An Integrated Lake Monitoring Framework for British Columbia

Prepared for:

Ministry of Environment and Climate Change Strategy

Final Report

Prepared by:

Norm Zirnhelt, Rick Nordin, Dawn Roumieu, Heather Leschied, Kat Hartwig

Table of Contents

Acknowledgements

The authors would like to thank the following ENV staff for their valuable input to this report: Deb Epps, Mike Sokal, Jody Fisher, Chris Swan, Lisa Torunski, Greg Warren, and Marge Sidney.

We would also like to thank Michele Sam of the Ktunaxa First Nation for an overview perspective on First Nations involvement in water stewardship.

Brad Peter, Executive Director of the Alberta Lake Management Society was very helpful with regard to how their lake program works in Alberta.

Executive Summary

The BC Ministry of Environment & Climate Change Strategy (ENV) contracted with the BC Lake Stewardship Society (BCLSS) to develop an integrated framework that incorporated the existing BCLSS volunteer monitoring framework, known as the BC Lake Stewardship and Monitoring Program (BCLSMP), with the BC Lake Monitoring Network (BCLMN). A joint proposal was developed and submitted by the BCLSS and Living Lakes Canada (LLC), which formed the terms of reference for this report.

Existing lake monitoring programs in BC were reviewed to ascertain whether they could contribute to an integrated monitoring framework. In addition, First Nations and lake stewardship organizations' activities related to monitoring in the province were also looked at. Programs reviewed included the Provincial Lakes Monitoring Network, the Department of Fisheries and Oceans, Lake Pulse Canada, Living Lakes Canada, the University of BC Okanagan, and the Fraser Basin Council.

This year (2018) is the 4th year of the BCLMN and the 3rd year of coordinated province-wide sampling. The lakes were prioritized by using a priority ranking tool based on values (e.g., drinking water supply, fisheries, recreation, tourism), risks (e.g., development), and known or potential impacts. At times, ENV has had difficulty in delivering the entire program due to limited resources.

A table was developed illustrating what different groups are doing in the way of monitoring in BC. The table included lakes in the BCLMN and potentially being added in 2019, as well as lakes that are not currently part of the BCLMN, but have the potential to be monitored by stewardship groups and included in the BCLMN. In addition, the table indicates whether there is a local lake stewardship group and whether they are actively monitoring.

The needs of the BC stewardship sector were reviewed based on experience at ENV, BCLSS over the course of the BCLSMP, and other CBM groups surveyed by LLC. Major needs identified were found to be:

- Support with forming a stewardship group
- Training on how to do monitoring correctly
- Personal contact for training and other aspects of lake management
- Information on lake ecology including enhanced training
- Auditing to correct problems
- Timely reporting (annually in some cases) on the data they have collected to help keep them engaged
- Connections with other groups who may have experience with similar lake management issues
- Assistance with identifying funding sources for projects and equipment

- Equipment available to borrow e.g., DO/T meters and/or assistance with purchasing equipment (i.e. type of DO meter, funding sources, and where to purchase)

It was determined that expansion of the work of the volunteer sector will require more support in generating interest in and forming stewardship groups, and a number of required tasks were identified with regard to working with stewardship groups:

- Determine resources, time commitment
- Develop model/structure for adding/interacting with stewardship groups
- Develop tools
- Training to ensure data is collected properly/accurately (BC Field sampling manual)
- Develop a systematic audit program to evaluate sampling techniques and ensure quality control and quality assurance
- Develop data management & reporting out

The capacity for lake monitoring and stewardship was reviewed. In cooperation with the BCLSS, 80 stewardship groups and 39 individuals have taken part in volunteer lake monitoring on 119 lakes throughout the province. Lake stewardship is variable throughout the province and there are many individuals who conduct monitoring but are not part of a stewardship group.

A potential area of stewardship capacity is the First Nations of BC. Indigenous communities in Canada hold a wealth of traditional environmental knowledge (TEK) on water and environmental health. This knowledge is valuable and important for Citizen Based Monitoring (CBM), whether it is combined with other forms of knowledge or not. Increasingly, CBM programs are endeavoring to bring together traditional knowledge and western science to develop rich, robust and holistic programs that draw on the strengths of both forms of knowledge. Indigenous communities are well positioned to monitor and collect data. collaborate with other entities, and create binding agreements with other parties..
Training and support needs of the volunteer sector were identified as the need for support for stewardship initiatives, assistance with forming and running a group, safety training as well as technical training for monitoring. Resources for the forgoing training were reviewed and updated to assist the volunteer sector in these areas going forward. These resources were developed as manuals and power point presentations. The success of the BCLSS LakeKeepers training course was noted through which the BCLSS held 24 multi-day sessions throughout the province from 2011-2016.

Reporting of lake data was discussed and it was noted that it is important that the data receive some level of written interpretation, so that the results are made available to the public, the partners in the sampling program, and other agencies. A number of possible ways of doing this were suggested including an overall report on the sampling for a calendar year posted on the

ENV website in a reasonable time. This could include summary tables for each lake with water chemistry results.

Examples of how various jurisdictions, including BC, have worked with and funded the volunteer stewardship sector for lake monitoring and assessment were examined. Options for integrating the volunteer sector with the BCLMN are presented.

Many different state and provincial jurisdictions were reviewed and common to all of these was a level of core funding provided by the province or state, to the volunteer sector. The results of this review was three options for the province to consider with regard to how to integrate the existing BCLSS volunteer monitoring framework with the BC Lake Monitoring Network. Option 1, the preferred and recommended option, is a modified BCLSMP.

The BCLSS / LLC could provide staff that could assist in several areas:

(a) Assistance with field sampling when ENV staff is not available. BCLSS / LLC staff could be thoroughly trained in the details of the BCLMN and be available on short notice to either do the lake sampling independently or assist ENV staff if a second team member were not available. This assistance could be set up to provide a trained technical person on 1-3 weeks' notice to assist with time sensitive water quality sampling.
(b) Establishing stewardship contacts. As part of the expansion or optimization of the BCLMN, BCLSS / LLC could develop and facilitate contacts and training of community monitoring groups so that they might be integrated efficiently into the Network. This might involve LakeKeepers workshops or training for specific sampling to develop water quality guidelines.
(c) Data organizing, checking editing and data entry. A notable gap in the BCLMN is a capability for data compilation and editing, data quality control assessment, and data entry. BCLSS could provide a trained staffer with appropriate background, education, and experience to review BCLMN data as it is reported
(d) Report write-up, public reporting, and community interaction. BCLSS has been involved in writing lake reports that summarize water quality sampling results for many years as part of the BCLSMP.

The cost for this option would be approximately $100,000/year and would include one full time staff member for the BCLSS / LLC partnership – an individual with appropriate university training, as well as training for the specific tasks that would be undertaken (field sampling, data analysis, report writing). This amount would also cover the cost of a part time office employee who would also be technically trained but specifically responsible for tasks like data entry, co-ordination, communication, and general administration.

Several options for long term funding of the preferred option were suggested. These were grants from ENV, allocation of water related revenue, and creative sentencing.

The report concludes with a proposal for set up of the integrated program following the recommended option (Option1) and specific deliverables are proposed for 2018/19, subject to funding by ENV to BCLSS.

List of Figures

List of Tables

1.0 Introduction

The BC Ministry of Environment & Climate Change Strategy (ENV) has contracted with the BC Lake Stewardship Society (BCLSS) to develop an integrated framework that incorporates the existing BCLSS volunteer monitoring framework[1] with the BC Lake Monitoring Network. Detailed terms of reference (Appendix A) were developed by the ENV and BCLSS. A joint proposal was developed and submitted by the BCLSS and Living Lakes Canada (LLC).

2.0 Existing Lake Monitoring Programs in BC

In order to assess monitoring needs and determine how to integrate lake monitoring programs, it is instructive to examine what these programs entail. In addition, it is valuable to look at what First Nations and non-First Nations communities, as well as what other lake stewardship organizations are doing in the province. These programs were reviewed to ascertain whether they could contribute to an integrated monitoring framework. The following sections summarize the major monitoring programs occurring in the province[2].

In April 2017, the BC Water Funders Collaborative commissioned a BC Water Monitoring Landscape Scan (Luttmer, 2018) to inform discussions on a shared vision for water monitoring and reporting in BC. The following is an excerpt from that report, authored by Carol Luttmer.

> *There is consensus that collection and accessibility of water monitoring data are vital for effective watershed management and currently there is insufficient data readily available. There is also consensus that it is an opportune time for an inclusive discussion on water monitoring and reporting with the implementation of BC's new Water Sustainability Act. However, there lacks a holistic synopsis about water monitoring and reporting to inform these discussions.*
>
> *This Scan collected information on water monitoring and reporting in BC through a literature review, internet research, and interviews with personnel in the freshwater community in order to provide a high-level summary of who is collecting what data at which locations and how. This Scan included monitoring and reporting of the quality and quantity of surface water and groundwater and focused on status and trend monitoring. It did not include other environmental components that are necessary to fully understand the state of water resources such as mapping of wetlands and aquifers, water withdrawals, glaciers, snowpack, and climate. This Scan identified the province-wide monitoring networks and examples of local, regional and issue-specific monitoring initiatives, including 122 monitoring programs and 42 data hubs that are summarized in a database.*

[1] The BCLSS volunteer monitoring framework is known as the BC Lake Stewardship and Monitoring Program (BCLSMP)

[2] Monitoring by private corporations is not included

Monitoring data are being collected and shared by all levels of government (local, provincial, federal), First Nations, community-based monitoring groups, industry, academia, and other non-government organizations. ***Over half of the monitoring and reporting initiatives identified in this Scan involved partnerships*** *- they were either directly collaborating or collecting and sharing data as part of a network. This highlights the need for frameworks to facilitate collaboration and information sharing.*

The scan compiled readily available information on who is collecting data and where, however, it is by no means comprehensive. There are many additional programs managed and delivered by industry, individuals, and academic institutions, which are not included. The scan emphasizes the need for collaboration and information sharing in order to fill important water data needs for the province. The following map shows the location of long-term surface water quality programs in BC delivered either via the BCLMN or by stewardship groups.

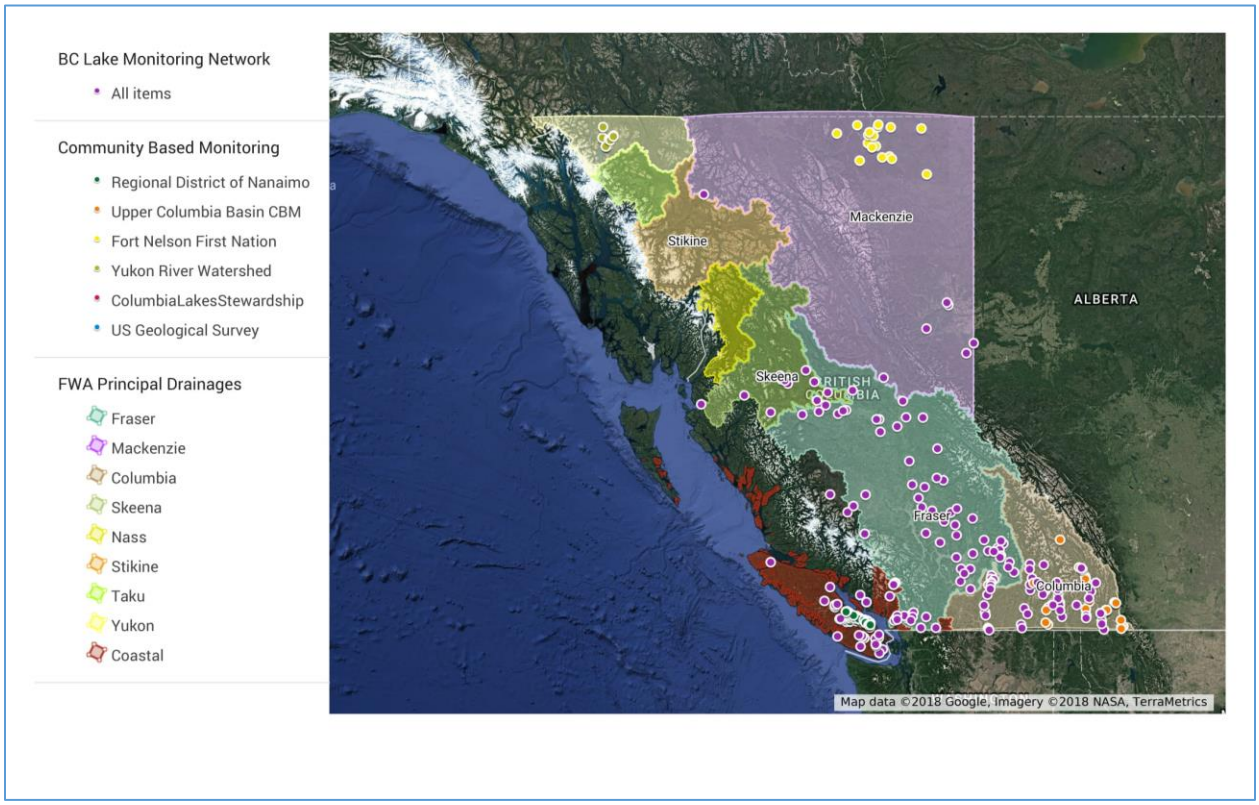

Figure 1: BC Lake Monitoring Network and Community Based Monitoring Map

2.1 Provincial Lakes Monitoring Program

Mike Sokal (2018), lake monitoring program co-ordinator for the Ministry of Environment and Climate Change Strategy (ENV) has provided the goals of the provincial lake monitoring program (BC Lake Monitoring Network or BCLMN):

- To determine background water quality of BC lakes to provide a baseline for environmental assessment, and assess the status and trends in response to watershed and climate change, pollution control and other management actions.
- To assess the potential cumulative risks to BC lakes and to evaluate the effectiveness of regulations around high priority initiatives that are underway in the province (e.g., LNG, mining, and built communities).
- To evaluate water quality status to established Water Quality Objectives for key parameters, and determine trophic status.
- To provide accessible, accurate and timely water quality data for BC lakes to inform decision makers within government, industry, and the public.
- To develop partnerships with stewardship groups and other programs such as BCLSS, to provide a strategic co-ordinated approach to provincial lake sampling.

Sokal (2018) also provided the following description of the Provincial Lake Water Quality Monitoring Strategy:

- Province-wide program delivery of lake monitoring and stewardship functions
  - Provide a strategic co-ordinated approach to lake monitoring across the province
  - Development and implementation of a cost-effective, science-based provincial lakes monitoring network
- Setting priorities, determining at risk water bodies, and identifying resource gaps
  - Development of priority ranking tool for monitoring BC lakes (values, risks, & impacts)
- Consistent approach
  - Standardization of lake sampling technique and effort
- Co-ordination/ integration with other groups and stakeholders
  - Promote, maintain and develop relationships with stewardship groups, BCLSS, and other groups and partner organizations

- Reporting out
    - Provide usable information and clear communication of findings to the public, stakeholders, and both internal and external decision makers

This year (2018) is the 4th year of the BCLMN and the 3rd year of coordinated province-wide sampling. The lakes were prioritized by using a priority ranking tool based on values (e.g., drinking water supply, fisheries, recreation, tourism), risks (e.g., development), and known or potential impacts. At times, ENV has had difficulty in delivering the entire program due to limited resources (Epps, 2018, Personal Communication). Currently, only approximately half of the program lakes are being monitored.

2.2 Department of Fisheries and Oceans

The Department of Fisheries and Oceans (DFO) conducts water quality monitoring associated with assessments of fish production, on a number of salmon nursery lakes throughout the province (e.g., Quesnel, Babine, Stuart, Francois, Harrison, Shuswap, Adams, Mabel, and Chilko lakes). However, the timing and parameters are not consistent with those of the ENV whose focus is more on eutrophication, habitat, or development studies, rather than fish. An exception might be Kootenay and Arrow lakes where fertilization (nutrient addition) is taking place (Sokal, 2018, Personal Communication).

However, there could be an opportunity for collaboration with more formal communication with DFO biologists. For example, ENV could pay for metals analysis and ask DFO to collect these samples while they are out on some of the large lakes. In exchange, ENV could sample some of the smaller lakes they work on (e.g., Bowron Lake) and ensure methods were consistent with those of DFO (Swan, 2018, Personal Communication).

There is potential for some efficiencies but this would have to be explored further between these agencies.

2.3 Lake Pulse Canada

The NSERC[3] Canadian Lake Pulse Network http://lakepulse.ca/ brings together 18 researchers from 15 Canadian universities and partner researchers from across Canada and around the world. Their complementary areas of expertise include all aspects of limnology, as well as spatial modelling, analytical chemistry, public health, remote sensing and a number of other disciplines. The network's researchers will be working closely with scientists from several

[3] NSERC is the Natural Sciences and Engineering Council of Canada

provincial and territorial environment ministries, a number of federal departments and agencies, and Ouranos, a Quebec-based consortium on regional climatology.

