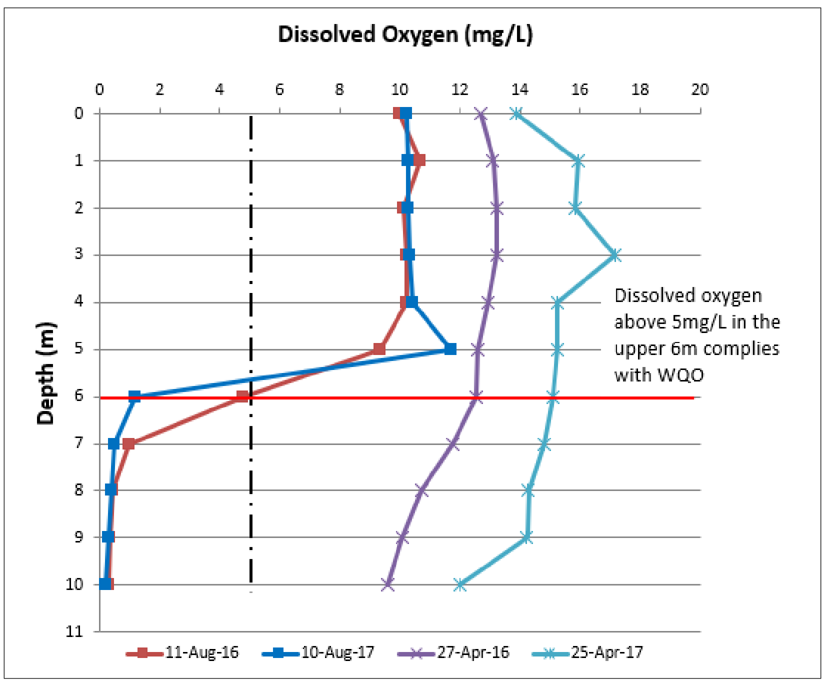


Figure 5. Dissolved oxygen profiles for Lake Kathlyn – April and August 2016 and 2017.

The minimum concentration of dissolved oxygen measured in Lake Kathlyn between July 2002 and August 2017 was 0.2 mg/L at a depth of 10 metres. This value is well below the minimum instantaneous guideline of 5 mg/L, and therefore is of concern. **For this reason, dissolved oxygen concentrations in the upper 6 metres of the water column should remain above 5 mg/L at all times of the year.** Data from August show that this objective may not be met during summer months when the lake is stratified (Figure 5).

6.1.3 Water Clarity

As water clarity is primarily affected by colour, suspended solids, and algal growth, Secchi discs provide a simple, inexpensive means of measuring changes in lake productivity. Citizen scientists can be easily trained in their use. For this reason, Secchi depths are a popular and useful measurement for volunteer water stewards and water quality professionals alike. Lakes with high Secchi depths tend to be oligotrophic (low biological productivity), while eutrophic lakes (those with high biological productivity) tend to have low Secchi depths. The recreational guideline for Secchi depths is a minimum of 1.2 metres (Caux, et al., 1997, as cited in Phippen and Epps, 2012).

Secchi depth was measured 25 times at the deep site between July 2002 and August 2017, including eleven readings in 2014 between June 11 and September 14 (Figure 6). Secchi depth values ranged from 1.2 metres to 7.3 metres, and a 15-year average of 3.2 metres. No readings fell below the 1.2 metres minimum for recreation and it appears that Secchi depths have improved in the last four years of the sampling period. Water clarity varies from year to year and within each season; therefore, seasonal data would be required for a more meaningful interpretation.

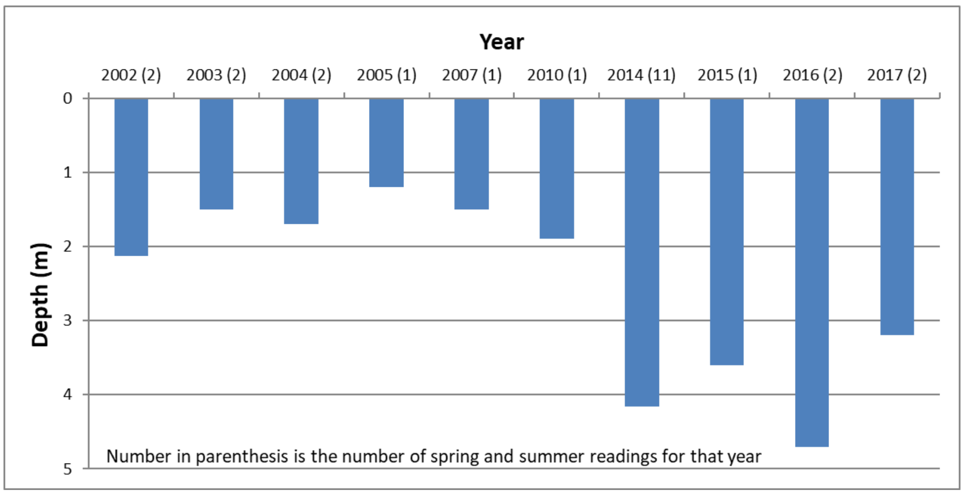


Figure 6. Average annual Secchi depth readings for Lake Kathlyn from 2002 to 2017.

6.2 Water Chemistry

6.2.1 pH

pH measures the concentration of hydrogen ions (H+) in water. The concentration of hydrogen ions in water can range over 14 orders of magnitude, so pH is defined on a logarithmic scale between 0 and 14. A pH between 0 and less than 7 is acidic (the lower the number, the more acidic the water) and a pH between 7 and 14 is alkaline (the higher the number, the more basic the water). The aesthetic water quality guideline for drinking water is a pH between 6.5 and 8.5 (Nagpal et al., 2006, as cited in Phippen and Epps, 2012). Corrosion of metal plumbing may occur at both low and high pH outside of this range, while scaling or encrustation of metal pipes may occur at high pH. The effectiveness of chlorine as a disinfectant is also reduced outside of this range. The aquatic life guideline spans a pH range between 6.5 and 9.0. Outside of this range, toxicity to fish begins to occur (McKean, et al., 1991, as cited in Phippen and Epps, 2012).

pH was measured 127 times in the lake from 1985 to 2014.[3] pH readings ranged from 6.25 to 7.46. Two readings were below the aquatic life guideline of 6.5, and both occurred on September 2, 2014. No obvious trend is evident with pH, however, given the two relatively low readings, it is recommended that both field and lab pH continue to be measured in future monitoring.

6.2.2 Turbidity

Turbidity is a measure of water clarity defined by the amount of light scattered by the particles present in a water sample. Turbidity values are reported as nephelometric turbidity units (NTU). Turbidity is most commonly an aesthetic consideration, but it is correlated with algal growth and bacterial contamination. The water quality target levels for turbidity have been set to ensure that the water is suitable for domestic water supply (the most sensitive use) with no water treatment in addition to disinfection (i.e., no removal of turbidity or suspended residues is required). The turbidity target for the Smithers area lakes includes a maximum acceptable level (which applies to any water sample taken from or near a domestic water intake) and a desirable level, which is the average of at least five weekly samples over 30 days (Downie and Kokelj, 2004).

The 1985 turbidity WQOs established for Lake Kathlyn include a maximum acceptable level of 5 NTU and an average level of 1 NTU based on the average of at least five samples (Boyd et al., 1985). These objectives were derived from B.C.'s ambient water quality guidelines for turbidity.

Turbidity levels in the epilimnion (< 5m from the surface) of Lake Kathlyn have been monitored at the deep station sampling site as well as at the three intake sites and one beach site. At the deep station, turbidity has also been sampled on occasion in the waters 1 meter above the bottom of the lake. Table 4 summarizes turbidity values measured at each of the monitoring locations on Lake Kathlyn.