The network's scientific work is steered by a scientific committee composed of senior researchers who are network members, as well as other researchers who work with it as partners or as international advisors. The network is overseen and advised by a board of directors representing its stakeholders. The following research objectives and outcomes are taken from NSERC (2018):

Research Objectives

To help its partners fulfill their role of lake stewardship, the network will attempt to answer the following four key research questions.

1. Where, by how much and why have Canadian lakes changed during the Anthropocene?

2. How do taxonomic, molecular and biochemical features of planktonic, benthic and microbial communities change with lake alteration and which of these changes can most effectively be used as indicators of the health of Canadian lakes?

3. What are the optical, morphometric and watershed properties of Canadian lakes that can be applied to "scale up" assessments of the health of individual lakes to groups of lakes by means of remote sensing and spatial modelling?

4. How will lake ecosystems and the services that they provide react to various scenarios of environmental change?

To answer these questions, the network will obtain a large database of lake characteristics and changes in them. Since the drivers of change and the responses of lakes are spatially heterogeneous, the network will rely heavily on extensive sampling and on the existing data sets developed by its partners, applying geomatic and spatial modelling tools to extrapolate local and regional results to larger scales.

Outcomes

The outcomes that the network hopes to provide will directly benefit the stewardship of Canadian lakes while advancing the science of limnology. These outcomes include:

1. **a large database of lake characteristics**, obtained through an extensive sampling program covering most of southern Canada and some parts of northern Canada;

2. **pan-Canadian and regional assessments** of the current health of Canadian lakes and the most important drivers of changes in these lakes;

3. **predictions of changes** that may occur in these lakes in the future, given realistic scenarios of land use and climate change.

The database and other outcomes will be posted publicly on an interactive website so that scientists can use them to map various indices and parameters for individual lakes across Canada.

Lake Pulse is a research-oriented program, and their team of about 50 researchers, students and field staff will be amassing lots of information about the state of Canada's lakes and watersheds (Brown, 2018, Email Communication). Lake Pulse is a 5-year program funded by NSERC to create the first national assessment of lake health by 2021. Over 3 summers, they are sampling 680 lakes that cover a range of lake sizes and human impact classes. The field teams sample each lake for over 100 variables (sampling takes a full day at each lake), which range from standard measurements to state-of-the-art indicators for emerging contaminants and genomics research. The field teams have a truck, boat and a mobile lab. These data are used in Lake Pulse for 10 main research projects (http://lakepulse.ca/research-themes/), which is academic research. They are a scientific program that also collaborates with government partners and NGOs because they want their research to reach a wider audience. Lake Pulse also has a mission to make their information accessible and meaningful to Canadians. This summer, field crews will sample about 31 lakes in BC. In 2019, Lake Pulse will return to BC to sample another 155 lakes (Brown, 2018, Email Communication).

The Lake Pulse program has the potential to compliment the BCLMN by:

- providing complimentary information to BCLMN lakes where there is overlap (e.g., sediment core samples for assessment of impacts)
- aiding in the assessment of how climate change is affecting BC lakes
- providing baseline data on lakes not currently part of the BCLMN
- adding trophic status indicators to supplement the lakes in BC's trophic status map

The BCLMN could contribute to the Lake Pulse Program in a number of ways:

- Provision of local knowledge (contacts, access to the lakes)
- Bathymetric maps, data previously collected on lakes
- ENV and Stewardship contacts
- Lake Pulse are generally summer samples, and the BCLMN is late-winter/spring and late-summer/early-fall samples, so these data might be complimentary

The Lake Pulse Program has different objectives, methods and protocols than the BCLMN, so it will not replace network lakes (i.e., will not result in it becoming unnecessary for the BCLMN to sample an overlapping lake in the network).

Efforts in 2018 are primarily focused on the Okanagan Region; however, future years will see an expansion to other parts of the province. Table 1 identifies lakes that are being monitored by both BCLMN and Lake Pulse in 2018.

2.4 Living Lakes Canada and Community Based Monitoring

Living Lakes Canada http://www.livinglakescanada.ca/ is a growing network of community organizations working to build capacity for the effective protection of Canada's freshwater resources. Living Lakes Canada (LLC) facilitates collaboration in education, monitoring, restoration and policy development initiatives for the long-term protection of Canada's lakes, rivers, wetlands and watersheds. LLC is affiliated with Living Lakes International, a global network of non-government associations that are working on the protection, restoration and rehabilitation of lakes and wetlands in 85 countries around the world. LLC bridges the gap between science and action to foster citizen-based water stewardship, and helps Canadians understand the connections between water quantity, water quality, climate change, biodiversity, and healthy communities through watershed stewardship.

LLC recently completed a national scan (http://www.ourlivingwaters.ca/cbmreport_sep2016) of community based monitoring in Canada in partnership with Simon Fraser University and the University of Acadia. The scan indicated that Community-Based Monitoring (CBM) projects have tripled across Canada since 2002, despite challenges such as lack of standardized protocols; easily accessible, transparent data hubs; the ability to incorporate Indigenous Knowledge; linking data analysis to applied policy; and, funding.

Living Lakes Canada has been a leader in delivering CBM programs in the Columbia Basin for over two decades. The successful lake stewardship templates of LLC have inspired over 13 other lakes and community stewardship groups to become organized entities for engaged and applied stewardship. These best practices have been shared in the Columbia Basin with the 30 monitoring groups involved with the Columbia Basin Water Stewardship Network.

LLC chaired the government, First Nations and community based, East Kootenay Integrated Lake Management Partnership and planning process for 10 years. LLC currently chairs the Kootenay Lake Partnership, a government-to-government initiative that has developed precedent setting Shoreline Management Guidelines via SHIM, for development of the Kootenay Lake foreshore that considers fish and wildlife values along with archaeological and Ktunaxa Nation cultural values.

There is potential for stewardship groups in the Kootenay region to sample some lakes for the BCLMN through LLC conducting training, enhancement of monitoring programs to follow BCLMN methods and protocols, as well as conducting regular audits.

2.5 BC Lake Stewardship and Monitoring Program (BCLSMP)

In the spring of 2003, the BCLSS launched a province-wide program in partnership with the Ministry of Environment & Climate Change Strategy (ENV) entitled: *The BC Lake Stewardship and Monitoring Program (BCLSMP)*. The program was a great success and surpassed many of the deliverables set out in the original program.

The ENV provided core funding for the BCLSMP from 2003 to 2013. As well, the Vancouver Foundation provided a grant for 2006-2007. With this financial assistance, the BCLSS was able to continue to implement and expand the program, conducting projects with a number of partners over the years. Expansions to the program included the development of more in-depth training courses as well as an aquatic plant survey program.

Under the BCLSMP, BCLSS staff train volunteers and provide them with equipment and support to facilitate the collection of water quality data and observations from lakes in BC. The objectives of this program were to:

1. Strengthen the volunteer stewardship sector in British Columbia by increasing the level of awareness of the importance and value of volunteer lake monitoring and environmental stewardship.
2. Provide LakeKeepers training in nine regions of BC.
3. Expand BC's participation in the Great North American Secchi Dip-in, to raise awareness of lake monitoring and increase the collection of data.
4. Monitor and report on 10 new lakes per year, with representation from all of BC's physiographic regions and as many biogeoclimatic zones as possible.
5. Produce lake-specific reports for 5-10 new lakes per year.

This program gives dedicated volunteers the knowledge and tools to become stewards of their favourite lake, which, in turn, means healthier, better-managed lakes in British Columbia. It also includes community-based involvement and extensive collaboration efforts. The BCLSMP resulted in a 4:1 return on dollars invested by the province in core funding for BCLSS.

This program includes five different levels of monitoring. Factors affecting water quality and the resources available to each region determine the level of monitoring for a particular lake. Further details on this program can be found in Section 5.

Under the BCLSMP, there is considerable potential for volunteers to take on sampling some of the BCLMN network lakes. BCLSS would have to conduct training, enhance monitoring programs to follow BCLMN methods and protocols, as well as conduct regular audits. Furthermore, through the promotion of stewardship throughout BC under a revitalized BCLSMP, there is potential to supplement the BCLMN in the years ahead.

2.6 University of British Columbia Okanagan

Dr. Janice Brahney, currently Assistant Professor, Utah State University Department of Watershed Sciences, led a high-elevation lake study in 2015-2016 as a former Post-Doctoral Research Associate at the University of British Columbia – Okanagan. Her research was part of a Columbia Basin Glacier Loss Study, and her focus was on climate-driven hydrologic and biogeochemical regime shifts in the Canadian Columbia Basin. She and her team sampled 35 high elevation lakes above 1,000 m across the Basin. The parameters that were collected are listed in Appendix C, as compared to other monitoring efforts. The lakes sampled are listed in Table 1.

2.7 The Fraser Basin Council

The Fraser Basin Council (FBC) is a charitable non-profit society that brings people together to advance sustainability in the Fraser Basin with a focus on climate change and air quality; watersheds and water resources; and local sustainability and resilience. They administer and co-ordinate many programs in the basin. In a phone conversation (Vieira, 2018, Personal Communication) the topic of stewardship was discussed and its importance in engaging the individuals and groups who contribute in a variety of ways to sustainability. The FRB has provided a Stewardship Award since 2007 to outstanding stewardship groups and individuals to acknowledge and encourage stewardship.

The importance of the provincial government in monitoring and co-ordinating complex planning and management programs like SHIM (now the Shuswap Watershed Council) was also discussed as the province has direct jurisdiction over water resources. The FBC was interested in the initiative of a partnership arrangement between Ministry of Environment and BCLSS and LLC. FBC was particularly interested in identification and engagement with stewardship groups in the Shuswap area.

3.0 Current Needs of Lake Stewardship in BC

In this section, ENV was consulted on what staff see as needs from both the perspective of ENV and stewardship groups.

Fisher (2017) conducted a review of the ENV's involvement with stewardship groups[4] in BC, covering benefits of working with stewardship groups as well as how to work with stewardship groups. In addition, goals and objectives for working with stewardship groups were suggested.

Suggested goals related to stewardship for ENV are (Fisher, 2017):

- To determine current involvement with stewardship groups, develop a list of active stewardship groups in the province, assess the value in working with these groups and develop the current program to ensure credible data is collected.
- To provide accessible and consistent guidance for water quality monitoring for BC stewardship groups to enable them to collect scientifically defensible data that inform decision makers within government, industry, and the public.
- To develop and maintain partnerships with stewardship groups and other programs such as the BC Lake Stewardship Society and Streamkeeper Groups (e.g., Columbia Basin Water Quality Monitoring Program), to provide a strategic co-ordinated approach to provincial water quality sampling.

These goals closely align with those of BCLSS and LLC.

3.1. Current Needs of the Ministry of Environment & Climate Change Strategy and the Volunteer Stewardship Sector

The needs of the stewardship sector below are based on experience at BCLSS over the course of the BCLSMP and other CBM groups surveyed by LLC who have found that in general the volunteers and CBM groups need:

- Support with forming a stewardship group
- Assistance with defining objectives for monitoring
- Help designing an appropriate monitoring program
- Training on how to do monitoring correctly
- Personal contact for training and other aspects of lake management
- Information on lake ecology including enhanced training such as LakeKeepers
- Auditing to correct problems and as part of Quality Assurance
- Timely reporting (annually in some cases) on the data they have collected to help keep them engaged
- Presentation in person delivery of lake reports when completed
- Assistance with resolution of lake management issues

[4] This review dealt with both lake and stream stewardship groups

- Communication/connection with specific government agencies or representatives involved in managing certain aspects of lakes (or BCLSS directing them to proper agencies that can assist)
- Connections with other groups who may have experience with similar lake management issues
- Assistance with identifying funding sources for projects and equipment
- Equipment available to borrow e.g., DO/T meters and/or assistance with purchasing equipment (i.e., type of DO meter, funding sources, and where to purchase)
- Regular communication such as the BCLSS Loonie News and quarterly newsletters[5]
- BCLSS and other stewardship based conferences held in communities throughout the province

In assessing current needs, it is instructive to clarify the objectives of working with stewardship groups. Objectives suggested by Fisher (2017) are:

- Province-wide program delivery of stewardship functions
- Provide a strategic co-ordinated approach to working with stewardship groups across the province
- Develop and implement a cost-effective and science-based system to collect quality data
- Setting priorities, determining at risk water bodies, and identifying resource gaps
- Develop priority ranking tool for evaluating the value that a group provides & the amount of resources that can be invested in supporting them (values, risks, & impacts)
- Consistent approach
- Standardize information (e.g., Water Quality 101, how to start a watershed group) provided to stewardship groups
- Develop a systematic audit program to evaluate sampling techniques and ensure quality control and quality assurance
- Co-ordination/ integration with other groups and stakeholders
- Promote, maintain and develop relationships with stewardship groups, BCLSS, and other groups and partner organizations
- Reporting out
- Provide usable information (EMS access, report posting on ERIS and ECOCAT) and clear communication of findings to the public, stakeholders, and both internal and external decision makers

[5] BCLSS has received feedback from members that the quarterly newsletters are important to them

The above ENV objectives of working with stewardship groups fit with the needs of volunteers that BCLSS has identified through experience with implementing the BCLSMP.

3.2 Needs for an Expanded Stewardship Program

Future needs of the volunteer stewardship sector would include all of the items identified in S.3.1 as current needs, however enhanced training and some offsetting of expenses (e.g., boat gas and the provision of DO/T meters), could be added to help facilitate volunteers taking on a greater role in monitoring under a potentially integrated monitoring program. Providing volunteers with modern and state of the art equipment[6] helps keep people engaged. The provision of a phone app for uploading data would also be an improvement in helping keep people engaged.

Expansion of the work of the volunteer sector will require more support in generating interest in and forming stewardship groups. Fisher (2017) has identified tasks that will need to be done by the ENV to meet their goals and objectives with regard to working with stewardship groups:

- Determine resources, time commitment
- Develop model/structure for adding/interacting with stewardship groups
- Develop tools
- Training to ensure data is collected properly/accurately (BC Field sampling manual)
- Develop a systematic audit program to evaluate sampling techniques and ensure quality control and quality assurance
- Develop data management & reporting out

These tasks have considerable overlap with the activities identified by BCLSS under the BCLSMP and most of this could be done by BCLSS with the provision of funds.

An issue identified by Sokal (2018, Personal Communication) is how to handle the data produced by the BC Lake Monitoring Network. Regional representatives carrying out the lake program, often have difficulty covering the QA/QC aspects. Data goes into spreadsheets and often needs to be QA/QC'd by the program coordinator, or assistant. In the future, the ENV needs a better way to handle this, and this could be an appropriate role for BCLSS.

[6] In some areas of the province, volunteers are using Hach kits to measure DO chemically. This is a time consuming and cumbersome method, generally resulting in incomplete profiles (not enough depths). BCLSS, and some ENV regions of the province have provided DO/T meters and have received positive feedback from volunteers about replacing their Hach kits with meters

4.0 Capacity for Lake Monitoring in BC

This section looks at the ENV capacity for lake monitoring and stewardship support and the potential for monitoring and stewardship support by volunteers in BC.

Table 1 below shows lakes being monitored in 2018 by the BCLMN, lakes potentially being added in 2019, and lakes that are not currently part of the BCLMN, but have the potential to be monitored by stewardship groups and included in the BCLMN. In addition, the table indicates whether there is a local lake stewardship group and whether they are actively monitoring.

Table 1: **BCLMN 2018, Potential BCLMN Lakes, and non-BCLMN Lakes.**

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Okanagan	Christina	2	✓			MOE	Christina Lake Stewardship Society	Yes	
	Kalamalka	3	✓			MOE/LakePulse	Society for the Protection of Kalamalka Lake	Unknown	
	Mabel	2	✓			MOE	Lower Shuswap Stewardship Society	Unknown	Lower Shuswap Stewardship Society focuses on Shuswap River and Lumby area streams
	Mara	2	✓			MOE	Swansea Point Community Association	Unknown	
	Okanagan	4	✓			MOE	Lake Country Sailing and Boating Association	Yes (very limited)	
	Osoyoos	3	✓			MOE	Osoyoos Lake Water Quality Society	Yes	OLWQS samples biweekly during summer for Secchi, DO, temp., etc.
	Skaha	3	✓			MOE/LakePulse			
	Sugar	1	✓			MOE			
	Wood	1	✓			MOE/LakePulse	Lake Country Sailing and Boating Association	No	
	Ellison	1	✓			MOE			
	Shannon	1			✓	LakePulse			
	Vaseux	1			✓	LakePulse			
	Sunday	1			✓	LakePulse			
	Peachland	1			✓	LakePulse			
	Robert	1			✓	LakePulse			
	St. Margaret	1			✓	LakePulse			
	Unnamed (near Vernon)	1			✓	LakePulse			

[7] Opportunity for BCLSS, LLC, or stewardship groups to fill gap.
[8] Opportunity for BCLSS, LLC, or stewardship groups to contribute data

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Okanagan (cont.)	Swan	1			✓	LakePulse			
	Chain				✓		Chain Lake Residents Association		
	Twin				✓		Lower Nipit Improvement District		
	Jewel				✓		Jewel Lake Environmental Protection Society		
Vancouver Island	Cowichan	3	✓			MOE	Cowichan Lake and River Stewardship Society	Yes	
	Elk	1	✓			MOE	Victoria Golden Rods and Reels Fishing and Social Club	No	
	Langford	1	✓			MOE	Westshore Water Society (Individual)	Yes	
	Quamichan	1	✓			MOE	Quamichan Watershed Stewardship Society	Unknown	
	Bainbridge	1	✓			MOE			City of Port Alberni – gated drinking water supply lake
	Brannen	1	✓			MOE			
	Lizard	1	✓			MOE			
	Quatse	1	✓			MOE			Village of Coal Harbour – gated drinking water supply lake
	Shawnigan	4	✓			MOE	Shawnigan Lake Residents Association	Yes	
	Comox	3		✓			Comox Fish and Game Club		Past members of BCLSS
	Sproat	4		✓			Sproat Lake Community Association	Unknown	
	Buttle	1		✓		Nyrstar Mining			
	Maxwell	1		✓		North Saltspring Island Water District	Salt Spring Island Water Preservation Society	No	
	St. Mary	1		✓		North Saltspring Island Water District	Salt Spring Island Water Preservation Society	No	

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Vancouver Island (cont.)	John Hart	1		✓		City of Campbell River			
	Gunflint				✓		Friends of Cortes Island Society		
	Hague				✓		Friends of Cortes Island Society		
	Prospect				✓		Prospect Lake Preservation Society/Friends of Tod Creek Watershed		
	Cusheon				✓		Salt Spring Island Water Preservation Society/Cusheon Lake Stewards		
	Weston				✓		Salt Spring Island Water Preservation Society		
	Glen				✓		Westshore Watershed Society		
	Florence				✓		Westshore Watershed Society		
	Spider				✓		Mount Arrowsmith biosphere Region Research Institute		
	Cameron				✓		Mount Arrowsmith biosphere Region Research Institute		
	Fork				✓		Friends of Fork Lake/Highlands Stewardship Foundation		
	Enos Lake				✓		Friends of Enos Lake		
	Killarney				✓		Friends of Tod Creek Watershed		
	Maltby				✓		Friends of Tod Creek Watershed		
	Somenous				✓		Somenos Marsh Wildlife Society		
Lower Mainland	Deer	1	✓			MOE			
	Alta	1	✓			MOE	Whistler Fisheries Stewardship Group	Unknown	
	Brohm	1	✓			MOE	Brohm Lake Stewardship Group	Yes	
	Chilliwack	1	✓			MOE	Fraser Valley Watershed Coalition	Unknown	
	Sasamat	1	✓			MOE			

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Lower Mainland (cont.)	Cultus	1	✓			MOE	Fraser Valley Watershed Coalition	Unknown	
	Como	1		✓					
	Burnaby	1		✓					
	Alpha	1		✓			Whistler Fisheries Stewardship Group	Unknown	
	Nita	1		✓			Whistler Fisheries Stewardship Group	Unknown	
	Lost	1		✓			Whistler Fisheries Stewardship Group	Unknown	
	Green	1		✓			Whistler Fisheries Stewardship Group	Unknown	
	Sakinaw	1		✓					
	Lois	1		✓					
	Buntzen	1		✓					
	Stave (3 stations)	3		✓		FLNRORD	Fraser Valley Watershed Coalition	Unknown	
	Alouette (3 stations)	3		✓		FLNRORD			
	Harrison	1		✓		FLNRORD			
	Pitt	1		✓		FLNRORD			
	Cat				✓		Brohm Lake Stewardship Group		
	Alice				✓		Brohm Lake Stewardship Group		
Kootenays	Columbia	1	✓			MOE	Columbia Lake Stewardship Society; Village of Canal Flats	Yes	
	Windermere	1	✓			MOE	Lake Windermere Ambassadors	Yes	
	Moyie	2	✓			MOE	Moyie Community Association	No	
	Slocan	2	✓			MOE/LakePulse	Slocan Lake Stewardship Society	Unknown	
	Premier	1	✓			MOE			
	Trout	1	✓			MOE			
	Whiteswan	1	✓			MOE			

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Kootenays (cont.)	St Mary's	1	✓			MOE	St. Mary Valley Rural Residents Association	Yes	
	Wasa	1	✓			MOE/LakePulse	Wasa Lake Land Improvement District (WLLID)	Yes	
	Summit (Nakusp)	1		✓					
	Jimsmith	1		✓			Jimsmith Lake Community Association	No	
	Kootenay	8		✓		FLNRORD	Friends of Kootenay Lake	Yes	FOKL monitors 3 sites on West Arm
	Tie	1		✓		LakePulse	Tie Lake Property Owners' Association	No	
	Koocanusa	5		✓		Teck Coal			
	Arrow	8		✓		FLNRORD			Cumulative Effects Monitoring Framework
	Surveyors	1		✓		LakePulse			
	Unnamed (Columbia Wetlands at Golden)	1		✓		LakePulse			
	Pingston (Revelstoke)	1		✓		LakePulse			
	Rosen				✓		Rosen Lake Ratepayers Association	No	
	Lillian				✓		Toby Benches Society	Yes	Limited capacity
	Kimbol	1			✓	UBCO			High elevation lakes program
	Horseshoe	1			✓	UBCO			High elevation lakes program
	Hird	1			✓	UBCO			High elevation lakes program
	Rocky	1			✓	UBCO			High elevation lakes program
	Gwillim	1			✓	UBCO			High elevation lakes program
	Valhalla SE	1			✓	UBCO			High elevation lakes program
	Coven	1			✓	UBCO			High elevation lakes program
	Gibson	1			✓	UBCO			High elevation lakes program

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Kootenays (cont.)	Kokanee	1			✓	UBCO			High elevation lakes program
	Keen	1			✓	UBCO			High elevation lakes program
	Kaslo	1			✓	UBCO			High elevation lakes program
	Helen Deane	1			✓	UBCO			High elevation lakes program
	Little Helen Deane	1			✓	UBCO			High elevation lakes program
	Helen Deane South	1			✓	UBCO			High elevation lakes program
	Kalmia	1			✓	UBCO			High elevation lakes program
	Hamling	1			✓	UBCO			High elevation lakes program
	New	1			✓	UBCO	Jimsmith Lake Community Association		High elevation lakes program
	Buster	1			✓	UBCO			High elevation lakes program
	Welsh (lower)	1			✓	UBCO			High elevation lakes program
	Welsh	1			✓	UBCO			High elevation lakes program
	Aberystwyth	1			✓	UBCO			High elevation lakes program
	Thunderwater	1			✓	UBCO			High elevation lakes program
	Whirlpool	1			✓	UBCO			High elevation lakes program
	Joker (upper)	1			✓	UBCO			High elevation lakes program
	Joker (lower)	1			✓	UBCO			High elevation lakes program
	Kokanee Toe	1			✓	UBCO			High elevation lakes program
	Walton	1			✓	UBCO			High elevation lakes program
	Sky Pilot	1			✓	UBCO			High elevation lakes program
	Poplar Baby	1			✓	UBCO			High elevation lakes program
	Poplar Camp	1			✓	UBCO			High elevation lakes program
	Cascade Blue	1			✓	UBCO			High elevation lakes program

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Skeena	Lakelse	1	✓			MOE	Lakelse Watershed Stewards Society	Yes	
	Diana	1	✓			MOE			
	Morice	1	✓			MOE	Morice Trust	Yes	
	Burns	2	✓			MOE			
	Babine	3	✓			MOE			
	Kathlyn	1	✓			MOE	Lake Kathlyn Protection Society	No	
	Tyhee	1	✓			MOE	Tyhee Lake Protection Society	No	
	Francois	3	✓			MOE	Glennanan Community Association	Unknown	
	Decker	1		✓					
	Round	1		✓			Round Lake Watershed Enhancement Society	Unknown	
	Seymour	1		✓					
	Dease	1		✓		BC Parks			
	Meziadin	1		✓					
	Tchesinkut				✓		Tchesinkut Watershed Protection Society	Unknown	
Thompson	Shuswap	6	✓			MOE	Shuswap Water Council – Fraser Basin Society	Yes	
	Adams	1	✓			MOE	Individual	Yes	
	Pennask	1	✓			MOE/LakePulse			
	Stump	1	✓			MOE/LakePulse			
	Nicola	1	✓			MOE	Nicola Lake Stewardship Society	Unknown	
	White	1	✓			MOE	White Lake Stewardship Group	Unknown	
	Monte	1	✓			MOE			
	Roche	1	✓			MOE/LakePulse			
	Peter Hope	1	✓			MOE			
	Big Bar	1		✓			Individuals	Unknown	

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Thompson (cont.)	Bonaparte	1		✓					
	Gun	1		✓			Gun Lake Ratepayers Association	Yes	
	Heffley	1		✓			Heffley Lake Community Association	Yes	
	Lac Le Jeune	1		✓			Lac Le Jeune Conservation Association	Yes	
	Loon	1		✓					
	Dutch	1		✓					
	Kamloops Lake	1		✓		DFO			
	Kentucky Lake	1			✓	LakePulse			
	Paradise Lake	1			✓	LakePulse			
	Palmer Meadows	1			✓	LakePulse			
	Otter	1			✓	LakePulse			
	Round	1			✓	LakePulse			
	Madeline	1			✓	LakePulse			
	Gardom	1			✓	LakePulse	Gardom Lake Stewardship Society/Friends of Gardom Lake		
	Upper Buse	1			✓	LakePulse			
	Little Shuswap	1			✓	LakePulse			
	Little White	1			✓	LakePulse			
	Unnamed (Columbia-Shuswap A)	1			✓	LakePulse			
	Hidden				✓		Lower Shuswap Stewardship Society		
	Lajoie				✓		Gun Lake Ratepayers Association		
	Lac Des Roches				✓		Lac Des Roches Watershed Society		
	Birch				✓		Lac Des Roches Watershed Society		

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Thompson (cont.)	Little Lac Des Roches				✓		Lac Des Roches Watershed Society		
	Phinetta				✓		Lac Des Roches Watershed Society		
	Logan				✓		Highland Valley Outdoor Association		
	Green				✓		Green Lake Area Ratepayers		
	Watch				✓		Green Lake Area Ratepayers		
	Heffley				✓		Heffley Lake Community Association		
	Pavillion				✓		Pavillion Lake Residents & Property Owners Association		
	Paska				✓		Paska Lake Protection Association		
Omineca-Peace	Nadsilnich (West)	1	✓			MOE	Nadsilnich Lake Community Association	No	
	Tabor	1	✓			MOE	Tabor Lake Clean-Up Society	Unknown	
	Clucultz (2 sites, 1 in 2019)	2	✓	✓		MOE			
	Fraser	2	✓			MOE	Nad'leh Bun Watershed Enhancement Society	Unknown	
	Stuart	1	✓			MOE			
	Moberly	1	✓			MOE	Moberly Lake Community Association	No	
	Swan	1	✓			MOE	Swan Lake Enhancement Society	No	
	Charlie (2 sites, 1 in 2019)	2	✓	✓		MOE	Charlie Lake Conservation Society	Yes	
	One Island	1		✓					
	Naltesby	1		✓					
	Purden	1		✓					
	Summit	1		✓			Summit Lake Stewardship Committee	Unknown	
	Carp	1		✓					

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Omineca-Peace (cont.)	Ness				✓		Ness Lake Environmental Protection Society		
	Bednesti				✓		Bednesti-Berman Community Association		
	Berman				✓		Bednesti-Berman Community Association		
	Nukko				✓		Nukko Environmental Lake Weed Society		
	Norman				✓		Norman Lake Community Association		
Cariboo	Williams	1	✓			MOE	Individual		Peter Ope
	Chimney	1	✓			MOE			
	Dragon	1	✓			MOE	Individual	Unknown	
	Horse	1	✓			MOE			
	Puntzi	1	✓			MOE			
	Quesnel		✓			MOE			Scheduled for MOE sampling in 2018, however capacity is uncertain
	Polley		✓			MOE			Scheduled for MOE sampling in 2018, however capacity is uncertain
	Bowron	1		✓		MOE			
	Big	1		✓		MOE			
	Bridge	1		✓		MOE	Friends of Bridge Lake	Unknown	
	Horn	1		✓		MOE			
	Lac La Hache	1		✓		MOE	Lac La Hache Stewardship Group (and individual)	Yes	
	McLeese	1		✓		MOE			
	Spanish	1		✓		MOE			
	Tatla	1		✓		MOE			
	Canim	2		✓		MOE			
	Quesnel	1		✓		DFO			
	Chilco	1		✓		DFO			

Region	Lake Name	# of Sites	BCLMN 2018 Lakes	Potential BCLMN Lakes[7]	Lakes outside of BCLMN[8]	Monitoring Lead	NGO/Stewardship Group	Actively Monitoring?	Comments
Cariboo (cont.)	Mahood				✓		Mahood Falls Community Society		
	Rose				✓		Rose Lake Stewardship Group		
	Ruth				✓		Ruth Lake Property Owners' Association		
	Charlotte				✓		Charlotte Lake Landowners & Leaseholders Association		

4.1 Assessment of Current ENV Capacity

At the time of writing of this report, the areas with the least capacity are the Cariboo, Skeena, and the South Coast. Capacity issues in these areas have arisen as the result of staff shortages due to maternity leave, temporary assignments, and other reasons. It is difficult to replace staff with new people experienced with lake monitoring, resulting in decisions regarding what gets done being made on the basis of capacity, rather than lake science (Sokal, 2018, Personal Communication). This is problematic for trend sites where consistency of sampling is critical for discerning long-term trends.

As of April, 2018 the lake program is being co-ordinated out of ENV Headquarters (Epps, 2018. Personal Communication), and the delivery model is presently being finalized. It is likely that capacity issues will arise from time to time in the future and this is an area that could be addressed by BCLSS. A summary of the potential for BCLSS to support ENV is provided in Section 4.3 with options for support addressed further in Section 6.

4.2 Volunteer Stewardship Groups in BC

4.2.1 Active Lake Stewardship Groups in BC

In cooperation with the BCLSS, 80 stewardship groups and 39 individuals have taken part in volunteer lake monitoring on 119 lakes throughout the province. These stewards also assisted by reviewing the lake report (often referred to as a Lake Specific Document) that provided an analysis of the data they collected. A total of 86 of these documents were produced and can be found on the BCLSS website.

Sixty-seven of these stewardship groups are members of the BC Lake Stewardship Society and it is expected that this number will grow due to a recent increase in enquiries at the BCLSS office, possibly due to improved communication with those interested in lake monitoring and stewardship (Roumieu, 2018, Personal Communication). Living Lakes Canada (LLC) has identified seven additional provincial lake stewardship groups that are not currently affiliated with the BCLSS but are involved in lake monitoring activities. LLC has also produced a comprehensive database that includes additional provincial groups and agencies with water monitoring interests.

Lake stewardship is variable throughout the province, as shown in the following table of regional summaries. In addition, as seen in Table 2, there are many individuals throughout the province who conduct monitoring but are not part of a stewardship group.

Table 2: Regional Summary of Lake Stewardship Groups and Individuals in BC

Region	Groups	Individuals	Non-BCLSS Groups
Vancouver Island	17	0	0
Lower Mainland	4	11	2
Okanagan	8	2	1
Skeena	5	0	2
Thompson	11	6	1
Kootenay	14	0	1
Cariboo	7	12	0
Omineca-Peace	14	8	0
Total	**80**	**39**	**7**

4.2.2 Potential Stewardship Capacity

Based on available lake stewardship group information from the BCLSS and LLC, the potential capacity for stewardship involvement specific to BCLMN lakes is indicated in Table 1. Those with unknown status are in the process of being determined.

Provincial First Nations

A potential area of stewardship capacity is the First Nations of BC.

Indigenous communities in Canada hold a wealth of traditional environmental knowledge (TEK) on water and environmental health. This knowledge is valuable and important for CBM in its own right, whether it is combined with other forms of knowledge or not. Increasingly, CBM programs are endeavoring to bring together traditional knowledge and western science to develop rich, robust and holistic programs that draw on the strengths of both forms of knowledge.