Table 4: Lake Kathlyn Turbidity Data, 1985 to 2014.

Sample Site[1]	Minimum (NTU)	Maximum (NTU)	Average (NTU)	Std Dev	# Samples
Lake Kathlyn, deep station (1131007)	0.18	26.60	4.21	4.6	66
Lake Kathlyn #1 (beach) (E207548)	0.66	1.03	0.84	0.2	5
Sites near intakes					
Lake Kathlyn #2 (E207549)	0.3	5.1	1.28	0.79	65
Lake Kathlyn #3 (E207550)	0.3	30.8	1.79	3.7	66
Lake Kathlyn #4 (E207551)	0.54	3.3	1.28	0.62	50

1 Turbidity was measured at the surface at all sites except the deep station where multiple depths were sampled.

As shown in Figure 7, 95 percent of the turbidity values are below 5 NTU with less than 25 percent of these values below 1 NTU. Eight of the twelve values exceeding 5 NTU were from water samples collected 1 metre from the bottom of the lake, where there is potential for disturbing the bottom sediments during sample collection.

[3] Based on all lab and field Environmental Monitoring System (EMS) pH data.

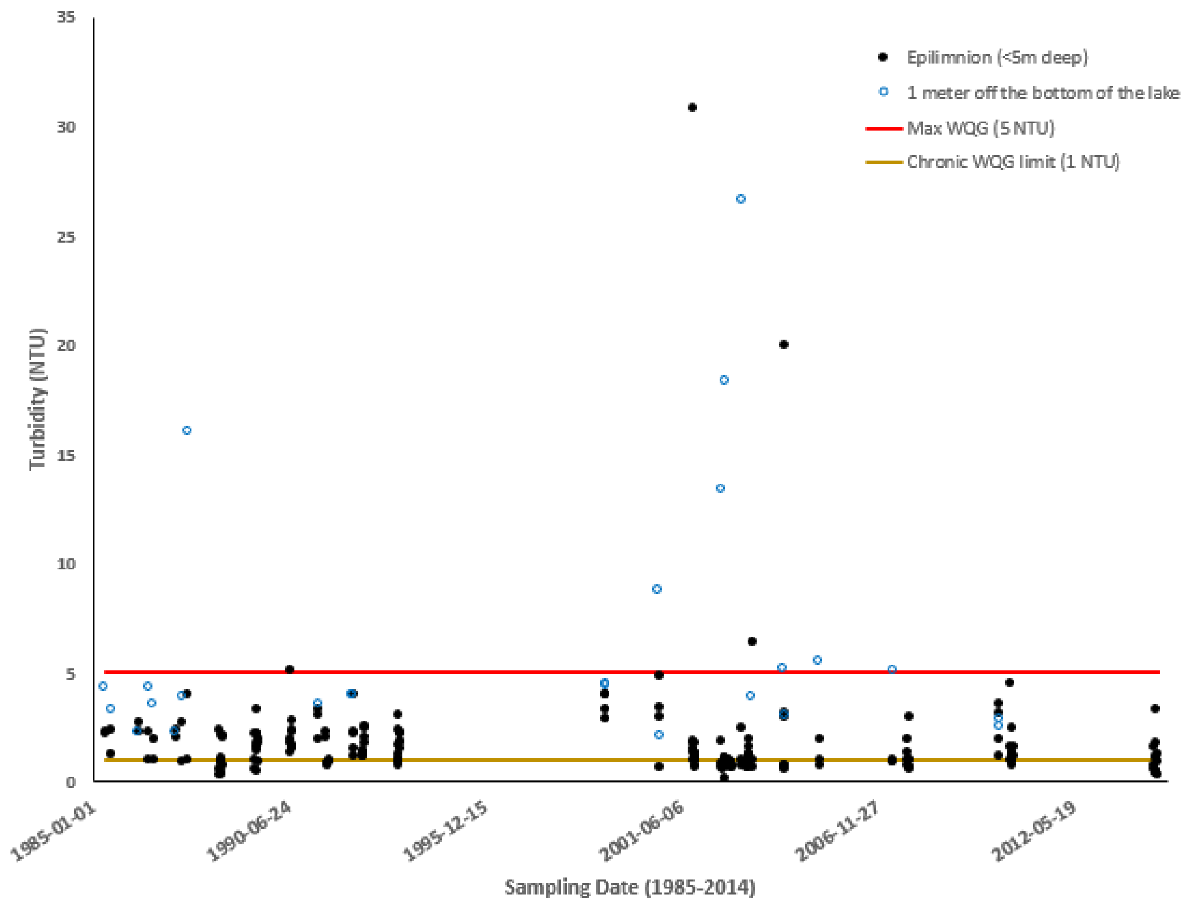


Figure 7. Lake Kathlyn surface and bottom-water turbidity (NTU) values from 1985 to 2014.

Exceedances of the existing turbidity objectives are relatively frequent, and the current objective protects drinking water use. The frequency of attainment should be expected to increase with improved watershed management. Recommendations for improved management practices that may reduce turbidity levels are outlined in the Lake Kathlyn Management Plan (Rysavy and Sharpe, 1995).

6.2.3 Colour and Total Organic Carbon

Colour in water is caused by dissolved and particulate organic and inorganic matter. True colour is a measure of the dissolved colour in water after the particulate matter has been removed, while apparent colour is a measure of the dissolved and particulate matter in water. Colour can affect the aesthetic acceptability of drinking water, and the drinking water guideline is that the maximum should not exceed 15 TCU (true colour units) (Moore and Caux, 1997). This guideline applies to systems where the ambient colour is less than 15 TCU. Colour is also an indicator of the amount of organic matter in water. When organic matter is chlorinated, it produces disinfection by-products such as trihalomethanes and haloacetic acids (Health Canada, 2008).

Lake Kathlyn is a very popular recreational area during the summer months and many residents rely on the lake for their drinking water. As such, it is important to maintain the lake's aesthetic quality as well as the lake's suitability as a drinking water source. At Lake Kathlyn, the maximum true colour value in any grab sample collected within 10 metres of a domestic intake should not exceed 15 TCU. This represents the aesthetic guideline for raw drinking water supply listed in the 2020 *British Columbia Source Drinking Water Quality Guidelines*.

Samples collected in the vicinity of three domestic intakes on Lake Kathlyn have generally had true colour values below the current drinking water guideline. Table 5 summarizes the colour concentrations for samples collected from the deep site, one beach site (Kathlyn Lk #1), and three domestic intake sites (Kathlyn Lk sites #2-4). The guideline for true colour for recreational use is 200 TCU and, as the table below shows, all values for the beach site were below this maximum guideline value.

Table 5: Summary of colour concentrations at Lake Kathlyn, 1985 to 2014.

Sample Site	# of Samples	# of results >15 TCU	Maximum (TCU)	Average (TCU)
Lake Kathlyn Deep Site[1]	58	24	60	18.5
Lake Kathlyn #1	5	0	5	5.0
Lake Kathlyn #2	60	4	20	9.4
Lake Kathlyn #3	61	4	20	10.1
Lake Kathlyn #4	45	3	20	9.3

1. There is no objective for the deep station. Colour readings are elevated because the results are from sampling at multiple depths.

Results for true colour are typically below the drinking water objective. Routine results below this objective will help ensure that the lake remains suitable as a source of raw drinking water and will help maintain recreational values.

Total organic carbon (TOC) in source waters comes from decaying natural organic matter as well as synthetic sources. Some detergents, pesticides, fertilizers, and herbicides are examples of synthetic sources which typically enter waterways in rainfall runoff. In water bodies, higher carbon and organic content is associated with greater oxygen consumption. A high organic content means an increase in the growth of microorganisms, including bacteria, fungi, and algae, which contribute to the depletion of oxygen supplies. Elevated (> 4 mg/L) total organic carbon (TOC) concentrations are a concern in water bodies designated as sources of raw drinking disinfected through chlorination. Reactions between organic carbon compounds and chlorine can produce haloforms, which are suspected carcinogens that are shown to be mutagenic in humans (Moore, 1998). TOC concentrations have been measured 18 times at the deep station monitoring site on Lake Kathlyn from 2004 to 2010. Additionally, TOC was measured at Lake Kathlyn sites #2, #3 and #4 in 2007 and 2014 and site #1 in 2014. Concentrations ranged from 1.3 mg/L to 5.84 mg/L and the mean value was 3.66 mg/L. **TOC concentrations for Lake Kathlyn should not exceed the B.C. drinking water maximum acceptable concentration of 4 mg/L in all grab samples.**

Consistently meeting the objective will help ensure that the health of domestic water users is protected should they rely on chlorine to sanitize their water. Controlling excess plant growth in the lake, and controlling the use of pesticides, fertilizers, and herbicides applied to the surrounding land are steps that could reduce the TOC concentrations.

6.2.4 Specific Conductance

Conductivity refers to the ability of a substance to conduct an electric current. The conductivity of a water sample indicates the concentration of dissolved ions in the water. The more ions dissolved in a solution, the greater the electrical conductivity. Temperature affects the conductivity of water (a 1°C increase in temperature results in approximately a 2% increase in conductivity), therefore specific conductivity is used (rather than simply conductivity) to compensate for temperature. Coastal systems, with high annual rainfall values and typically short water retention times, generally have low specific conductivity (<80 µS/cm), while interior watersheds generally have higher values. Precipitation events or snowmelt tend to dilute the ions, resulting in decreasing specific conductivity levels with increasing flow levels. Therefore, water level and specific conductivity tend to be inversely related. However, in situations such as landslides where high levels of dissolved and suspended solids are introduced to a water body, specific conductivity levels tend to increase. As such, significant changes in specific conductivity can be used as an indicator of potential impacts. (Phippen and Epps, 2012).

Specific conductance values measured in Lake Kathlyn in 2014 ranged from 45.1 µS/cm to 48.4 µS/cm (Table 6). Specific conductance results were relatively low, typical of freshwater lakes.

Table 6: Summary of field measured specific conductance (µS/cm) data for 2014 at Lake Kathlyn.

Minimum	Average	Maximum	Std Dev	No. of samples
45.1	45.9	48.4	0.80	14

6.2.5 Nutrients (Nitrate, Nitrite, and Phosphorus)

Phosphorus is generally the limiting nutrient in freshwater aquatic ecosystems. Boyd et al., (1985) assessed the weight ratio of nitrogen to phosphorus of water samples collected from Lake Kathlyn and determined that productivity within Lake Kathlyn was limited by the availability of phosphorus (1985). A review of historic nitrogen concentrations (as nitrate and nitrite) suggests that these parameters are present in levels well below current drinking water and recreational guidelines. The maximum recorded concentration of nitrate at the Lake Kathlyn deep station was 0.103 mg/L. In 2014, data was collected at Watson's Landing rather than the deep station. The nitrate sample concentration in 2014 was < 0.002 mg/L. The current guideline for the protection of drinking water and recreational use is a maximum nitrate concentration of 10 mg/L.

The maximum recorded concentration of nitrite at the Lake Kathlyn deep station was 0.006 mg/L. In 2014, the nitrite concentration measured at Watson's Landing was <0.020 mg/L. The current guideline for the protection of drinking water and recreational use is a maximum nitrite concentration of 1 mg/L.

Phosphorus is the limiting nutrient in Lake Kathlyn. This means that the overall productivity of the lake is directly proportional to the availability of phosphorus. Elevated phosphorus concentrations can lead to excessive algal growth, which can cause undesirable taste and odour in drinking water, aesthetic problems, poor water clarity and hypolimnetic oxygen depletion that results in loss of fisheries habitat and possible winter and summer fish kills (Nordin, 2001). A total phosphorus short-term objective of ≤ 15 µg/L (at spring overturn) was put in place to manage the potential for nuisance algal growth (Downie and Kokelj, 2004). The long-term objective of ≤ 10 µg/L is the B.C. drinking water guideline listed in the B.C. Water Quality Criteria for Nutrients and Algae (Nordin, 2001).

Total phosphorus concentrations at spring overturn have been measured at the deep station monitoring site 64 times since 1985. Samples have typically been collected from the surface and depths of four metres and nine metres during late April or early May. Surface grab samples were collected on two occasions at the Watson's Landing offshore sampling location (E283209). The total phosphorus concentrations here on August 19, 2010, and September 1, 2014, were 6.0 µg/L and 7.2 µg/L, respectively.

Table 7 summarizes the results of spring overturn total phosphorus monitoring at the Lake Kathlyn deep station. The table illustrates that most of the results from the deep station had total phosphorus concentrations exceeding the existing long-term objective of ≤ 15 µg/L. This trend of non-attainment was predicted by Boyd et al. (1985) when the original objectives were established, as Lake Kathlyn has historically contained concentrations of total phosphorus that exceed the objective.

Table 7: Summary of spring overturn phosphorus concentrations in Lake Kathlyn from 1985 to 2010 relative to the short-term objective value.

Monitoring Location	Total # of Samples	# of Samples ≤ 15 µg/L	# of Samples > 15 µg/L
Deep Station	64	12	52

Boyd et al. (1985) identified and explored numerous potential sources of phosphorus loading to the lake and suggested that the most significant sources were the inputs from streams and other surface water sources. The most significant of these was a drainage ditch that diverted dilute fire retardant from the Ministry of Forests' tanker base at the Smithers Airport directly into Lake Kathlyn. Historic samples of the effluent within the ditch returned total phosphorus concentrations over 1,500 µg/L. Based on the hydrological calculations that had been completed for the area, Boyd et al (1985) suggested that the runoff from the airport area would account for approximately 45% of Lake Kathlyn's annual phosphorus budget and was likely a major contributing factor to the elevated phosphorus concentrations observed in the lake.

Numerous complaints from concerned citizens, a report authored by R.S. Hawthorn in 1976, and the findings and recommendations of the original objectives report for the Smithers lakes led to the proposed amendment of the original permit to discharge held by the Ministry of Forests. The proposed amendments required that effluent from the air tanker base be pumped from a storage lagoon into a tanker truck and land-sprayed over a designated disposal area located within the southeastern portion of the Smithers Airport. Runoff from this area flows in an easterly direction through mature pine and willow forest which provides a significant source of nutrient uptake before the effluent reaches the Bulkley River, which is approximately 900 metres from the disposal site.

Proposed amendments were submitted to various government agencies for comment, and no concerns were noted, so the amendment was issued on June 8, 1983. Boyd et al (1985) suggested that it would take a few years for the effects of the amendment to be seen at the lake, but they were reasonably confident that this simple control measure would have a positive impact on the lake in the form of reduced total phosphorus concentrations and increased frequency of attainment of the phosphorus objective.

The aquatic plant harvesting efforts by the Lake Kathlyn Protection Society between 1997 to 2002 to remove great volumes of plant material should not be underestimated as contributing to a reduction in stored nutrients in the lake from 2004 to 2010.

A review of historic phosphorus data in Figure 8 suggests that phosphorus concentrations in the lake may be declining. Average spring overturn phosphorus concentrations have met the objective five times since 2003, with the results of spring overturn sampling in 2010 being the lowest on record. In 2014, phosphorus at spring overturn was not sampled; however, in the fall, it measured 7.2 µg/L.