Connecting traditional knowledge and western science as part of a CBM program can present a number of challenges. These include cultural differences in understanding and interpreting different forms of knowledge, the ability to translate this knowledge into decisions, as well as navigating the challenge of ensuring transparency while respecting cultural privacy. Important insights and lessons for addressing these challenges are:

- It is important to be clear on the intention for why you are developing the CBM program and realistic about the funding available to sustain it;
- To be useful and pragmatic, start with TEK indicators that already have anecdotal data for, such as observing new insects or birds as an indicator for climate change. Collecting anecdotal stories and tracking over two decades becomes extremely powerful data for

the community and complementary to western science climate change monitoring;
- As part of establishing the program, it is important to determine who will maintain it and how it will be operated (i.e., through the community groups, NGOs, local government, academic community).

Involving Indigenous Knowledge holders from the beginning of program development will allow for more community engagement and ownership. To overcome hesitation from western science to take Indigenous Knowledge (IK) indicators at face value, work should be done to connect the IK indicator to a definitive western science indicator. For example, with increased phosphorus levels, Elders and land users will observe changes such as foamy scum and a change in the smell and colour of the water while scientists will collect water quality samples to check phosphorus levels. In this case, two different systems using different languages and techniques end up with the same result that the system under eutrophication pressure. Connecting these systems respectfully creates the space for a new relationship between Indigenous and non-Indigenous people monitoring environmental change to expand and evolve (Hartwig et al., 2016).

Indigenous communities are well positioned to monitor and collect data, collaborate with other entities, and create binding agreements with other parties. Building capacity and trust are key issues affecting the extent of water monitoring and data sharing by First Nations. First Nations are collecting traditional ecological knowledge and western science data for various purposes including managing ancestral lands according to traditional laws and values and to support treaty negotiations, environmental assessments, resource management, fisheries protection, water management plans, and source water protection. Some First Nations share data online and others have data sharing agreements with other First Nations and third parties. However, the extent of First Nations monitoring was difficult to assess, as availability and accessibility to the public of data collected by First Nations are variable and influenced by many factors (Luttmer, 2018).

The Centre for Indigenous Environmental Resources (CIER), is a national First Nation directed environmental non-profit organization that offers research, advisory, and education and training services to Indigenous communities, governments and private companies through four program areas: Taking Action on Climate Change, Building Sustainable Communities, Protecting Lands and Waters, and Conserving Biodiversity www.cier.ca

Living Lakes Canada has worked with First Nations and has identified First Nations groups involved in community based monitoring efforts in Table 3.

Table 3: First Nations groups involved in community based monitoring efforts.

Region	First Nation Group	Actively Monitoring?	Comments
Kootenay	Ktunaxa Nation Council	Yes	?Akisq'nuk First Nation (FN), Yaqan Nukiy Indian Band (IB), Aq'am FN, Tobacco Plains IB
	Shuswap First Nation	Yes	• Environmental Monitoring Program
	Okanagan Nation Alliance	Yes	Lower Similkameen, Osoyoos IB, Upper and Lower Similkameen IB, Penticton IB, Westbank FN, Okanagan IB, Upper Nicola IB, Colville Confederated Tribes
Thompson Okanagan	Ashcroft First Nation	Unknown	
	Nicola Tribal Association	Yes	Coldwater, Nooaitch FN, Siska FN, Nicomen IB, Cook's Ferry FN, Shackan FN, Nooaitch FN, Upper Nicola
	High Bar First Nation	Unknown	
	Kanaka Bar First Nation	Unknown	
	Little Shuswap First Nation	Unknown	
	Lower Nicola Indian Band	Unknown	
	Okanagan Nation Alliance	Yes	Lower Similkameen, Osoyoos IB, Upper and Lower Similkameen IB, Penticton IB, Westbank FN, Okanagan IB, Upper Nicola IB, Colville Confederated Tribes • Okanagan Nation Alliance Data Portal • Okanagan Basin Monitoring and Evaluation Program
	Shuswap Nation Tribal Council	Yes	Splatsin First Nation, Adams Lake FN, Neskonlith IB, Simpcw First Nation, Whispering Pines/Clinton, Tk'emlups te Secwepe'mc, Skeetchestn, Bonaparte FN, Upper Nicola
	Northern Shuswap Tribal Council	Yes	Canim Lake, Stswecem'c Xgat'tem First Nation, Williams Lake IB, Xat'sull FN,
	Esk'etemc	Unknown	
	Lheidli T'enneh Firsht Nation	Unknown	
	McLeod Lake Indian Band	Unknown	
	Tsilhqot'in National Government	Yes	Tl'esqox, Yunesit'in Government, Tl'etinqox-t'in Government, ?Esdilagh First Nation, Xeni Gwet'in First Nations Government, Alexis Creek • Tsilhqot'in Lands Portal
	Carrier Chilcotin Tribal Council		Lhtako Dene Nation, Kluskus, Nazko First Nation, Ulkatcho FN

Region	First Nation Group	Actively Monitoring?	Comments
Northeast	Blueberry River First Nations	Yes	
	Doig River	Potential Capacity	
	Fort Nelson	Yes	• Nde'h Ke' ndihi, Fort Nelson First Nation Guardian Program
	Halfway River First Nation	Potential capacity	
	Kwadacha	Potential capacity	
	Prophet River Band, Dene Tsaa TseK'Nai First Nation	Yes	
	Saulteau First Nation	Potential Capacity	
	Tsay Keh Dene	Unknown	
	West Moberly First Nation	Unknown	
Lower Mainland Southwest	Lillooet Tribal Council	Potential capacity	Ts'kw'aylaxw First Nation, Bridge River, Seton Lakes, Xaxli'p, T'it'q'et, Cayoose Creek
	N'Quatqua (Lower Lillooet)	Unknown	
	Lil'Wat	Unknown	
	Nlaka'pamux Nation Tribal Council	Potential Capacity	Boothroyd Indian Band, Boston Bar First Nation, Skuppah Indian Band, Lytton First Nation, Oregon Jack Creek Band, Spuzzum First Nation
	Yale First Nation	Unknown	
	Union Bar First Nation	Unknown	
	Sto:Lo Nation	Potential capacity	Aitchelit First Nation, Shxwha:y Village ,Leq'a:Mel First Nation, Squiala First Nation, Matsqui First Nation, Sumas First Nation, Popkum First Nation, Tzeachten First Nation, Skawahlook First Nation, Yakweakwioose First Nation, Skowkale First Nation, Shxw'ow'hamel First Nation
	Peters Band	Unknown	
	Cheam First Nation	Unknown	
	Skwah	Unknown	
	Kwantlen First Nation	Unknown	
	Katzie First Nation	Unknown	
	Semiahmoo First Nation	Unknown	Coast Salish sub group
	Kwikwetlem First Nation	Unknown	
	Qayqayt First Nation	Unknown	
	Tsawwassen First Nation	Potential capacity	

Region	First Nation Group	Actively Monitoring?	Comments
	Tsleil Waututh Nation	Unknown	
	Squamish First Nation	Potential capacity	
	Musqueam First Nation	Potential capacity	
	Sechelt First Nation	Unknown	
	Tla'amin Nation	Yes	
Vancouver Island and Coast	Kwiakah First Nation	Unknown	
	Kwakiutl Disrtict Council	Yes	Da'naxda'xw First Nation, Mamalilikulla First Nation, Tlatlasikwala First Nation, We Wai Kai First Nation, Wei Wai Kum First Nation, Kwiakah First Nation, K'omoks First Nation, Kwakiutl First Nation, Gwa'sala-Nakwaxda'xw Band, Quatsino First Nation • Gwa'sala-'Nakwaxda'xw Nations Guardians
	Tlowitsis Nation	Unknown	
	Dzawada'enuxw First Nation	Unknown	Kwicksutaineuk-ah-kwaw-ah-mish First nation
	Gwawaenuk Tribe	Unknown	
	Wuikinuxv Nation	Yes	Coastal Stewardship Network Regional Monitoring System Database
	Nuxalk Nation	Yes	Coastal Stewardship Network Regional Monitoring System Database
	Heiltsuk First Nation	Yes	• Coastal Stewardship Network Regional Monitoring System Database • HEILTSUK Integrated Resource Management Department
	Te'mexw Treaty Association	Potential Capacity	Scia'new First Nation, T'Sou-ke First Nation, Songhees First Nation, Malahat First Nation
	Equimalt First Nation	Unknown	
	Tsawout First Nation	Unknown	
	Tsartlip First Nation	Unknown	
	Pauquachin First Nation	Unknown	
	Tseycum First Nation	Unknown	
	Hul'qumi'num Treaty Group	Potential capacity	Penelakut Tribe, Cowichan Tribes, Halalt First Nation, Cowichan Lake First Nation, Stz'uminus First Nation
	Naut'sa mawt Tribal Council	Unknown	Snuneymuxw First Nation, Nanoose First Nation

Region	First Nation Group	Actively Monitoring?	Comments
	Qualicum	Unknown	
	Nuu-chah-nulth Tribal Council	Potential Capacity	Hupaċasath First Nation, Tseshaht First Nation, Ditidaht First Nation, Tla-o-qui-aht First Nations, Ahousaht First Nations, Hesquiaht First Nation, Mowachaht/Muchalaht First Nation
	Maa-nulth First Nations	Potential Capacity	Ucluelet First Nation, Toquaht First Nation, Uchucklesaht First Nation, Huu-ay-aht First Nation
	Pacheedaht First Nation	Unknown	
	Namgis First Nation	Unknown	
North Coast	Council of Haida Nation	Yes	Skidegate Band Council, Old Massett Village Council • Coastal Stewardship Network Regional Monitoring System Database
	Gitxaala Nation	Potential capacity	
	Tsimshian First Nations	Yes	Metlakatla village, Kitasoo (Xai'xais), Gitga'at Nation, Kitselas Nation, Kitsumkalum • Coastal Stewardship Network Regional Monitoring System Database • Coastal First Nations Great Bear Initiative Regional Monitoring System • Kitsumkalum Guardian Program
	Haisla Nation	Yes	• Coastal Stewardship Network Regional Monitoring System Database
	Lax-kw'alaams	Yes	
	Nisga'a Lisims Government	Potential capacity	Gingolx Village, Laxgalts'ap Village, Gitwinksihlkw, Gitlaxt'aamix Village (New Aiyansh)
	Wet'suwet'en Society	Unknown	Moricetown, Hagwilget village, Skin Tyee
	Gitxsan Nation	Yes	Gitwangak Indian Band, Gitsequkla, Gitanmaax Band, Glen Vowell, Kispiox Band
	Gitanyow	Yes	• Gitanyow Fisheries Authority
	Tahltan Central Government	Yes	Iskut First Nation, Tahltan First Nation
Nechako	Nee-Thai-Bun	Unknown	

Region	First Nation Group	Actively Monitoring?	Comments
Nechako	Cheslatta Carrier Nation	Unknown	
	Carrier Sekani Tribal Council		Wet'suwet'en First Nation, Burns Lake (Ts'il Kaz Koh) Nation, Stellaat'en First Nation, Nadleh Whuten, Saik'uz First Nation, Nak'azdli First Nation, Tl'azt'en First Nation, Takla Lake First Nation
	Lake Babine Nation	Unknown	
	Yekooche First Nation	Unknown	
	Taku River Tlingit	Yes	
	Kaska Dene Council	Yes	Dease River First Nation, Daylu Dena Council

4.2.3 Training and Support Needs for Volunteers

Training and Support

Training includes both technical and safety training. Training and support needs fall into several categories:

- Newly formed stewardship groups or individuals
- Areas where the BCLSS and/or the ENV would like to foster stewardship and perhaps the formation of groups
- Existing groups or individuals needing assistance with information about how to resolve lake issues, further training, support with funding projects (i.e., identifying sources or providing letters of support for project funding)
- Existing groups or individuals needing audits of their monitoring

The BCLSS developed a LakeKeepers training course[9] to provide training for sampling as well as an understanding of the fundamentals of limnology. LakeKeepers training sessions have been held throughout the province for over 10 years. Feedback from these courses has been very positive.

Fostering stewardship requires ongoing support from the BCLSS. The BCLSS has found since they have been operating on a very small budget, membership renewals have fallen off. This is likely the result of reduced service such as lateness in responding to requests for information, and possibly a perceived lack of activity by the BCLSS (Roumieu, 2018, Personal Communication).

[9] Note: Volunteer Technical and Safety Training has been updated to reflect current ENV practices as part of this project (separate submission)

Newly formed groups need assistance with forming and running a group, as well as training for monitoring. LakeKeepers training has been very successful with much positive feedback from those having taken the 1.5-day training[10] including two First Nations groups in Northern BC. The course has an accompanying manual that is a valuable resource for people once they have taken the course.

It is not always possible for a LakeKeepers training session to be offered to all those who are monitoring, therefore a shorter version has been developed that focuses on the essentials of technical and safety. This package could be delivered by BCLSS or ENV personnel in less than one half day to ensure people are trained to sample safely and properly. Volunteer stewards could request the longer LakeKeepers course if there is an interest in going deeper into the science behind lake assessment. It is important that people beginning to sample have at least this much training or be scheduled for an audit shortly after they begin monitoring.

Similar to the Volunteer Technical and Safety Program, a Lake Stewardship Education Package has been designed to inform people about the value of forming a stewardship group and how to do so. This is also envisioned as a course of less than one half day, or as a package to be sent out. It also contains information specific to First Nations stewardship.

An emerging area of interest for the public is aquatic plant management and BCLSS has recently completed a chapter for LakeKeepers on aquatic plant surveys. These surveys are intended to be conducted by lake stewards and can provide valuable information on species present, invasives, and extent of beds for future reference. This is a separate course from LakeKeepers and is of similar length (i.e. 1.5 days).

Audits

Auditing of volunteers is essential to avoid later problems with data, especially with new groups and individuals. Auditing would require travel as training would only be effective if it were done face to face – an initial training session and support on the initial sampling trip. If QA/QC results were good, minimal follow up would be necessary. Depending how many lake groups would need training and support, this could be a significant demand on the time of the BCLSS staff person. One option to be consider would be to spread audits out (i.e. schedule them over a 3-5 year period).

Stewardship Awareness

In order to see the lake stewardship community grow and enabled to conduct meaningful activities and monitoring, there needs to be an active campaign to promote the formation of groups, especially in areas of the province that don't have many e.g., northern BC. This is a logical role for BCLSS, with its existing network of groups and LakeKeepers training course. This

[10] From 2011-2016, the BCLSS held 24 multi-day LakeKeepers training sessions throughout the province

will require additional resources for BCLSS who at present are operating on about 4 hours of staff time per week.

As noted in 4.2.2, experience with LakeKeepers training of First Nations groups has demonstrated a strong interest in stewardship on the part of First Nations and an eagerness to learn about the science behind lake assessment and monitoring. Similarly, First Nations can provide valuable traditional and local information (elder's knowledge) about the environment by bringing this knowledge to the LakeKeepers training and/or to the stewardship groups.

LakeKeepers training must be kept up to date, including the manual, which is a valuable resource.

The BCLSS has held annual conferences throughout BC from 1998 through to 2014. The BCLSS staff typically organized the conferences with the BCLSS Board of Directors providing input to the agenda. The BCLSS partners with a stewardship group in the region where the conference is being held, and this is valuable for ensuring local issues and interests are addressed during the conference, as well as providing input to logistics such as venues and field trips.

Since it is often difficult for people to travel to conferences from different areas of BC, the notion behind moving the conferences is to bring the conferences to local people throughout the province. This brings outside experts on lake ecology and management to the people and groups in various areas of the province. This promotes stewardship and understanding of the science behind lake management and lake water quality problems.

Feedback via conference evaluations was always excellent from lake stewards, groups, and the general public attending these conferences.

4.3 Summary of Potential for BCLSS to Support ENV

Some common areas where ENV is falling short due to lack of resources have emerged from the interviews with ENV staff in S.4.1:

- Staff are generally able to meet the sampling commitments to the BCLMN with some exceptions where temporary staff shortfalls arise for a variety of reasons
- There is difficulty in most regions with timely data entry and conducting QA/QC checks on the data collected under the BCLMN
- Summarizing the existing network data into spreadsheets is currently being done by contractor and reviewed /supported by the lake program coordinator
- Reporting on the data is difficult for staff to do, given other commitments
- Staff in most regions have difficulty adequately supporting stewardship groups conducting monitoring

- Staff have little time to promote the formation of new stewardship groups that have the potential to help with some of the BCLMN lakes
- There is difficulty with adequately auditing the monitoring activities of stewardship groups and individuals
- There is difficulty with responding, or unable to respond to public inquiries about lake *problems (e.g., algal blooms)*
- There is currently no capacity to expand the number of lakes in the program

BCLSS could assist ENV with the foregoing activities and this will be discussed further in S. 6.