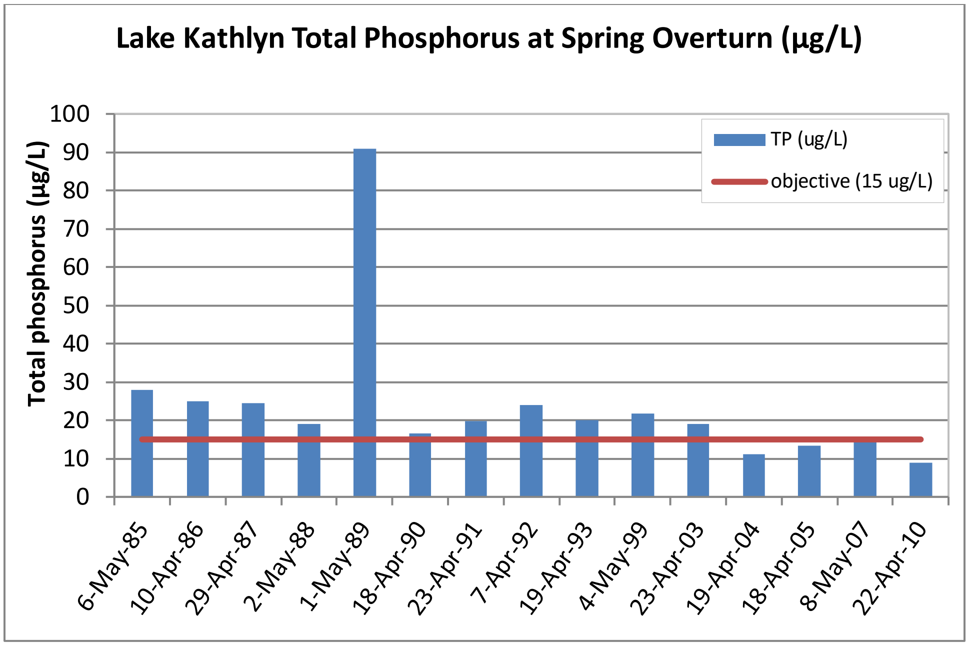


Figure 8. Lake Kathlyn total phosphorus at spring overturn from 1985 to 2010.

If the results of subsequent monitoring suggest that total phosphorus concentrations are decreasing, it is reasonable to expect total phosphorus at the deep station monitoring site to drop below the B.C. drinking water guideline of ≤ 10 µg/L during spring overturn. This applies to the average of three discrete samples collected from 1 metre below the surface, a middle depth and near the bottom of the lake.

Historic phosphorus levels in Lake Kathlyn are discussed further in section 6.4.

6.2.6 Metals

Total and dissolved metals concentrations have been measured between 20 and 37 times at the deep station site. Detailed analysis and comparison of the data to provincial guidelines revealed that metal concentrations are generally below the most stringent applicable guidelines (typically the protection of aquatic life), with many of the results being below laboratory detection limits. Exceptions to this general trend include occasionally elevated concentrations of dissolved aluminum, total arsenic, total manganese, and dissolved and total iron. Dissolved copper concentrations exceeded the long-term guideline when assessed against the 2019 B.C. Biotic Ligand Model (BLM) for copper.

Aluminum

Dissolved aluminum was sampled 20 times between 1985 and 2014. Only on one sample day, April 7, 1992, did dissolved aluminum (average concentration of 0.09 mg/L) exceed the current freshwater aquatic life, long term guideline of 0.05 mg/L. Given that the sample result in question marginally exceeds the aquatic life guideline and is well below the drinking water guideline of 0.2 mg/L, it is unlikely that dissolved aluminum concentrations at Lake Kathlyn are causing effects.

Arsenic

Total arsenic was sampled 34 times during the monitoring period. The results from four samples exceeded the aquatic life short term guideline of 5 µg/L. All these samples were collected from the bottom sampling depth and were associated with relatively high turbidity. It is probable that the elevated concentrations noted were caused by re-suspended sediment from the bottom of the lake, which was disturbed as a result of sampling activities. The total arsenic concentrations in the remainder of the samples were below detection limits or current guidelines. Total arsenic concentrations are not currently of concern at Lake Kathlyn.

Iron

Dissolved iron was sampled 17 times during the monitoring period. The results from five samples slightly exceeded the aquatic life guideline of 0.35 mg/L. The samples in question were collected on April 7, 1992, and represent five depths (0, 2, 4, 6, and 8 m). None of the samples collected since the 1992 sampling event have exceeded the guideline. Elevated concentrations appear to have been a one-time occurrence.

Total iron was sampled 34 times during the monitoring period. The results of five samples exceeded the aquatic life guideline of 1 mg/L. Three of the samples are associated with elevated turbidity values, likely attributed to sediment from the bottom of the lake being re-suspended due to sampling activities. The two remaining samples have total iron concentrations near guideline levels (1.08 mg/L and 1.04 mg/L).

The guidelines for dissolved and total iron were approved in 2008. The technical appendix which describes how these guidelines were set suggests that the relationships which influence the bioavailability and resulting toxicity of iron are highly complex. The guidelines are therefore quite conservative and include safety factors of at least 10 (Phippen et al, 2008). Given the relatively low magnitude of the exceedances, the robustness of the current aquatic life guidelines, and the fact that there are currently no recommended guidelines for drinking water, effects from iron concentrations are a low risk at Lake Kathlyn at this time.

Manganese

Total manganese was sampled 37 times during the monitoring period. The results of six samples exceeded the aquatic life guideline of 0.8 mg/L. Three of the samples are associated with elevated turbidity values and can likely be attributed to sediment from the bottom of the lake being re-suspended as a result of sampling activities. Two of the remaining samples have total manganese concentrations close to the guideline (0.81 and 0.82 mg/L). The remaining result did not include an analysis of turbidity. It is therefore unknown whether the elevated total manganese concentration noted is associated with the re-suspension of sediments, or if the concentration is indeed elevated. Considerable time has passed since the sample was collected (1992), and subsequent samples have been below guidelines. Therefore, there is a low probability that manganese concentrations are a concern at Lake Kathlyn.

Copper

Total and dissolved copper were sampled 34 and 20 times, respectively, at the deep station between 1985 and 2010. All total copper concentrations were below the aesthetic objective of < 1 mg/L for drinking water and ranged from 0.001 mg/L to 0.01 mg/L, with an average of 0.0034 mg/L.

The B.C. copper BLM (ENV, 2019) was used to calculate the dissolved copper short-term and long-term water quality guidelines of 6.6 µg/L and 1.1 µg/L, respectively, for the protection of aquatic life. Specifically, the copper water quality guidelines look-up table was employed using average lake values for pH of 7.3; DOC of 5.5 mg/L; and hardness of 30 mg/L. The guidelines for dissolved copper are meant to be applied to a mean calculated from five samples in 30 days; however, the current data set includes only single-day multi-depth samples, which creates some uncertainty concerning the assessment of dissolved copper data and supports continued monitoring of metals.

The 20 data points represent four spring sampling events and two late summer sampling events between 1992 and 2010. The average spring concentrations ranged from 1.92 µg/L on May 30, 2003, to 3.2 µg/L on April 7, 1992, and the late summer average concentrations were 2.49 µg/L on July 22, 2002, and 2.15

µg/L on August 19, 2010 (Table 8). The range of values for dissolved copper in Lake Kathlyn is within the background concentration range for sites in the Skeena Region (northwest B.C.) of 0.1 to 5 µg/L (ENV 2019). While no single concentration at the deep station exceeded the short-term guideline of 6.6 µg/L, all dissolved copper concentrations (1992-2010) exceeded the long-term guideline of 1.1 µg/L with the highest values measured in 1992. The guideline represents low-risk conditions and ambient concentrations exceeding guideline concentrations do not necessarily imply increased risk. However, the assessment of the potential impact of copper is inconclusive and requires more frequent monitoring during spring overturn.

Table 8: Summary of dissolved copper concentrations (µg/L) data for the Lake Kathlyn deep station, 1992-2010.

Date	Minimum	Average	Maximum	No. of samples	Depth range (m)
April 7, 1992	2	3.2	5	5	0.5 to 8
July 22, 2002	1.79	2.49	3.23	3	0.5 to 9.5
April 23, 2003	2.01	2.15	2.38	4	na
May 30, 2003	1.83	1.92	1.98	3	0.5 to 9.5
April 22, 2010	1.92	2.34	3.04	4	0.5 to 9.5
August 19, 2010	2.15	-	2.15	1	na

Possible sources of dissolved copper may include an internal source within the lake, or the glacial water being diverted to the lake. Data from Rescan (2006b) suggests high copper concentrations in Glacier Gulch Creek are natural and sourced at the glacier, and that concentrations decrease with increasing distance downstream in Glacier Gulch.

6.3 Biological Analysis

6.3.1 Coliform Bacteria

Fecal contamination of surface waters used for drinking and recreating can result in high risks to human health from pathogenic microbiological organisms, as well as significant economic losses due to the closure of beaches (Scott et al., 2002; as cited in Phippen and Epps, 2012). The direct measurement and monitoring of pathogens in water, however, is difficult due to their low numbers, intermittent and generally unpredictable occurrence, and specific growth requirements (Krewski et al., 2004; Ishii and Sadowsky, 2008; as cited in Phippen and Epps, 2012). To assess the risk of microbiological contamination from fecal matter, resource managers commonly measure fecal indicator bacteria levels (Field and Samadpour, 2007; Ishii and Sadowsky, 2008; as cited in Phippen and Epps, 2012). The most commonly used indicator organisms for assessing the microbiological quality of water are the total coliforms, fecal coliforms (a subgroup of the total coliforms more appropriately termed thermotolerant coliforms as they can grow at elevated temperatures), and *E. coli* (a thermotolerant coliform considered to be specifically of fecal origin) (Yates, 2007; as cited in Phippen and Epps, 2012).

Total and fecal coliforms have traditionally been used in the assessment of water for domestic and recreational uses. However, research has shown that there are many differences between the coliforms and the pathogenic microorganisms they are a surrogate for, which limit the use of coliforms as an indicator of fecal contamination (Scott et al., 2002; as cited in Phippen and Epps, 2012). For example, many pathogens, such as enteric viruses and parasites, are not as easily inactivated by water and wastewater treatment processes as coliforms are. As a result, disease outbreaks do occur when indicator bacteria counts are at acceptable levels (Yates, 2007; Haack et al., 2009; as cited in Phippen and Epps, 2012). Additionally, some members of the coliform group, such as *Klebsiella*, can originate from non-fecal sources (Ishii and Sadowsky, 2008; as cited in Phippen and Epps, 2012) adding a level of uncertainty when analyzing data. Measurement of total and fecal coliforms does not indicate the source of contamination, which can make the actual risk to human health uncertain; thus, it is not always clear where to direct management efforts.

The B.C. approved water quality guidelines for microbiological indicators were developed in 1988 and include *E. coli, Enterococcus spp., Pseudomonas aeruginosa*, and fecal coliforms. As small pieces of fecal matter in a sample can skew the overall results, the 90th percentiles (for drinking water) and geometric means (for recreation) are generally used to determine if the water quality guideline is exceeded for a site, as extreme values would have less effect on the data. The B.C. drinking water quality guideline for raw waters receiving disinfection only is that the 90th percentile of at least five weekly samples collected in 30-days should not exceed 10 CFU/100 mL for either fecal coliforms or *E. coli* (Warrington, 2001; as cited in Phippen and Epps, 2012).

Fecal coliform monitoring for Lake Kathlyn has taken place at three sites near private water intakes (Kathlyn #2, #3 & #4) and one site at a public beach (Kathlyn #1). Five weekly samples collected within thirty days represent a single sampling event (Table 9).

Table 9: Summary of fecal coliform sampling at Lake Kathlyn from 1988 to 2007.

Sample Site	Total # of Samples	Samples exceeding drinking water guideline (<10CFU/mL)
Kathlyn Lk #1 (beach)	7	**4**
Kathlyn Lk #2 (intake)	11	0
Kathlyn Lk #3 (intake)	11	**7**
Kathlyn Lk #4 (intake)	7	0

Recent studies have explored the limitations of using traditional fecal coliform analysis as an indicator of human fecal contamination of water. *E. coli* is now generally recognized as being a more specific indicator of human fecal contamination (Warrington, 2001). *E. coli* sampling at three Lake Kathlyn intake sites was initiated in 2001. Table 10 summarizes the results of *E. coli* monitoring at Lake Kathlyn.

Table 10: Summary of E. coli sampling at Lake Kathlyn between 2001 and 2014.

Sample Site	Total # of samples	Samples exceeding B.C. Drinking water guideline (< 10CFU/mL)	Samples exceeding Recreational water guideline (< 77 CFU/100 mL)
Kathlyn Lk #1 (beach)	3	**3**	0
Kathlyn Lk #2 (intake)	7	0	0
Kathlyn Lk #3 (intake)	7	**5**	**1**
Kathlyn Lk #4 (intake)	6	0	0

Although the fecal coliform and *E. coli* drinking water guidelines were met most of the time over the sampling period, Tables 9 and 10 illustrate that the possibility of fecal contamination from non-point sources still exists at Lake Kathlyn. In contrast, guidelines intended to protect recreational users were met every time fecal coliform samples were collected (geometric mean of five samples in 30 days <200 CFU), and on all but one occasion when *E. coli* samples were collected (geometric mean of at least five samples collected in 30-days should not exceed 77 CFU/100 mL).

Based on these findings, bacteria sampling should continue for Kathlyn Lake and the primary parameter for bacteria sampling should be *E. coli*. At intake sites, the 90th percentile of a minimum of five weekly *E. coli* samples collected within 30 days should not exceed 10 CFU/100 mL. At beach sites, the geometric mean of a minimum of five weekly *E. coli* samples collected within 30 days should not exceed 77 CFU/100 mL.

Samples should be collected from drinking water intakes as well as from established recreational bathing beaches. Sampling from numerous locations will help protect all recreational lake users, not just those who recreate at established beaches.

6.3.2 Phytoplankton and Chlorophyll *a*

Water quality has traditionally been based on the physical, chemical, and bacteriological characteristics of the water body in question. Physical and chemical parameters have been the primary focus for characterizing the conditions in a water body because they are relatively simple and inexpensive to sample, and the resulting data analysis and interpretation are readily understood. Biological indicators, which are fundamental to the overall health of a given water body, have typically been underutilized due to the high level of specialized knowledge required to interpret sampling results and the difficulty associated with applying the results from the data in a quantitative manner (Epps and Phippen, 2011).

Baillie and Buchanan performed a preliminary assessment of Lake Kathlyn's phytoplankton species composition and density in 1973. Boyd et al. (1985) conducted further sampling during the preparation of the original objectives report for the Smithers lakes. The results of both parties' limited sampling suggested that Lake Kathlyn was productive and supported algal species typical of other eutrophic lakes (1974 and 1985 respectively). In August 2018, measurable concentrations for seven algal taxa were identified in a single phytoplankton sample collected by the B.C. Lake Monitoring Network (Figure 9). The dominant taxa were *Anabaena sp.*, (72.7%) which are recognised as indicators of mesotrophic to eutrophic trophic conditions (Rawson, 1956).