5.0 Current BCLMN Program

5.1 Description of the BCLMN

The Ministry of Environment and Climate Change Strategy, Environmental Protection Division Monitoring, Assessment and Stewardship Section, proposed in 2015 a Lake Water Quality Monitoring Strategy – the British Columbia Lake Monitoring Network (BCLMN). It was designed to be a province-wide program delivery of lake monitoring and stewardship functions by providing a strategic coordinated approach to lake monitoring and Development and implementation of a cost-effective, science-based provincial lakes monitoring network.

The implementation of the BCLMN program is focused on one specific set of parameters and protocols that are to be used province-wide to provide a baseline for water quality to assess changes that might occur for a variety of reasons. The sampling is to be conducted at two key periods, spring and late summer.

Another important technical component of the BCLMN is the choice of sampling parameters. Shown below is the table of parameters to be used in the lake sampling.

BC Lake Monitoring Network: Sampling Parameters

Physical	Chemical	Biological	Vertical Profiles	QA/QC
Secchi	Total P, Dissolved P, Ortho-P	Chlorophyll-a	Temperature	various
Temperature	Total N, NO_3+NO_2, Ammonia, TKN, Total Org. N	Phytoplankton taxonomy**	Dissolved Oxygen	
	Silica	Zooplankton taxonomy**	Chlorophyll-a	
	Cl, SO4, Ca, Mg, Hardness	Phytoplankton biomass**	pH	
	TOC	Zooplankton biomass**	Conductivity	
	pH	Periphyton**	Turbidity	
	Conductivity	Fish tissue**		
	Dissolved Oxygen	Benthic Invertebrates**		
	Metals and other parameters as needed			

**if funds allow

Figure 2: BC Lake Monitoring Network Sampling Parameters

BC Lake Monitoring Network: Status & Trend

- New province-wide monitoring approach – coverage across regions, for small and large lakes, impacted and non-impacted and unique lakes
- Sampling conducted in late-winter/spring & late-summer/fall every year (dependent on where in the province the lakes are located)
- Minimum parameters to sample
    - Physical: Secchi, temperature (vertical profile)
    - Chemical: (epilimnion & hypolimnion composites), total P, dissolved P, ortho-P, total nitrogen, NO2+NO3, TKN, ammonia, silica, TOC, Cl, SO_4, Ca, Mg, Hardness, metals (shallow/epilimnion spring only), dissolved oxygen (vertical profile)
    - Biological: chlorophyll-a
- Sampling conducted by ENV staff and partners/stewardship groups/ volunteers

A **suggestion** for a potential addition in future years for productive lakes that have noticeable blooms of cyanobacteria, is to add a test for microcystin. This would be important for lakes that serve as drinking water supplies or with important recreation values.

Future Lake Selection

British Columbia has many lakes, with some sources citing 16,000 lakes, and others citing 60,000. It depends on the criteria for the waterbody size (surface area) that is used to decide what a lake is. Some use a criterion of 1 km^2 others use 0.1 km^2 (10 ha) and the national inventory uses a much larger minimum size of 3 km^2 (Atlas of Canada) to come up with a number of **31,752** lakes in the whole country, with **561 lakes** with a surface area larger than 100 km^2. Whatever the case, choosing a representative sample set is a difficult task but there are other systems for choosing additional lakes.

As the program is developed, an ongoing review of network data gaps can be identified, and solutions / recommendations provided to determine how to add these lakes and who will sample them. **One suggestion** for future inclusion in the data set is to include some high elevation mountain lakes that might provide insight into issues like climate change, long-range transport of contaminants, and provide a reference point for relatively undisturbed lake ecosystems. The largest challenge with sampling high elevation lakes is sampling logistics.

5.2 Recommended Enhancements to the BCLMN

5.2.1 Data Analysis

It is important that the analytical results from sampling are processed in a systematic way to ensure their accuracy. Suggested below is a protocol for (a) examining data after being transcribed from the field logs or data sheets and (b) the results received from the laboratory.

Field Data

Manual entry of field data such as Secchi depth, profile data for temperature, dissolved, conductivity and other measurements from the field are one aspect that is subject to error. These transcriptions should be done as soon as the sampling team returns from the field and preferably by the person who wrote the data down (less likelihood of errors reading someone else's handwriting). The data will be entered into the BC Government database: Environmental Management System (EMS). Regular checks should be made within EMS to ensure that the database values are identical to the data in the field books. Each person sampling should include as much information as possible on the water chemistry requisitions under field parameters. This would assist with the EMS QA/QC process.

Laboratory Data

The sample data from a lake after being analyzed is posted to EMS by the analytical lab. The laboratory will also provide an electronic result sheet to the sampler. The initial results should be checked for:

1. any obvious problems or unexpected results
2. comparison to previous data for any anomalies
3. QA/QC data to check for contamination or lab performance

QA/QC

The entire QA/QC process is an essential one. Many of the procedures described in this report are adapted from the ENV document prepared in 1997 titled Guidelines for Interpreting Water Quality Data (Cavanagh et. al ., 1997). They are provided as a reference to possible changes in the program as it is presently proposed.

The proposed QA/AC program in the BCLMN recommends QA/QC samples only for two sites in each of the eight geographical regions. Each region has between 14 and 22 sites, to be sampled spring and fall. The QA/QC is to include two replicate samples and one trip blank or field blank. An alternative to the trip or field blank would be an equipment blank.

This should be regarded as the very minimal QA/QC program – perhaps only for lakes that are being sampled by experienced Ministry staff. The BCLMN will be incorporating samplers from other agencies (water utilities, regional governments) as well as stewardship groups and individuals. In these cases, it would be prudent to have a more detailed QA/QC program in place.

It is also important that as data are reported that changes can be implemented to add additional QA/QC samples to find and correct any problems with data collection. The existing QA/QC program does not include metals in QA/QC but this may need to be changed if metals are an issue of concern in a particular lake.

Recommendation 1: Consider an enhanced QA/QC program for non-Ministry samplers (stewardship groups, volunteers or other government agencies), until there is assurance that the data coming out of this sampling is judged to be consistently of high quality.

Recommendation 2: Consider a flexible and responsive model for what QA/QC measures are used to adapt to any issues that arise – rather than a fixed QA/QC program. If QA/QC issues are identified, there needs to be a process in place to correct any problems in a timely period.

A discussion and description of water quality QA/QC is attached as Appendix B.

5.2.2 Reporting of Data by Lake

It is also important that the data receive some level of written interpretation, so that the results are made available to the public, the partners in the sampling program, and other agencies. There are a number of possible ways of doing this.

An overall report on the sampling for a calendar year could be posted on the ENV website in a reasonable time. This could include summary tables for each lake with water chemistry results. The amount of interpretation would be dependent on the resources available and the purpose of the sampling. The form could vary from a simple text in a document to much more elaborate presentation formats. The posting of report documents is the approach taken by many agencies, like the City of Vancouver.

http://www.metrovancouver.org/services/water/quality-facilities/testing-reporting/Pages/default.aspx

Some regional governments and agencies provide webpages reporting on water quality monitoring in specific areas. The Okanagan Basin Water Board provides a portal for monitoring that is conducted in the Okanagan Basin.

http://www.obwb.ca/water-quality-monitoring/

The Fraser basin Council has a water quality portal – with a guide for using EMS

https://www.fraserbasin.bc.ca/Water_Quality_Data.html

The Capital Regional District provides a web page reporting on drinking water sources in the Victoria / lower Island area.

https://www.crd.bc.ca/about/data/drinking-water-quality-reports/greater-victoria-water-quality-reports

An example of a very effective presentation is that published by the Alberta Lake Management Society for their LakeWatch program. It is a map based on which the lakes sampled are designated by red dots which can be zoomed in on and when the lake location is clicked on, a table is displayed with data results in table form.

See at https://alms.ca/

The government of Alberta also provides a website that presents data collected on both lakes and streams

http://aep.alberta.ca/water/reports-data/surface-water-quality-data/default.aspx

Some examples of other jurisdictions with public reporting of results on websites include:

The Muskoka Lake area of Ontario

http://www.muskokawaterweb.ca/news

The government of Nova Scotia for their automated sampling sites – that includes one lake station

https://novascotia.ca/nse/surface.water/automatedqualitymonitoring.asp

State of Maine that has a stewardship sampling program (http://www.mainevlmp.org/#)

http://www.maine.gov/dep/water/monitoring/lake/lakedata.htm

State of Minnesota

https://www.pca.state.mn.us/water/lake-monitoring-0

The BCLSS prepared four to twelve page, illustrated summary reports of the lakes that were sampled during the BCLSMP as well as lakes that were subsequently sampled by ENV and other member groups. These summaries provide a very effective communication and reporting tool. All 86 lake reports are posted on the BCLSS website. This is recommended as an example that has worked very well. http://www.bclss.org/document-library

Two options for reporting the water quality results for each lake in the network are recommended here.

The first option would assume there are the resources within ENV to create and maintain a webpage that highlights the BCLMN program. For each lake sampled, a standard format report (in pdf) would be prepared with summary tables and interpretation of data for each lake for each year. At regular intervals (i.e. 5 years), overall summaries for each lake would be prepared which would provide the range of data and any apparent trends.

The second option would have the partners (BCLSS and LLC) prepare the reports and post the lake reports on the BCLSS or LLC website which could be mirrored on the ENV website. This would make maintaining the content much more efficient – especially if BCLSS / LLC were tasked with writing the lake reports (with review and input from ENV). The model used would be the BCLSS lake reports enhanced with whatever additional data is deemed appropriate.

Reporting of data for the program

Information on individual lakes provides information on individual lakes but it is also useful to have an overall evaluation for the program from a provincial perspective. Overview of where lakes might fit in in the range of data gathered or how a lake might be characterized by a classification scheme or in a lake quality index is also useful.

Water Quality Indices

For reporting the status of water quality to the public (and other users of water quality information), it is often useful to have a single numerical value to describe the lake condition. This is a common approach to rating from everything from movie or restaurant reviews to student grades to earthquake magnitude or stock market performance. Indices are not perfect but do serve a purpose in providing a quantitative scale that the general public can relate to.

The most important issue for most lakes in BC is anthropogenic eutrophication since water clarity (increased algal biomass) is an obvious visible manifestation of the desirability of the water for recreation or drinking water supply or changes in fisheries populations.

Trophic State Index

Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state:

oligotrophic - nutrient poor and low productivity; high transparency (deep Secchi depth), low chlorophyll-a, low phosphorus

mesotrophic - moderately productive; intermediate clarity, chlorophyll and phosphorus concentration

eutrophic - very productive and fertile; low clarity/shallow Secchi; high chlorophyll and phosphorus concentrations.

hypereutrophic - extremely productive with noxious surface scums of algae

Carlson's Trophic State Index (TSI)

Trophic State Indices (TSIs) are an attempt to provide a single quantitative index for the purpose of classifying and ranking lakes, most often from the standpoint of assessing water quality. In recent years, the Carlson (1977) Index appears to have attained general acceptance in the limnological community as a reasonable approach to this problem. This is a measure of the trophic status of a body of water using several measures of water quality including transparency or turbidity (using Secchi disk depth recordings), chlorophyll-a concentrations (algal biomass), and total phosphorus levels (usually the nutrient in shortest supply for algal growth).

TSI ranges along a scale from 0-100 that is based upon relationships between Secchi depth and surface water concentrations of algal chlorophyll, and total phosphorus for a set of North

American lakes. Its major assumptions is that suspended particulate material in the water controls Secchi depth and that algal biomass is the major source of particulates. The lowest value of zero would correspond to a Secchi depth of 64 meters. A value of 100 would correspond to a Secchi of only 6.4 cm (less than 3 inches). A set of equations were then derived to describe these relationships with higher values corresponding to increased fertility, that is, more eutrophic. An increase in TSI of 10 units corresponds to a halving of Secchi depth and a doubling of phosphorus concentration. http://www.lakeaccess.org/lakedata/datainfotsi.html

The data from the BCLMN do not lend themselves well to characterization with the TSI since the Secchi and chlorophyll should preferably use growing season averages and sampling only twice a year (spring and fall) provides only marginally appropriate data.

A simple version of Carlson's TSI Trophic Index (as TI) is provided below.

TI	Chl	P	SD	Trophic Class
< 30—40	0—2.6	0—12	> 8—4	Oligotrophic
40—50	2.6—20	12—24	4—2	Mesotrophic
50—70	20—56	24—96	2—0.5	Eutrophic
70—100+	56—155+	96—384+	0.5— < 0.25	Hypereutrophic

Figure 3: Carlson's Trophic Index

The limitation of the TSI is that not applicable to lakes where aquatic macrophytes contribute to the productivity of the lake or where there is a significant input to the lake of inorganic suspended material (silt from creek or river runoff).

The TSI is derived from three key water quality parameters and are generally averaged to derive a single index number.

The TSI equations can be simplified for everyday use. The simplified equations are below:

$TSI(SD) = 60 - 14.41 \ln(SD)$

$TSI(CHL) = 9.81 \ln(CHL) + 30.6$

$TSI(TP) = 14.42 \ln(TP) + 4.15$

Two examples for two BC lakes are shown below. Elk Lake is a productive lake near Victoria and Okanagan Lake is an oligotrophic lake.

Elk Lake in 2014 had a spring TP of 33µg/L, an average Secchi of 4.2m and an average chlorophyll a of 8.1 µg/L. The TSI(SD) would be 39.4 the TSI(CHL) would be 51.2 and the TSI(TP) would be 54.6 and the mean of the three would be 48.4. This would place the lake in the high

mesotrophic area or low eutrophic area. Elk Lake is not ideally suited for the TSI as it has a significant aquatic plant coverage that certainly affects the index (especially Secchi).

Okanagan Lake is a more suitable lake for this kind of characterization. The data for 2011-2014 (Larratt 2015) give a spring TP of 7 µg/L, an average Secchi of 6.6 m and an average chlorophyll a of 1.9 µg/L. The TSI(SD) would be 32.8 the TSI(CHL) would be 36.9 and the TSI(TP) would be 32.4 and the mean of the three would be 34.0 putting it clearly in the oligotrophic range.

An initiative to derive a Trophic State Index for British Columbia lakes was proposed by Mike Sokal. It differs from the TSI in that it adds the parameter of total nitrogen to Secchi, chlorophyll and total phosphorus. It is presently under development but has the handicap of only collecting spring and late summer data so only total P and total N in a restricted set of lakes (ones with long residence times) has much inherent value. Unless a more comprehensive program is established where more detailed data are collected (summer average chlorophyll and Secchi, summer average phosphorus for lakes with relatively short water residence times and detailed oxygen deficit data), pursuing a version of a Trophic State Index would be a challenge.

Given the limitations of the data sampling timing (spring and late summer only), it is still possible to develop a Trophic State Index with the existing data using an algorithm with a specific sequence of determinants and range categorizations. For example, TN:TP ratio would be an essential initial filter to determine nutrient limitation. Then using both spring and late summer data for TP and Secchi, and weighted influence of summer chlorophyll and near bottom dissolved oxygen concentration could produce a Trophic State Index that would be useful for placing lakes in a trophic spectrum – perhaps a 1-100 scale as was used in the Carlson index.

Two other indices that might be worth considering and developing are:

(a) An Index of Water Quality Change. This would provide and indicator of whether water quality might be improving or deteriorating based on a five year data set and using indicator parameters such as spring nutrient concentrations or late summer dissolved oxygen.

(b) An index of Water Quality Vulnerability. This index might be constructed using not only the water quality data for the lake but other information such as population increases, watershed development and whether climate change (evaporation increases, lengthened thermal stratification) might be major drivers of changes in lake water quality

The CCME Water Quality Index

A more wide-ranging index designed for all water bodies but perhaps more applicable to streams although still applicable to lakes was commissioned by the Canadian Council of

Ministers of Environment. It is dependent on a water body having a detailed assessment and water quality objectives being set for that water body. One of the goals for the BCLMN is to provide the data to set water quality objectives for lakes but as of present, relatively few lakes have had water quality objectives set for them.

A water quality index provides a convenient means of summarizing complex water quality data and facilitating its communication to a general audience. The CCME Water Quality Index (1.0) is based on a formula developed by ENV and modified by the Alberta Environment. The Index incorporates three elements: scope - the number of variables not meeting water quality objectives; frequency - the number of times these objectives are not met; and amplitude - the amount by which the objectives are not met. The index produces a number between 0 (worst water quality) and 100 (best water quality). These numbers are divided into 5 descriptive categories to simplify presentation.

A description of the CCME water quality Index version 1.0 is at

http://ceqg-rcqe.ccme.ca/download/en/138

Some examples of BC lakes that have had water quality objectives set are:

*Elk Lake (1992), *Comox Lake (2011), *Cowichan Lake (2011), *Cusheon lake (2015), Stocking Lake (1996), *John Hart Lake / McIvor lake (2012), Kemp lake (2012), *Langford Lake (2007), *Quatse lake (1997), Quinsam Lake (1989), *Shawnigan Lake (2007), *Loon Lake (1986), *Columbia and *Windermere (1985), *Windermere Lake (2010), *Williams Lake (1987), *Lakelse Lake (1986), *Kathyln / *Round/ *Tyhee / *Seymour (1985), *Charlie Lake (1985), *Christina Lake (1994), *Okanagan Lake (2005), *Osoyoos Lake (2011).

* lakes of the BCLMN

The use of the CCME Water Quality Index for lakes of the BCLMN is not recommended at the present time as in most cases insufficient data are available.

The preferred option for an index of the four discussed above, would be dependent on what the priority of government might be but it would seem that development of a Trophic State Index (rather than an Index of Water Quality Change or of Water Quality Vulnerability) would be the most useful path to investigate.

5.2.3 Database Integration

With so many agencies and groups collecting water quality information for different purposes, a central water quality data hub for the province would have many advantages. This concept was proposed and discussed at a conference organized by Living Lakes Canada in Invermere, November 29-30, 2017. There was overall consensus for the concept, but no concrete

suggestions as to how to implement a central data hub for the Columbia Basin. A data hub for the province would be a significantly larger challenge and would require substantial work and cost, and is not feasible at present.

Recommendation: For the purposes of the BCLMN at this time, it would seem prudent to use EMS as the repository for water quality information collected by the BCLMN. It is established and available to the public and is by far the largest water quality database in the province.

6.0 BC Lake Monitoring Framework

This section examines examples of how various jurisdictions, including BC, have worked with and funded the volunteer stewardship sector for lake monitoring and assessment. Options for integrating the volunteer sector with the BCLMN are presented.

6.1 Option 1: Modified BCLSMP

The collaborative partnership between the ENV and BCLSS that was in place from 2003 - 2013 was a successful and efficient program that achieved several goals. It increased the Ministry effectiveness to deal with lakes for which there were public concerns about water quality when government resources were limited and not sufficient to gather the data that is necessary to properly manage and protect the lakes that the Ministry is responsible for – and at present are under the same resource constraints. Another major and important benefit of the program was to engage and motivate stewardship groups who contributed to the collection of data and provided many resources and much information on lake water quality.

The circumstances at present are different and the needs are different as well. In communication with the Ministry of Environment and Climate Change Strategy (ENV) staff, there appear to be four major areas that BCLSS / LLC could assist with the implementation of the BCLMN.

The BCLSS / LLC could provide staff that could assist in several areas:

(e) **Assistance with field sampling when ENV staff is not available.** BCLSS / LLC staff could be thoroughly trained in the details of the BCLMN and be available on short notice to either do the lake sampling independently or assist ENV staff if a second team member were not available. This assistance could be set up to provide a trained technical person on 1-3 weeks' notice to assist with time sensitive water quality sampling. BCLSS would provide all the necessary transportation, sampling equipment and safety gear for either sampling independently or as part of ENV staff field crews.

(f) **Establishing stewardship contacts.** As part of the expansion or optimization of the BCLMN, BCLSS / LLC could develop and facilitate contacts and training of community

monitoring groups so that they might be integrated efficiently into the Network. This might involve LakeKeepers workshops or training for specific sampling to develop water quality guidelines. BCLSS has contacts with many stewardship groups around the province and the experience of providing technical training, education and co-ordination to local groups and local government organizations and First Nations. These lake stewards could possibly be available to assist ENV staff where an extra person was needed, sample lakes in the BCLMN in place of ENV staff (where there is confidence in the quality of that data), or sample new lakes added to the BCLMN (i.e., expansion of the program).

(g) **Data organizing, checking editing and data entry.** A notable gap in the BCLMN is a capability for data compilation and editing, data quality control assessment, and data entry. BCLSS could provide a trained staffer with appropriate background, education and experience to review BCLMN data as it is reported, apply appropriate criteria to ensure that it is acceptable quality and to enter the data into EMS (assuming that access to EMS is provided).

(h) **Report write-up, public reporting and community interaction.** BCLSS has been involved in writing lake reports that summarize water quality sampling results for many years as part of the BCLSMP. The format and content of reports produced for the BCLMP would be determined in negotiation with ENV. Reports could be presented at public meetings if desired, or posted on either a specific website for BCLMN, or on a page on the Ministry website (or on the BCLSS website?) depending on what the preference might be from ENV staff.

The mix of relative percentage of tasks would be at the discretion of ENV and could be flexible to match whatever circumstances might be in place at any specific time. In this circumstance, BCLSS would resolve to be as flexible as possible and respond as quickly as possible.

The cost for this option would be approximately $100,000/year and would include one full time staff member for the BCLSS / LLC partnership – an individual with appropriate university training, as well as training for the specific tasks that would be undertaken (field sampling, data analysis, report writing). This amount would also cover the cost of a part time office employee who would also be technically trained but specifically responsible for tasks like data entry, co-ordination, communication, and general administration.

It is anticipated that this funding would come to BCLSS as lead organization, and a network of lake groups in the province, but that LLC may cover the Kootenay region where they are based. In this case funding sampling would be by contract from BCLSS to LLC. This could apply to other contractors that BCLSS may hire to assist with lake sampling on other regions of the province. **Option 1 is the recommended option for BC.**

6.2 Option 2: Modified Alberta Lake Management Society Program

The Alberta Lake Management Society (ALMS) has an established program, LakeWatch, which receives funding from Alberta Environment and Parks. In 2017, this funding was $160,000 and in 2016 it was $140,000 (ALMS, 2018). This core funding pays for a Program Co-ordinator and lab budget. In addition to the Program Co-ordinator, the ALMS has an Executive Director. These permanent staff then hire technicians each summer to conduct sampling. LakeWatch follows Alberta Environment protocols and conducts sampling of 15 lakes that are provincial program lakes, 5 of which are long term trend lakes in parks. Alberta Environment provides an in-kind office space for the ALMS. ALMS staff samples each lake 5X over the summer and has volunteers assist and supply boats (the ALMS does not own a boat).

Having permanent staff allows the ALMS to leverage funds with other partners due to its' non-profit and charitable status. The ALMS then samples up to an additional 15 lakes for a total of 30 lakes per year (Peter, 2018, Personal Communication). Municipalities and Watershed Advisory Councils also provide funding in some instances if they want a lake sampled.

The ALMS has an interactive map on their website of lake water quality data and characteristics. Annual summary reports (snapshot) using a limited number of parameters are published very shortly after the completion of the sampling with the qualifier that the data has not undergone the final validation process. Later on, individual lake reports are published that include all of the parameters collected, and these are published on the ALMS website.

BCLSS / LLC could provide a variation of this program suited to the needs of the BCLMN. An overall full-time co-ordinator position with BCLSS would be the primary contact for ENV and provide supervision for part time staff who would do lake sampling as well as data compilation and reporting for the overall program and for individual lakes sampled and be published on the BCLSS website – similar to what is done by ALMS. It is proposed to hire four technically trained individuals for the six month period from April to September, who in two teams of two individuals would sample 32 lakes in both the late-winter/spring and late-summer sampling periods. Spring sampling would be scheduled for the times that are appropriate for the very different geography of the province (Vancouver Island lakes are samples in February/March, some Lower Mainland lakes are sampled February through April, and lakes in the Okanagan/ Thompson region are sampled in March/April depending on weather and ice-off. June and July time would be spent on data verification, and posting the results on the website. The full-time position would work in the post – September period to analyse data and post results to the BCLSS website. The choice of which lakes would be covered by BCLSS would be negotiated with ENV.

Salaries would be equivalent to 3 FTEs and additional funding would be required for travel costs (vehicle rental, accommodation, meals). This assumes that the lab analytical costs are to be

covered by ENV. The cost of this level of program (32 lakes – half of the scheduled number of lakes for the BCLMN in 2018) would be $175,000 per year. If a program with fewer lakes sampled (16) were deemed to be more desirable, the proposed budget would be $120,000 as a co-ordinator and two 6 month contract staff would still be required. **Option 2 is the recommended second choice of an option for BC should ENV not want to choose Option 1.**

6.3 Option 3: Modified US State Volunteer Lake Sampling Model

If ENV prefers a course different from Options 1 and 2, many US states have extensive programs using Community Based Monitoring/Lake Volunteer Monitoring/Stewardship Monitoring (program names vary according to jurisdiction). These were reviewed as background to developing options for BC and are summarized below. There are features in many programs that could be adapted to the BC situation.

The program in the state of Virginia has a number of unique features including the specific purpose that the data might be used for and set a level of confidence based on the training of the volunteer samplers and other factors. The program collects data for lakes and streams that makes for more complexity than exists for a very structured program like the BCLMN.

Fisher (2018, Personal communication & Email Communication) provided the following information on the Virginia Citizen Monitoring Program:

- They start by being specific on what stewardship data can be used for.
- They separate stewardship by level of monitoring reliability, quality, etc. and give them a rating number (1-3).
    - The group's level then determines which management decisions the data can be used for.
- They have an extensive quality assurance plan template that groups must fill out. This plan is used to assess the level of the group.
- Volunteer data is used in a number of ways: to educate students and the community, to collect baseline information to prioritize monitoring needs and establish background conditions, to contribute to local land use decisions, to indicate unusual conditions, for special studies, and for statewide water quality assessment reports. The use of volunteer data as direct evidence in enforcement actions is not considered appropriate.

Further information can be found at:

http://deq.state.va.us/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring/Guidance.aspx

The concept of rating data by purpose has merit and is one way to balance the amount of support given to groups by ENV with the value of the data, especially when resources available for stewardship support are limited. Another way to address this is by better training/auditing, and an enhanced QA/QC program for stewardship groups.

Since 1998, the Virginia Department of Environmental Quality (DEQ) has provided support to citizen volunteer groups to elevate the importance of volunteer monitoring and quality assurance of volunteer data. In addition, in 1999 the state initiated a Citizen Water Quality Grant Program, which provides various levels of support to promote and sustain volunteer monitoring efforts. This has been highly successful.

http://deq.state.va.us/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring/Guidance.aspx

Maine

The Maine Department of Environmental Protection and the US EPA provide support to a non-profit society, the Maine Volunteer Lake Monitoring Program. This society also has private donors as well as many collaborating organizations https://www.mainevlmp.org/#

Wisconsin

Wisconsin has a well-developed program that is a partnership between the Wisconsin Department of Natural Resources and stewardship groups that began in 1986. Citizen Lake Monitoring Network, the core of the Wisconsin Lakes Partnership, creates a bond between over 1000 citizen volunteers statewide and the Wisconsin DNR. The goals are to collect high quality data, to educate and empower volunteers, and to share this data and knowledge. http://dnr.wi.gov/lakes/clmn/

The program has many aspects because of its long history and experience that could be used as a model for BC. One example is their QA program that was developed for their stewardship sampling program: http://dnr.wi.gov/lakes/CLMN/qualityassurance/CLMNQAPP2010.pdf

Ontario

The Ministry of the Environment's Lake Partner Program works in partnership with the Federation of Ontario Cottagers' Associations, the Lake of the Woods District Property Owners Association and many other organizations to foster lake stewardship by increasing the public's awareness of the links between phosphorus and water clarity in Ontario lakes.

The program uses volunteers to collect total phosphorus (TP) and water clarity data for lakes throughout Ontario and cooperates with many science partners (including other MOE departments and municipalities) to provide accurate TP monitoring for specific lakes

of interest. The program has been quite successful: in 2004, water quality information was collected from more than 1,000 locations scattered throughout the major cottage areas of the province. https://www.ontario.ca/document/lakeshore-capacity-assessment-handbook-protecting-water-quality-inland-lakes/monitoring-lake-water-quality

Idaho

The state of Idaho also has an active Citizen Volunteer Monitoring program. It is also described as a partnership and provided as an example of a "cost-effective method of acquiring data and a great way to involve citizens in protecting water quality". https://www.deq.idaho.gov/media/1060462-citizen_volunteer_monitoring_program.pdf

Montana

The Northwest Montana Lakes Volunteer Monitoring Network (NWMTLVMN) is a partnership between Montana Fish, Wildlife & Parks and the Whitefish Lake Institute. Their mission is to recruit and train citizen scientist volunteers to monitor water quality, identify and report Aquatic Invasive Species (AIS) and promote watershed stewardship in Northwest Montana. Volunteers are generally the first responders to a water quality issue or an AIS sighting.

Through the work of the volunteers in the program, lake data is collected and an annual report is prepared detailing the health and status of these lakes. Volunteer monitoring is a critical component for the early detection of AIS in the Flathead Basin (Flathead, Lake and Lincoln counties). http://www.nwmtlvmn.org/

Washington State

Washington State is the most obvious point of reference for British Columbia. After a successful program of lake monitoring was conducted from 1989-1999 by the Washington State Department of Ecology, an alternative approach to sampling using citizen volunteers was proposed – with a pilot project in the late 1980s using volunteer lake samplers. With the discontinuing of State funding, the Washington State Lake Protection Association (equivalent to BCLSS) is still advocating for a state wide funded citizen monitoring program.

https://ecology.wa.gov/Research-Data/Monitoring-assessment/Lake-water-quality

http://www.walpa.org/waterline/march-2016/statewide-volunteer-lake-water-quality-monitoring/

A commonality of all the US lake monitoring programs is significant government funding to the volunteer sector – often through some innovative revenue allocation initiatives. There are also some innovative approaches to funding water management, monitoring and protection that might be considered.

What is proposed for the third option is development of an enhanced water stewardship program within the Ministry. Assignment of Ministry staff members (one individual in each geographical region) with a specified role to develop and facilitate community based monitoring. The goal would be to make community based monitoring a more important feature of the Ministry activities. In the initial startup phase (2-3 years) BCLSS and LLC would play the role of facilitators for training, education and establishment of local stewardship groups with eventual complete management and co-ordination being taken on by the Ministry.

This direction would require government to undergo a change in the way it monitors the resources it is responsible for. With regard to water management, the scope could be larger than just lake water quality monitoring and might include stream flow gauges, groundwater observation wells and snowpack measurement. Community groups could become the ears, eyes and hands of the Ministry in many ways.

The cost for this option would be similar to option 1 at approximately $100,000/year and would include one full time staff member for the BCLSS / LLC partnership – an individual with appropriate university training, as well as training for the specific tasks that would be undertaken (CBM group establishment, training, co-ordination). This amount would also cover the cost of a part time office employee who would also be technically trained but specifically responsible for tasks like data entry, co-ordination, communication, and general administration.

The major difference from option 1 is that the Ministry would take on a more active role in promoting community based monitoring by dedicating staff to this goal and the role of BCLSS/LLC would be a facilitator in building and establishing a provincial community based monitoring network but would after 2-3 years, the Ministry would be completely responsible as it becomes apparent there are advantages and efficiencies in using community based monitoring.

6.4 Advantages of Volunteer / Stewardship / Community Based Monitoring

There are a number of reasons for using volunteers in lake water quality programs, one of which (cost) is further discussed below but there are other, potentially more important reasons that using volunteer monitors is a desirable way to proceed. Many government and scientific/research agencies use volunteers to gather data. Many US states use volunteer samplers, as do some Canadian provinces (Ontario, Quebec, Alberta).

Scientists have also used volunteer samplers and have reported very favourably on their use as seen in the following publications:

Canfield, D.E., C.D. Brown, R.W. Bachman and M.V.Hoyer. 2002. Volunteer lake monitoring: testing the reliability of data collected by the Florida LAKEWATCH program. Lake and Reservoir Management 18(1): 1-8.

Fore, L.S., K. Paulson and K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams. Freshwater Biology 46:109-123.

Stokes, P., M. Havas, T. Brydges. 1990. Public participation and volunteer help in monitoring programs: An Assessment. Environmental Monitoring and Assessment November 1990, Volume 15, Issue 3: 225–229.

Documented reasons for using volunteer monitors:

Volunteer monitors are motivated and conscientious and would like to provide data that is of the highest quality. They care about their lake. They are eager to learn and many have professional skills that enhance their abilities.

Volunteer monitors generally live on the lake and can provide daily (if needed) data. Constant observation of factors like storm events, contamination, ice-on/ ice off data, fish kills, algal blooms etc., can only be provided by people living on or near the lake.

Lake residents can provide historical context – dam construction, stream diversions, fish introductions that might not otherwise be available. First Nations can provide local knowledge from elders and observations.