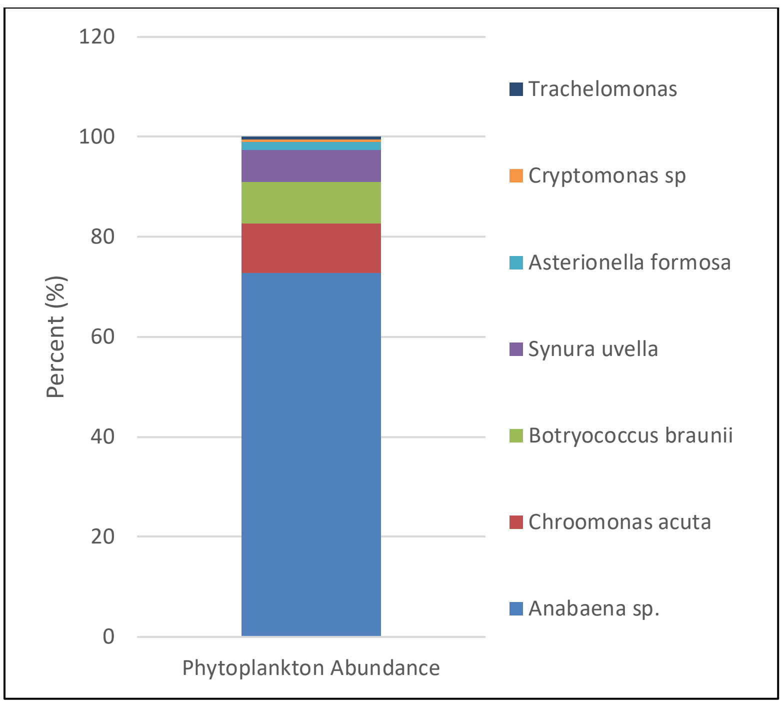


Figure 9. Lake Kathlyn 2018 dominant phytoplankton species.

Despite the overall lack of phytoplankton data currently available, if phosphorus is in a declining trend (as suggested in section 6.2.5), phytoplankton species composition will likely respond by shifting to the more desirable mesotrophic/oligotrophic species. Future sampling should consider collecting and interpreting phytoplankton data as an indicator of change and trophic status.

Chlorophyll *a* is a measure of the photosynthetic pigment present in a water sample. Most of this pigment is associated with the phytoplankton present in the water. Chlorophyll *a*, therefore, acts as a surrogate for detailed phytoplankton sampling and provides a basic indicator of a lake's productivity level (Epps and Phippen, 2011). Concentrations of chlorophyll *a* greater than 15 µg/L are generally considered to indicate high productivity (Epps and Phippen, 2011).

Chlorophyll *a* was measured 46 times in Lake Kathlyn between 1985 and 2002. Most samples were collected during the spring and summer months. Results range from a maximum recorded value of 27.2 µg/L to a low of 2.0 µg/L, with a mean value of 8.0 µg/L, indicating relatively high productivity.

The relationship between spring overturn total phosphorus concentrations and mean summer chlorophyll *a* has been studied extensively and is well documented. Nordin and McKean (1984) explored this relationship within B.C. lakes and established a direct correlation between the two parameters. Based on Nordin and McKean's findings, the expected mean summer chlorophyll *a* concentration at Lake Kathlyn would be between 3.5 µg/L and 4.0 µg/L if the proposed spring overturn phosphorus objective of 15 µg/L was met.

Recent data shows a trend toward the attainment of the phosphorus objective (Section 6.2.5). In time, total chlorophyll *a* and phosphorus data being collected by the Provincial Lake Monitoring Program and through future attainment monitoring may provide the information needed to further investigate the above correlation and predicted mean summer chlorophyll *a* concentration at Lake Kathlyn.

6.4 Sediment Chemistry

In 2000, sediment cores were taken from Lake Kathlyn and sent to Queen's University for analysis. The analysis indicated that sedimentation rates have not varied much over 100 years. It also showed an increase in organic matter that started about 1900, which can be attributed to several factors including increased in-lake production of organic matter, increased wash of organic matter into the lake, or decreases in the load of inorganic matter to the lake. Post-1945, the cores showed an unprecedented increase in meso-eutrophic plankton from the previously dominant oligotrophic plankton. These factors suggest that the trophic status of the lake has changed slightly over the past 70 years i.e. the lake was historically oligotrophic.

The existing phosphorus objective of 15 µg/L discussed in section 6.2.5 is consistent with the historical inferred phosphorus concentration from the sediment core; achieving this level would place Lake Kathlyn in the lower mesotrophic to oligotrophic range (Wetzel, 2001). Further monitoring of spring overturn phosphorus levels is required to verify if perceived declines in phosphorus are an established trend.

7. CONCLUSIONS

The data continues to indicate Lake Kathlyn is eutrophic. It is a relatively small, shallow lake with few freshwater inputs. It experiences high summer surface temperatures, anoxic bottom waters, and relatively high productivity, as indicated in part by the concentrations of phosphorus and chlorophyll *a*.

To avoid potential risk to aquatic life and lake users from reduced flows, it is important that the seasonal diversion of glacial water into the lake is maintained.

Dissolved copper concentrations in the lake may be two times the long-term guideline for the protection of aquatic life. The assessment of potential impacts from copper is inconclusive and requires additional monitoring during spring overturn.

Identified water uses for Lake Kathlyn that are sensitive and should be protected are raw drinking water, recreation, aquatic life, and wildlife.

Management efforts like the intensive volunteer aquatic plant harvesting program can aid in slowing down, or reversing, the lake's eutrophication processes through the removal of contaminant and nutrient sources. However, the main influence on water chemistry is residential development around the lakes. Therefore, additional management actions to address non-point sources may need to be considered to minimize potential impacts on the water quality in Lake Kathlyn and protect the priority uses of the lake.

Most options to treat the causes of cultural eutrophication involve reducing point and non-point sources of external nutrient and sediment inputs by implementing specific land use management practices. These measures are usually doubly rewarded since any reduction in contaminant loading to a water body as a result of land use management practices often reduces the nutrients available for internal cycling over the long term and can maintain or extend the effectiveness of in-lake controls (Gibbons, 1994). Several management practices to address residential inputs were originally identified in the 1995 Lake Kathlyn management plan produced for the Lake Kathlyn Protection Society (Rysavy, and Sharpe, 1995). These include public education, source mapping, maintenance and remediation of individual onsite sewage disposal systems, and the control of inputs from new development.

8. MONITORING RECOMMENDATIONS

The recommended water quality monitoring program for Lake Kathlyn is summarized in Table 11. It is recommended that future attainment monitoring occur once every five to ten years, unless land-use activities, such as forestry or development, or other potential pollution sources indicate a need for greater frequency. Attainment sampling is generally conducted throughout the open water period.

Table 11: Proposed schedule for future water quality monitoring of Lake Kathlyn.

Frequency and timing	Characteristic to be measured
Deep station site (depths sampled: surface, mid-depth and 1 m from bottom) – 5 samples in 30 days during spring overturn and monthly summer sampling	pH, specific conductivity, total suspended solids, turbidity, true colour, TOC, DOC, nitrogen species, total phosphorus, total and dissolved metals (spring overturn only), chlorophyll *a*, DO/temperature profile and Secchi disc
Deep station site – minimum of 12 evenly spaced samples between ice-off and ice-on	DO/temperature profile and Secchi disc
Deep station site (1 m below surface only) – monthly summer sampling	Chlorophyll *a*
Intake sites, recreational beaches and offshore of Watson's Landing strata subdivision – 5 samples in 30 days	pH, specific conductivity, total suspended solids, turbidity, true colour, and *E. coli*
Deep station sites - twice per year (spring overturn and summer)	Phytoplankton and zooplankton

Attainment monitoring should consist of full water chemistry sampling at the deep station. Parameter sampling methods should align with those currently used by the B.C. Lake Monitoring Network for provincial ambient water quality monitoring[4].