Engaging with citizen groups gives them a better sense of being involved with the protection of the lakes that they regard as an important part of their life. Co-operation and collaboration provide citizen groups with some sense of participating in working toward a solution to a problem - being a part of the process. This can lead from potentially antagonizing situations to creative solutions and 'buy-in' on the part of citizens.

6.4.1 Estimating cost for sampling BCLMN lakes using stewardship and Ministry staff: advantages of Community Based Monitoring

One critical piece of information requested in the terms for this proposal was to identify what the costs might be per sampling site if the sampling were to be done by community-based monitors. After considerable thought and discussion, it was determined that arriving at such a single monetary cost was not feasible – for a variety of reasons but there are significant monetary savings – as well as other advantages - to integrating stewardship samplers into the BCLMN program.

Table 4 shows the relative costs associated with different organizations and combinations of those organizations conducting sampling and Table 5 illustrates equipment costs for BCLSS, LLC, or stewardship groups.

Table 4: Costs of different organizations, and combinations of organizations, conducting sampling.

Group Sampling	Labour Costs	Lab Costs	Travel Costs	Other
MOE	Staff time	Standard[11]	Accommodation, per diem, regional travel	Boat gas
MOE & BCLSS or LLC[12]	BCLSS staff time/LLC contract[13]	Standard	Accommodation, per diem, regional travel	Boat gas
BCLSS with Stewardship Group[14]	BCLSS time only	Standard	Accommodation, per diem, regional travel	Set of equipment, boat gas
LLC with Stewardship Group (Kootenay Region only)	LLC contract	Standard	Accommodation, per diem, regional travel	Set of equipment, boat gas
BCLSS & LLC[15]	BCLSS staff time/LLC contract	Standard	Accommodation, per diem, regional travel	Set of equipment, boat, boat gas
Stewardship Group[16]	N/A	Standard	Per diem, local travel	Set of equipment, boat gas

[11] As per table provided by Mike Sokal of ENV. Lab costs are based on current BCLMN parameters. Incremental costs for additional sites on a lake are lab only.
[12] BCLSS or LLC assists ENV
[13] Assumes BCLSS has a staff person, LLC by contract
[14] Assumes use of volunteer's boat
[15] BCLSS sampling together
[16] Full set of equipment may be required

Table 5: Equipment costs for BCLSS, LLC, or stewardship groups.

YSI Pro ODO	30 m cable	Hoskins Scientific	$2,250
Van Dorn Bottle	2.2L	Idaho Aquatic Research Instruments	$575
Secchi Disk		Idaho Aquatic Research Instruments	$66
Plankton net	64µ mesh size 30 cm mouth size	Idaho Aquatic Research Instruments	$447
Miscellaneous	Tape measure, weights for Secchi disk, etc.	Various	$50
	Total Cost		**$3,388**

There are a number of fixed costs where sampling is done by ENV staff or by stewardship groups – the major one being the analytical costs. The analytical costs should be similar when done by either sampler (Table 4). There are no significant cost advantages using either approach.

The major advantage for stewardship sampling is in the cost of labour to travel to the lake sampling site and the labour costs involved with the sampling. The advantages of using local stewardship groups who are already at the lake may be explained by some of the following factors.

The savings in staff costs are significant because the stewardship samplers are at or near the lake. ENV staff incur travel costs as well as salary costs in sampling the lake. In the information provided by Mike Sokal, the operational costs are estimated in two categories; for day trips and overnight trips but include only meal and accommodation costs.

To provide a better comparison, ENV staff time and travel costs need to be included. Using the example of two ENV staff (Biologist 24 step 3 and an Engineering/Resource Aide 7 step three) on a day trip the salary costs for a seven hour day would be $403.62. With standard benefits, the actual cost to government would be much higher. Vehicle costs are also not included. The cost of a day trip to a lake 100 km away would be another $100 (200 km at $0.51 per km) at government mileage compensation. Other expenses like boat fuel, depreciation on boats and equipment are also not considered. For the case of overnight sampling trips, and additional cost for accommodation ($130 plus per diem meal costs of $50-70 per trip) need to be included.

If a local stewardship were to undertake the sampling, the travel and staff costs would be near zero. Local stewards do the work as volunteers and generally provide their own boats at no cost. They are invariably very conscientious, and with appropriate training and auditing can provide sampling that is equal to government staff.

Two examples:

Sampling Elk and Langford Lakes near Victoria. To sample these two lakes, ENV staff would drive a truck from Nanaimo towing a boat approximately 100 km each way. It would require two person days of time (approximately $400 staff time, $100 mileage cost plus meals – at least $500). The lakes could alternatively be sampled by local stewardship groups with co-ordination and support by BCLSS. Two samplings per year result in a cost saving of a minimum of $1000 a year for these two small lakes.

Sampling Charlie Lake near Fort St John. The driving distance from the Prince George ENV office to Fort St John is 437 km and 5-6 hours driving time and would require an overnight stay. The ENV cost in staff time (two staff as above) would be approximately $1000, the vehicle mileage cost about $500, accommodation $260 and meals $200 so approximately $2000. The local stewardship group costs would be negligible with co-ordination and support from BCLSS. For spring and summer sampling the cost difference is $4000 per year for this lake.

For a relatively small number of sites, it could be possible for BCLSS and/or LLC to provide support and training – with some support from ENV. BCLSS has directors in all parts of the province who are technically trained and typically volunteer 10 hours a month to the operation of the organization.

A general estimate that is for a lake sampling program, approximately 50% of the total cost is the laboratory analytical charges and 50% is the cost of collecting the samples (staff and travel). The analytical cost for water chemistry for the program is estimated at $44,692 (plus a potential cost of $116,850 for taxonomic samples). Anywhere from $500 to $4000 per year per site is probably a more realistic actual cost for sample collection (fieldwork and travel) when done by ENV staff.

Lakes with two or more sites should only incur marginally higher cost for the sampling costs – not double or the multiple cost, as is the case with the analytical costs.

The cost per site sampled by stewardship groups would depend on how many sites were to be covered by stewardship groups. There is a fixed cost in BCLSS/LLC providing the co-ordination, training and management of local samplers. If only a few sites (<10) were to be sampled by stewardship groups, the cost for training and co-ordination is relatively high on a per site cost but would decrease (on a cost per site comparison) as the number of sites sampled by stewardship / community groups increases. If sampling programs are considered with monthly or biweekly sampling, stewardship sampling becomes even more advantageous.

In conclusion, the major cost savings and efficiency for stewardship participation in the BCLMN is for sites that are remote from ENV offices and have existing lake stewardship groups or are lakes not presently in the network that have stewardship groups and for which the data from those lakes would be a valuable addition.

7.0 Potential Funding Sources

7.1 Grants from ENV

Under the previous BCLSMP, funding was provided for the BCLSMP by ENV for staff and support (essentially 1 FTE and office rental), water chemistry analysis through the Ministry lab, and staff review of lake reports.

The source of this funding was a grants program from the ENV budget, where annually a number of organizations were provided funding for various environmental endeavours. This program was cut in 2011, thus the funding to BCLSS for core operations was cut. Unless this grants program was to be permanently reinstated, this is not a sustainable source of continued core funding.

7.2 Water Related Revenue

In discussions with ENV staff, a common theme is lack of resources to do basic monitoring that is required for water management and protection. Many NGOs and small local agencies struggle to provide funding for projects and for initiatives that are not undertaken by the provincial government agencies like FLNRO who primarily deal with the standard licensing and permits processes or even through the activities of the Ministry of Environment & Climate Change Strategy which does not seem to have the capacity to deal with many emerging local and provincial issues. The opportunity exists for collaborative partnerships between government, NGOs, and community stewardship groups to greatly expand the capabilities of understanding problems related to water management and protection by creating a fund specifically managing water in British Columbia.

Proposed here is the establishment of a fund specifically to assist with the management of water resources in the province of BC. One percent of the annual income from water license fees collected by the province should be placed in a special fund to collaborate with non – government agencies and others to help manage water resources in BC. This fund would be administered by an Independent Trust Agency and funds dispersed to projects that are vetted by a Trust Committee.

The precedent for this proposal is the system that exists for the management of fish and wildlife. Under an agreement signed between the Province and the Freshwater Fisheries

Society of BC in 2015, 100% of the revenue generated from fishing licences directly benefits recreational fisheries. Funds goes into research, conservation and education programs, improving angler access and stocking programs.

The Habitat Conservation Trust Foundation receives 100% of the surcharge revenue collected from angling license sales to provide grants for fish conservation projects.

No money from the sale of fish licenses now goes to Provincial general revenue – it is all transferred to two non-governmental agencies who administer its allocation to a wide variety of organizations and projects. In British Columbia, water related revenue from tourism would be expected the generate tens of millions of dollars to the economy of the province, and it would seem appropriate that funding to protect and manage water quality and other aspects of the provincial water resource should receive similar funding – perhaps all of the revenue from water licenses might be appropriate (as is done with fish licenses) but in this proposal only one percent is proposed.

The benefits of this proposal are:

The provision of funding for community and NGO groups (as well and potentially including provincial government agencies), that have projects or proposals that would benefit the water resources of the province. Specifically, it would benefit government agencies, citizen stewardship groups and community based organizations interested in protection of water resources that are presently poorly funded. The enhancement of basic water management tools such as stream flow gauges, groundwater monitoring wells and lake and stream sampling programs, which have been reduced in many locations, would be of significant public benefit.

A flexible and rapid funding process – with quarterly calls for proposals and funding grant dispersals is proposed. Some issues require a much shorter response time that might be accommodated by existing funding options (of which few exist).

Opportunity for collaborative projects that might involve other related (fisheries, agriculture, wildlife, forestry) problems that bear on water management.

Charges on water bills on the North Saskatchewan R (Peter, 2018, personal communication) are being used to fund a monitoring program on the North Saskatchewan River. A surcharge of 10 to 15 cents per month on residential water bills is expected to result in a 1 million dollar fund that with will be linked to an Alberta government contribution of up to $2 million dollars if in kind support for the program (Edmonton Journal 2017).

Other governments have established similar independent agencies to fund water management projects. As an example, North Carolina in 1997 established the Cleanwater Management Trust Fund https://cwmtf.nc.gov/ It receives funding as an appropriation from government as well as revenue from special vehicle registration plates.

7.3 Creative Sentencing

Creative sentencing enables presiding judges to use sentencing alternatives where courts can order offenders to invest in measures to protect the environment. This is a significant source of funds for the BC Habitat Conservation Trust Fund (HCTF) who invests the funds in conservation projects. To date, HCTF has invested over 1.3 M dollars in projects throughout the province

Furthermore, to 2009, 46% of the total value of court awards was from the provisions of the Waste Management Act and its successor, the Environmental Management Act. 2.1 M dollars was received by HCTF from court awards up to 2009 (HCTF, 2011).

If only a small portion of this money was invested in lake stewardship, core funding would be available for BCLSS with a 4:1 return on dollars invested. [17]

7.4 BCCF – MFLNRO Model

The BC Conservation Foundation (BCCF) is a society with registered charitable status and was founded by the BC Wildlife Federation to promote and assist in the conservation of fish and wildlife in BC. The BCCF carries out projects of their own and as well as providing clients and partners with project management services for the administration, implementation and delivery of conservation projects, and has personnel that manage projects in three regional offices. (https://www.bccf.com)

Base funding comes from the BC Wildlife Federation and the rest comes from 13.5% overhead charged on projects they administer (Ashley, 2018, Personal Communication). BCCF maintains core staff that allows them to apply for funding for projects as well as administer projects for partners.

Many of the projects are in partnership with the Ministry of Forests and Natural Resource Operations (MFLNRO), and a similar model between BCLSS and the ENV could be implemented between ENV and the volunteer lake stewardship sector.

8.0 Integrated Program Setup

Basic equipment costs for monitoring are shown in Table 5 (Section 6.4). Both BCLSS and LLC may need to obtain this equipment for the 2018 field season.

Table 4 (Section 6.4) shows a breakdown of costs associated with different organizations, and combinations of organizations conducting sampling. This will vary according to the needs of

[17] This is based on BCLSS experience with the BC Lake Stewardship and Monitoring Program.

ENV, which is anticipated to vary from year to year and region to region. Options for integrating the programs must therefore be somewhat flexible as described in Section 6.

Program deliverables for 2018, which is a start up year, are proposed as follows:

- Engagement of 70 Stewardship Groups
- Monitoring of 5-10 Provincial Program Lakes
- 10 Lake Brochures (typical BCLSS reports)
- Presentations of lake data summaries to 5 community groups
- Delivery of 6-10 volunteer safety and training sessions
- Data compilation, QA/QC and entry of all results into the EMS data base

It is anticipated that LLC will assist in the Kootenay Region and BCLSS will be available for the rest of the province to conduct monitoring, and that ENV will work with both groups to ensure consistency with current ENV methods and protocols. Since BCLSS will be lead organization receiving funding from the province, a Memorandum of Understanding will have to be developed between the two organizations for transfer of funds from BCLSS to LLC.

9.0 References

ALMS, 2018. *Alberta Lake Management Society.* https://www.facebook.com/AlbertaLakeManagement/. Accessed on Feb. 15, 2018.

Ashley, K. 2018. Board Member, Habitat Conservation Trust Foundation. *Personal Communication.*

Brahney, Janice. 2018. Department of Earth and Environmental Sciences. University of British Columbia, Okanagan (formerly with UBC). *Email Communication.*

Brown, C. 2018. Manager, NSERC Canadian Lake Pulse Network. *Email Communication.* January 31, 2018.

Burns N.M., J. C. Rutherford & J. S. Clayton (1999) *A Monitoring and Classification System for New Zealand Lakes and Reservoirs, Lake and Reservoir Management*, 15:4, 255-271, DOI: 10.1080/07438149909354122

Carlson, R.E. (1977) *A trophic state index for lakes.* Limnology and Oceanography. 22:2 361--369.

Carlson, R.E. and J. Simpson. 1996. *A Coordinator's Guide to Volunteer Lake Monitoring Methods*. North American Lake Management Society. 96 pp.

Carver, Martin. 2017. *Water Monitoring and Climate in the Upper Columbia Basin, Summary of Current Status and Opportunities*. Columbia Basin Trust.

Cavanagh, N., Nordin, R.N., Pommen, L.W., and Swain, L.G. 1998. Guidelines for designing and implementing a water quality monitoring program in British Columbia. BC Ministry of Environment, Lands and Parks, Water Management Branch.

Chapra S.C. and F.H. Dobson. 1982. *Quantification of Lake trophic typologies of Nauman (surface water) and Thieneman (oxygen) with special reference to the Great Lakes*. J. Great Lakes Research 7 :182-193.

CIER, 2011.Centre for Indigenous Environmental Resources. *First Nations Integrated Watershed Planning Guide.*Winnipeg, Manitoba. http://www.yourcier.org/water-guidebooks.html

Doshi, S. 2010. Recreational Carrying Capacity in Lakes. Indiana Clean lakes Program Factsheet 10-42. http://www.indiana.edu/~clp/documents/Carrying%20Capacity%20Factsheet.pdf

Edmonton Journal 2017**.** *New charge on water bills to help study North Saskatchewan River headwaters*. 21 August 2017. http://edmontonjournal.com/news/local-news/new-charge-on-water-bills-to-help-study-north-saskatchewan-river-headwaters

Epps, D. 2018. Section Head. Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Personal Communication*.

EAUBC Freshwater Ecoregion. 2014. Published by the Ministry of Environment & Climate Change Strategy and Climate Change Strategy - Knowledge Management . https://catalogue.data.gov.bc.ca/dataset/eaubc-freshwater-ecoregion

Fisher, J. 2018. Environmental Impact Assessment Biologist. Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Personal Communication*.

Fisher, J. 2017. Environmental Impact Assessment Biologist. Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Power Point Presentation dated Dec. 7, 2017 presented to Monitoring, Assessment, and Stewardship Team Meeting.*

Habitat Conservation Trust Foundation. 2011. *Investing in Conservation with revenue from creative sentencing – The characteristics of the court award portfolio managed by the BC Habitat Conservation Trust Foundation, 1993 – 2009*. http://dffsw7ptgbl26.cloudfront.net/images/hctf-creative-sentencing-report-web-version.pdf

Hartwig, K., A.Kanu, C. DuBois, E. Hendriks, K. Cave, J. Fresque-Baxter, K. Trembath, and E. Kelly. 2016. *Realizing the Potential of Community Based Monitoring in Assessing the Health of Our Waters.* http://awsassets.wwf.ca/downloads/realizing_the_potential_of_community_based_monitoring_in_assessing_the_health_of_our_.pdf

Larratt Aquatic Consulting. 2014. *Okanagan Lake Collaborative Monitoring Agreement 2011-2014 Sampling Program Synthesis Report November 2014.* Prepared for BC Ministry of Environment & Climate Change Strategy, Environmental Protection Division.