The deep station samples, one discrete surface grab sample (1 m below the surface and) and one bottom discrete grab sample (1 m above the sediment surface) should be analyzed for general water chemistry (including pH, specific conductivity, TSS, turbidity, true colour, TOC, DOC, and nutrients). Chlorophyll *a* should be collected from 1 m below the surface at the deep station monitoring location. This sampling should occur once weekly for five consecutive weeks in 30 days during spring overturn, and a minimum of once per month throughout the summer lake stratification. Physical measurements of dissolved oxygen and temperature (taken at 1 m increments throughout the water column) and water clarity should be measured during spring overturn and continued for a minimum of 12 evenly spaced samples collected until ice-on.

Bacteriological samples (*E. coli*) should be collected at the intake and beach sites once weekly for five consecutive weeks in 30 days both in late summer and mid-fall. These samples should also be analyzed for general water chemistry (pH, specific conductivity, total suspended solids, turbidity, and true colour).

Phytoplankton and zooplankton samples should be collected twice per sample year, at spring overturn and during the summer.

Finally, sampling locations should include the high-density residences in the shallow bay to the east of the Kathlyn #4 site and offshore of the Watson's Landing strata subdivision (EMS E283209).

Possible sources of dissolved copper may include an internal source in the lake, or the glacial water being diverted to the lake. To address the latter, a one-time monitoring recommendation of the glacial water diversion is suggested in combination with a comprehensive review of Glacier Gulch Creek data from the B.C. Environmental Monitoring System (EMS) database and associated water quality reports[5]. Specifically, monitoring should include five in 30 days sampling during the spring and summer peak flow when Club Creek is flowing into Kathlyn Lake. The parameters to be sampled are the same as the physical and chemical parameters sampled at the deep station during spring overturn (Table 11).

[4] B.C. Lake Monitoring Network for provincial ambient water quality monitoring https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/lake-monitoring/bc-lake-monitoring-network

[5] B.C. ENV Water Quality Assessment and Objectives for the Toboggan Creek Watershed Technical Report March 2012 DRAFT and Rescan Environmental Services Ltd. 2006. Raw data from the water quality monitoring program related to the Davidson Project. Vancouver, B.C.

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APPENDIX A: SUMMARY OF WATER QUALITY DATA

Table A 1: Summary of general water chemistry for Lake Kathlyn's deep station (EMS 1131007), 1985 to 2010.

Parameter (mg/L)	Maximum	Minimum	Average	Std. Dev	No. of samples	BC Guideline ($AL^{ST,LT}$ /DW/OWQ)[1,2]
Ag-D (mg/L)	0.01000	<0.000005	0.00251	0.00444	20	
Ag-T (mg/L)[3]	0.01000	<0.000005	0.00187	0.00395	27	0.05µg/ AL^{LT}
Al-D (mg/L)	0.11000	0.00240	0.03649	0.03679	20	0.05mg/L AL^{LT}
Al-T (mg/L)	0.44700	<0.0182	0.09473	0.09639	30	
Alkalinity Total 4.5 (mg/L)	28.40000	10.00000	17.52941	4.11032	17	
Alkalinity pH 8.3 (mg/L)	1.00000	<0.5	0.75000	0.26726	8	
ammonia Dissolved (mg/L)	0.66000	<0.005	0.06788	0.12824	68	
Ammonia (mg/L)	0.07000	<0.01	0.05600	0.02608	5	
As-D (mg/L)	0.04000	<0.00083	0.01132	0.01703	20	
As-T (mg/L)	0.30000	<0.00086	0.03394	0.07541	34	5µg/L AL^{ST}
B--D (mg/L)	0.05000	<0.008	0.02900	0.02214	10	
B--T (mg/L)	0.07400	<0.008	0.05236	0.01696	11	1.2mg/L AL^{LT}
Ba-D (mg/L)	0.02390	0.00551	0.01280	0.00425	20	
Ba-T (mg/L)	0.03490	0.00642	0.01517	0.00701	27	1mg/L AL^{LT}
Be-D (mg/L)	0.00100	<0.00001	0.00026	0.00044	20	
Be-T (mg/L)	0.00100	<0.00001	0.00020	0.00039	27	0.13µg/L AL^{LT} 4µg/L DW
Bi-D (mg/L)	0.02000	<0.000005	0.00502	0.00887	20	
Bi-T (mg/L)	0.02000	<0.000005	0.00374	0.00790	27	
Bromide Dissolved (mg/L)	0.05000	<0.05	0.05000	0.00000	8	
Ca-D (mg/L)	8.08000	4.90000	6.53250	0.99559	20	
Ca-T (mg/L)	8.44000	4.74000	6.56471	0.96072	34	
Carbon Total Organic (mg/L)	5.30000	2.30000	3.81667	0.74301	18	<4mg/L OWQ
Cd-D (mg/L)	0.00200	<0.000007	0.00052	0.00088	20	
Cd-T (mg/L)	0.01000	<0.000007	0.00210	0.00378	34	0.01µg/L AL^{LT}
Chlorophyll A (mg/L)	0.02720	0.00200	0.00803	0.00585	46	
Chlrid:D (mg/L)	7.90000	0.80000	3.02727	1.52731	22	250mg/L DW
Co-D (mg/L)	0.00300	<0.000005	0.00078	0.00131	20	
Co-T (mg/L)[3]	0.10000	<0.000005	0.02112	0.04078	34	0.004mg/L AL^{LT}L
Color True (Col.unit)	60.00000	<5	18.40741	14.42681	54	
Cr-D (mg/L)	0.00200	<0.0001	0.00063	0.00082	20	
Cr-T (mg/L)	0.01000	<0.0001	0.00247	0.00395	34	0.05mg/L DW
Cu-D (mg/L)	0.00500	0.00179	0.00247	0.00082	20	0.0011 mg/L BLM AL^{LT}
Cu-T (mg/L)	0.01000	<0.001	0.00342	0.00203	34	
Fe-D (mg/L)	0.55800	0.02500	0.32965	0.16334	17	0.35mg/L AL^{ST}
Fe-T (mg/L)	5.46000	0.10000	0.93653	1.22016	34	1.0mg/L AL^{ST}
FluordeD (mg/L)	0.07000	0.04000	0.05200	0.00775	15	0.8mg/L AL^{ST}

Parameter (mg/L)	Maximum	Minimum	Average	Std. Dev	No. of samples	BC Guideline ($AL^{ST,LT}$ /DW/OWQ)[1,2]
Hardness Total (D) (mg/L)	23.17543	15.90000	20.47975	2.33248	16	
Hardness Total (T) (mg/L)	27.10669	15.78906	20.86064	2.75643	22	
K--D (mg/L)	1.40000	0.41000	0.85800	0.32754	10	
K--T (mg/L)	1.20000	0.42000	0.88182	0.26076	11	
Li-D (mg/L)	0.00050	<0.00005	0.00024	0.00020	15	
Li-T (mg/L)	0.00150	<0.00005	0.00036	0.00041	22	
Mg-D (mg/L)	1.98000	0.88000	1.43100	0.32382	20	
Mg-T (mg/L)	2.04000	0.90000	1.42471	0.28149	34	
Mn-D (mg/L)	1.25000	0.00033	0.26575	0.27437	20	
Mn-T (mg/L)	2.20000	0.00534	0.44768	0.57168	37	0.8mg/L AL^{ST}
Mo-D (mg/L)	0.02120	0.00600	0.01269	0.00422	20	
Mo-T (mg/L)	0.03990	<0.006	0.01462	0.00710	34	0.088mg/L DW
N.Kjel:T (mg/L)	2.79000	0.08000	0.42791	0.41601	43	
NO2+NO3 (mg/L)	0.02000	0.00000	0.00600	0.00894	5	
Na-D (mg/L)	3.98000	1.49000	2.93900	1.05399	10	
Na-T (mg/L)	4.35000	2.93000	3.89833	0.49443	6	
Ni-D (mg/L)	0.00800	<0.00005	0.00212	0.00348	20	
Ni-T (mg/L)	0.05000	<0.00008	0.01159	0.02004	34	0.025µg/L AL^{LT}
Nitrate (NO3) Dissolved (mg/L)	0.10300	<-0.001	0.03660	0.03368	42	
Nitrate + Nitrite Diss. (mg/L)	0.37000	<0.002	0.05493	0.06884	83	
Nitrogen (Kjel.) Tot Diss (mg/L)	0.42000	0.27000	0.34167	0.05811	6	
Nitrogen - Nitrite Diss. (mg/L)	0.00600	<0.002	0.00437	0.00125	83	
Nitrogen Organic-Total (mg/L)	0.34000	<0.02	0.19273	0.13192	11	
Nitrogen Total (mg/L)	1.09000	0.09000	0.34452	0.17589	42	
Nitrogen Total Dissolved (mg/L)	0.51800	<0.302	0.38917	0.09109	6	
Ortho-Phosphate Dissolved (mg/L)	0.05900	<0.001	0.01000	0.01574	80	
P--T (mg/L)	0.76400	<0.006	0.03055	0.07460	110	<0.015mg/L OWQ
Pb-D (mg/L)	0.02000	<0.000005	0.00502	0.00887	20	
Pb-T (mg/L)	0.10000	<0.00001	0.00642	0.01799	34	
Phosphorus Tot. Dissolved (mg/L)	0.04600	<0.002	0.01007	0.01119	61	
Res:Tot (mg/L)	76.00000	<30	47.90909	13.84525	11	
Residue Filterable 1.0u (mg/L)	60.00000	26.00000	37.63636	11.41291	11	
Residue Non-filterable (mg/L)	17.00000	<1	5.10526	3.46241	19	
S--D (mg/L)	1.59000	1.52000	1.56200	0.02950	5	
S--T (mg/L)	2.10000	1.51000	1.63667	0.22844	6	
Sb-D (mg/L)	0.01500	<0.000038	0.00381	0.00663	20	
Sb-T (mg/L)[3]	0.01500	<0.000042	0.00284	0.00591	27	0.006mg/L DW
Se-D (mg/L)	0.03000	<0.00004	0.00762	0.01326	20	
Se-T (mg/L)[3]	0.03000	<0.00004	0.00569	0.01181	27	0.002mg/L AL^{LT}
Si-D (mg/L)	3.88000	1.69000	2.93800	0.96669	10	
Si-T (mg/L)	4.26000	1.99000	3.26800	0.89518	10	

Parameter (mg/L)	Maximum	Minimum	Average	Std. Dev	No. of samples	BC Guideline ($AL^{ST,LT}$ /DW/OWQ)[1,2]
Sn-D (mg/L)	0.02000	<0.00001	0.00503	0.00887	20	
Sn-T (mg/L)	0.02000	<0.00001	0.00372	0.00791	27	
Specific Conductance (uS/cm)	81.00000	44.00000	61.05882	8.26213	51	
Sr-D (mg/L)	0.04200	0.02210	0.03224	0.00599	20	
Sr-T (mg/L)	0.04400	0.02190	0.03219	0.00613	27	
Sulfate:D (mg/L)	10.00000	5.00000	6.53960	1.09477	25	128mg/L AL^{LT}
Te-D (mg/L)	0.02000	<0.02	0.02000	0.00000	5	
Te-T (mg/L)	0.02000	<0.02	0.02000	0.00000	5	
Ti-D (mg/L)	0.00300	<0.0005	0.00184	0.00124	10	
Ti-T (mg/L)	0.00500	<0.0005	0.00285	0.00217	11	
Tl-D (mg/L)	0.00300	<0.000002	0.00075	0.00133	20	
Tl-T (mg/L)[3]	0.00900	<0.000002	0.00101	0.00237	27	0.0008 mg/L AL^{LT}
Turbidity (NTU)	26.60000	0.18000	4.21121	4.62991	66	Max <5NTU, Avg <1NTU OWQ
U--D (mg/L)	0.00001	<0.000002	0.00000	0.00000	15	
U--T (mg/L)	0.00003	<0.000002	0.00001	0.00001	22	0.0085mg/L AL^{LT}
V--D (mg/L)	0.00300	<0.00006	0.00085	0.00127	20	
V--T (mg/L)	0.01000	<0.00011	0.00267	0.00391	34	
Zn-D (mg/L)	0.01100	<0.0001	0.00216	0.00271	18	0.033mg/L AL
Zn-T (mg/L)	0.02200	<0.0005	0.00481	0.00535	34	0.0075mg/L AL^{LT}
Zr-D (mg/L)	0.00300	<0.0001	0.00157	0.00151	10	
Zr-T (mg/L)	0.00300	<0.0001	0.00155	0.00153	10	
pH (pH units)	7.60000	6.50000	7.18636	0.28740	44	

[1] AL = Aquatic Life (ST = Short term, LT = Long term), DW= Drinking Water, OWQ = Objectives for Water Quality derived from B.C.'s ambient water quality guidelines

[2] Parameter units are in mg/L and WQG and OWQ units are in mg/L or µg/L

[3] Parameter with variable decreasing method detection limits (MDLs) over the sampling period

Table A 2: Summary of general water chemistry resulting from the 2014, 5 in 30 days sampling at EMS 207548 (Kathlyn Lk #1), EMS 207549 (Kathlyn Lk #2), EMS 207550 (Kathlyn Lk #3) and EMS 207551 (Kathlyn Lk #4).

Parameter	Min	Average	Max	Std Dev	No. of samples
Field Conductivity (µS/cm)	45.1	45.9	48.4	0.80	14
Total Organic Carbon (C)(mg/L)	2.39	4.21	5.84	1.88	4
Field Dissolved Oxygen (mg/L)	8.4	8.78	9.4	0.26	16
True Colour (TCU)	5	5.3	10	1.25	20
Field Temperature (°C)	13.3	16.2	19.1	2.13	20
LAB pH	7.22	7.34	7.46	0.08	20
FIELD pH	6.25	6.72	6.98	0.21	16
Turbidity (NTU)	0.57	0.86	1.11	0.16	20
E. coli (cfu/100mL)	1	5	15	4.63	20
Enterococcus spp. (cfu/100mL)	1	8	33	8.58	20
Pseudomonas aeruginosa (cfu/100mL)	<1	n/a	<1	n/a	20

Table A 3: Summary of phytoplankton resulting from the August 30, 2018 sample at EMS 1131007 (Kathlyn Lk deep station).

Taxa	Concentration (cells/mL)	Percent Abundance
Anabaena sp.	2474.2	72.8
Chroomonas acuta	338.2	9.9
Botryococcus braunii	284.8	8.4
Synura uvella	213.6	6.3
Asterionella formosa	53.4	1.6
Cryptomonas sp	17.8	0.5
Trachelomonas	17.8	0.5