Leschied, H. 2018. Program Director, Living Lakes Canada. *Email Communication.* February 2, 2018.

Luttmer, 2018. *BC Water Monitoring Landscape Scan*. Prepared for BC Water Funders Collaborative. Golden, BC.

Mitchell, M. 2018. Lay Monitoring Program Coordinator, Vermont Department of Environmental Conservation Watershed Management Division, Lakes and Ponds Program. *Personal Communication.* February 28, 2018.

NSERC, 2018. http://www.nserc-crsng.gc.ca/Business-Entreprise/How-Comment/Networks-Reseaux/NCLPN-NCLPN_eng.asp accessed Feb. 2, 2018.

Neufeld, Alison. 2010. *Water Quality Assessment and Objectives for Windermere Lake*. Ministry of Environment, Environmental Protection Division.

Ontario 2017. *Lakeshore Capacity Assessment Handbook: Protecting Water Quality in Inland Lakes on Ontario's Precambrian Shield Appendix A: Rationale for a Revised Phosphorus Criterion for Precambian Shield Lakes in Ontario*. https://www.ontario.ca/page/lakeshore-capacity-assessment-handbook-protecting-water-quality-inland-lakes-ontarios-precambrian. Accessed Feb 25, 2018.

Ontario 2018. *Lakeshore Capacity Assessment Handbook: Water quality in Inland Lakes*. https://www.ontario.ca/document/lakeshore-capacity-assessment-handbook-protecting-water-quality-inland-lakes accessed 25Feb 2018

Perrin, C and A Blyth. 1998. *An Ecozone Classification for Lakes and Streams of British Columbia*. Prepared for the Ministry of Environment & Climate Change Strategy Lands and Parks. 95p

Perrin, C and A Blyth. 1999. *Index sites for Aquatic Ecoregions of British Columbia*. Prepared for the Ministry of Environment & Climate Change Strategy Lands and Parks. 56p

Peter, Brad. 2018. Executive Director. Alberta Lake Management Society. *Personal Communication.*

Roumieu, D. 2018. Program Coordinator, BCLSS. *Personal Communication.*

Sam, Michelle. 2018. Ktunaxa First Nation. *Email Communication via Living Lakes Canada.* Feb. 20, 2018.

Secchi Dip in web page. http://www.secchidipin.org/index.php/monitoring-methods/trophic-state-equations/

Sidney, M. 2018. Environmental Impact Assessment Biologist, Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Personal Communication.*

Sokal, M. 2018. Coordinator, Provincial Lakes Network. Monitoring, Assessment, and Stewardship. Environmental Protection. *Email Communication.* February 5, 2018.

Sokal, M. 2018. Coordinator, Provincial Lakes Network. Monitoring, Assessment, and Stewardship. Environmental Protection. *Personal Communication*.

Swan, C. 2018. Environmental Impact Assessment Biologist, Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Personal Communication*.

Torunski, L. 2018. Environmental Impact Assessment Biologist, Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Personal Communication.*

Vieira, E. 2018. Associate Regional Manager, Thompson Region. Fraser Basin Council. Personal Communication.

Warren, G. 2018. Environmental Impact Assessment Biologist, Monitoring, Assessment, and Stewardship. Environmental Protection Division, BC Ministry of Environment & Climate Change Strategy. *Email Communication*.

Appendix A: Terms of Reference for the Integrated Monitoring Framework

The Contractor will provide the following services:

1. Develop an integrated monitoring framework that incorporates both the existing BCLSS volunteer lake monitoring program with the Provincial Lakes Monitoring Network.

    - Assess the current and future needs of ENV and the community based, volunteer stewardship sector and revise the BCLSMP accordingly. This will involve some consultation with key staff in the ENV and assessment from both a regional and provincial perspective i.e., determination of the needs of each provincial region, as well as the overarching provincial needs.
    - Co-ordinate with the provincial lakes network co-ordinator – Mike Sokal, EIA Biologist in Penticton.
    - Ensure provincial sampling requirements are met.
    - Assess the ability of ENV to support volunteer monitors in the different regions across the province and determine how BCLSS and Living Lakes Canada (LLC) can help with this.
    - Assess the applicability of the BC Conservation Foundation/MFLNRO model to the BCLSS/ENV partnership.
    - Both BCLSS and LLC will reach out to its partnerships to determine potential linkages and synergies with initiatives such as; Lakes Pulse Canada, Fraser Basin Council, Okanagan Basin Water Board, BC Water Leaders Consortium, etc.
    - Determine requirements and budget necessary for a BCLSS staff person to be available to assist ENV with lake sampling throughout the province including, qualifications, technical and safety training, equipment needed, travel costs etc.
    - Determine the requirements for setting up volunteers in key locations across the province, to provide technical assistance for sampling for or with ENV, and others (i.e., BCLSS or LLC) to conduct lake sampling.
    - Prepare BCLSS and LLC to be able to assist ENV with monitoring beginning in April, 2018.
    - Identify regional priorities based on readiness of volunteer groups, and other regional needs.
    - Determine how BCLSS can best partner with Living Lakes Canada in Year 2 and beyond to maximize the efficiency of both organizations in their support of the provincial lake monitoring network needs.
    - Data base integration – identify how the data collected by volunteers will be integrated into provincial database (i.e. EMS) and what data this would include.

- Data Analysis – identify roles and responsibilities with respect to data analysis. This includes tabulating data, QA/QC of data/results back from lab, and basic review of the data.
- Reporting function – Identify options on how the data can be reported out. Consideration of adopting a unique water quality index for BC Lakes (how to make the information collected useful for public and decision makers), such as trophic status.

2. Completion of monitoring program set-up and field prep.

    - Completion of this task requires the results of Task 1. It will be led by LLC with input from BCLSS and the ENV. LLC will draw on how their programs can best contribute to the integration of the provincial volunteer monitoring framework and the provincial lakes monitoring program.
    - LLC will identify their ability to meet the needs in the Kootenay/Columbia Region. LLC and BCLSS will collaborate on identifying how to best meet the needs for the rest of the province.
    - Integrate local, regional and provincial First Nations knowledge/perspective in field design and delivery for their identified priority monitoring sites.
    - Equipment needed for the volunteer monitoring component will be identified e.g., DO/T meters, van dorn samplers or equivalent, Secchi disks.
    - Establish a unit cost/sample/lake (some lakes may have more than one sample site) model based on who is conducting the sampling (i.e., volunteer organization, BCLSS, LLC, ENV or some combination thereof).
    - Implementation of the volunteer lake monitoring program in 2018, with full implementation in 2019 (see Year 2 below).

3. Completion of volunteer technical and safety training program.

    - This will be updated from existing BCLSS & ENV guidance documents e.g., LakeKeepers Training with input from the ENV, BC field sampling manuals.

4. Completion of lake stewardship education materials package.

    - This will be incorporating existing BCLSS & ENV guidance documents e.g., LakeKeepers Training with input from the ENV and potentially updated in order to help reflect both FN and non FN lake stewardship work.

Appendix B: Discussion of Water Quality QA/QC

Replicate samples

Replicate sampling (at a minimum duplicates that are collected either simultaneously or in close succession) provide a rough estimate of the overall precision associated with the field technique and laboratory analysis. When the data values for replicate samples have low variability, then contamination during collection or analysis is unlikely and uncertainty associated with data collection can be ruled out. When the data have high variability, contamination may have occurred during collection/analysis or as a result of environmental conditions that were highly variable. In these instances, the best attempt at documenting the

true conditions is to record the mean of the values plus/minus one standard deviation (66% confidence) or, plus/minus two standard deviations (95 % confidence). The standard deviation is a quantifiable representation of the imprecision. The following hypothetical example demonstrates how replicate data values should be interpreted when high variability exists (precision is low):

As an example. Triplicate samples at site X were analyzed for total phosphorus and yielded results of 24 µg P/L, 20 µg P/L and 32 µg P/L, respectively. In this case, the mean value is 25.34 µg P/L with a standard deviation of 6.11. The value should be recorded as 25.34:6.ll µg P/L. All that can be stated about the total phosphorus concentration at site X at that particular time is that it was likely to be in the range of 19.23-31.45 µg/L (with a confidence of 66%). For Interpreting Water Quality Data greater confidence (i.e., 95%), the range must be expressed as 25.34:12.22 µg P/L (or 13.21-37.56 µg P/L).

Precision can be expressed as a relative percent mean difference when duplicates were collected as per the absolute value of the following equation:

$$\frac{(\text{data value A} - \text{data value B})}{(A+B)/2} * 100$$

When three or more replicates were collected, precision can be expressed as a percent relative standard deviation by dividing the standard deviation of the analytical result by the mean and then multiplying by 100. Ideally the percent relative standard deviation should be close to 0%. For the above example the precision would be 24% (6.11 + 25.34 x 100).

Note: the precision is influenced by how close the analytical value is to the method detection limit (MDL). The MDL is the level above which there is a high probability (e.g., 95 %+) that a substance can be detected. The percent relative standard deviation increases rapidly as the analytical value approaches the MDL. Consequently, the use of percent mean difference or percent relative standard deviation is limited to analytical values that are at least five times the MDL. The following are 'rule of thumb' criteria for precision values (above which the data should be viewed with caution):

A 25% relative difference for duplicates (i.e., a value exceeding 25% is considered too imprecise); a18% relative standard deviation for triplicates;

And 10% relative standard deviation for six or more replicates.

Note: Information from replicate samples at one site cannot be used to infer ranges for values at other sites where replicates were not collected. A single data value at another site does not constitute a mean. Therefore, the value in assessing replicate data early in the program is apparent. If imprecision exists then the source of variability should be assessed. To test the sample collection and handling techniques, field replicates must be submitted. To test the analytical process, replicate analyses of one sample must be done, or replicates of a certified reference sample (section 2.3) should be submitted "blind" to the laboratory. Since imprecision can be due to poor field or laboratory technique, it is necessary to identify specifically where the contamination was introduced. This can be accomplished through the use of blank samples. Once the source of contamination is identified, lab or field staff may require re-training to ensure that standard protocols are being followed [see 'Field Protocol Series' (Cavanagh, et al., l994a,b,c) in the case of field staff]. If, after all this, environmental variability is suspected then a study of the site should be conducted to assess its suitability as a sample site.

Blank samples

Blanks are designed to detect contamination that contribute to imprecision and bias. For details about how each blank is prepared, refer to the 'Ambient Fresh Water and Effluent Sampling Manual' (Cavanagh, et al., 1994a). The different types of blanks are:

Trip blanks — laboratory provided de-ionized water preserved prior to the sample trip in the same manner as the associated field sample. It remains unopened throughout the duration of the trip. These blanks detect any widespread contamination resulting from the container or preservative during transport and storage.

Field blanks — de-ionized water which is exposed to the sampling environment at the sample site and handled in the same manner as the real sample (e.g., preserved, filtered). These blanks provide information on contamination resulting from the handling technique and from exposure to the atmosphere.

Equipment blanks — samples of de-ionized water that is used to rinse sampling equipment. This type of blank is useful in documenting the effectiveness of the cleaning or decontamination of equipment.

Filtration blanks (or rinse blanks) — de-ionized water that is passed through the filtration apparatus in the same manner as the sample. Analysis of the filtrate provides an indication of the types of contaminants that may have been introduced through contact with the filtration apparatus. Filtration blanks are also used as a check for potential cross-contamination through inadequate field filtration/cleaning techniques.

When blank samples provide evidence of contamination, the real samples are likely to be biased high and towards false positive results. Under some circumstances, a correction factor can be incorporated into the real data, but this must be flagged in the report. Rules of thumb for assessing contamination are

(1) not more than 5% of the blanks should exceed the 'method detection limit' and

(2) blanks should not exceed 10% of the environmental levels (based on pilot study information) or 10% of the level of interest (e.g., a criterion or objective). These rules of thumb are, in effect, data quality objectives for contamination.

The following key represents a step-by—step process for addressing contamination:

1. Do all blanks show any level of contamination? If the answer to this question is no, then all field and analytical techniques that the blanks tested for can be considered clean and the real sample data are treated as uncontaminated. If the answer is yes, proceed to step 2.

2. When blanks demonstrate that contamination has occurred (as per above), then the objectives of the study must be considered when deciding how to treat the real sample data. If the objective is to detect minute changes in variable concentrations then even small levels of contamination reduce the ability to interpret the data with confidence. In the case where the contamination values approach the real data values, the data collected during the particular sample trip may be invalid. Conversely, when the purpose of the study is to monitor for large variations, then small levels of contamination are not significant. In this case, a correction of the data can be made (subtract blank data values from the sample data values to get the reported value).

For pre- and post-blanks, such as the case with filtration blanks (before use of apparatus and after at least one real sample has been filtered), the situation is more complicated. If neither the pre- nor the post-blank are contaminated then the filtration apparatus was sufficiently cleaned before and between samples. If both blanks were contaminated to the same degree then it can be assumed that all the real samples were equally contaminated. If this level of contamination is not severe then the data can be corrected as above. A general rule regarding

blanks is that if contamination is severe (i.e., blank values exceed data quality objectives), then the data for that particular sample round should be excluded from interpretation. If the post-filtration blank is contaminated while the pre-filtration blank is not, then it is assumed that the cleaning technique was insufficient and all samples (except the first collected) are generally invalid. This is the case because there is no way of calculating the degree to which any one sample was contaminated by technique or previous samples. Under these circumstances, staff must be retrained.

Note: Whenever blanks are found to be contaminated in excess of the data quality objectives, the source of contamination should be addressed to eliminate it in the future.

Reference samples

Standard reference samples aim to measure the accuracy of analyses performed by the analyzing laboratory. The variable concentrations in these reference solutions can vary depending on the source of the sample and the variable being tested. It is often desirable to use reference samples that are close to the criterion levels established to protect aquatic life, but preferably close to the range of values expected in the real samples. Therefore, the results present a measure of confidence in the laboratory's ability to provide reliable data in those variable ranges that are critical.

Accuracy is expressed as a percent by dividing the analytical result by the certified ('true') concentration of the reference solution and multiplying by 100. Ideally, the expressed accuracy value should approach 100%. When reference sample values exceed 100% then the reported real sample values are expected to be the same increment greater than the true value.

For example, if a reference sample certified at 300 µg/L for iron is reported by the analyzing lab to be 420 µg/L then the accuracy is 140%. It can therefore be expected that the lab may have over-estimated the iron concentration in the real samples by about 40%. The same rationale follows when the lab provides values that are below the true value for the reference sample (<100%).

The accuracy for measuring the concentration in the standard material must also be taken into account. Different laboratories can use different and equally valid test methods. This can lead to different results for the same sample, which leads to all certified reference samples having an acceptable range documented for each (e.g. +/- l0%). For the above example, the acceptable range would be 300 +/- 30 µg/L. Analytical laboratories reporting values between 270 and 330 µg Fe/L would be considered accurate and no correction of sample data would be necessary.

Whenever correcting data for these sorts of discrepancies, the data should always be flagged and the rationale for the correction explained.

Spiked samples

Spiked samples for each variable being tested can be prepared by spiking aliquots of a single water sample with pre-measured amounts of the variable of interest. The information gained from spiked samples is used to reveal any systematic errors (or bias) in the analytical method.

Since a spiked sample is analyzed in conjunction with un-spiked aliquots of the same sample, the accuracy of the analytical technique is tested. The difference between the reported spiked sample value and the un-spiked sample values should be the spike concentration. The accuracy can be expressed as a percent by dividing this calculated spike concentration by the 'true' spike concentration and multiplying by 100. If the value approaches 100% then the analysis can be considered accurate and unbiased. Therefore, the aliquots that were un-spiked can be considered to be accurate. When the value deviates from 100% (either above or below) then it can be assumed that the laboratory is making similar errors with real samples (refer to section 2.3 for an explanation of how to account for analytical bias). A rule of thumb is that % recovery of spike should be l00 +/- l0%.

When either spiked or reference samples indicate that the analyzing laboratory is providing biased results, then it is necessary that the program manager consult with the lab in order that they may address the problem.

Quality Assurance / Quality Control Water Quality Sampling Considerations

This QA/QC information provides an estimate of the total uncertainty and degree of contamination associated with the data. Total uncertainty is the variability (precision plus bias) associated with the sample collection and sample analyses. An allowable upper limit on total uncertainty (i.e., data quality objectives) should be established for each program and this value should not be exceeded. The limit will reflect the required level of confidence in the data and is arrived at with the assistance of a statistician (an example of the required level of confidence might be 95% confidence that the data are within 30% of the true conditions). In those instances where the level is exceeded, all associated sample values (or outliers) must be flagged in both the database and in the final report. It might be worth considering a threshold for acceptable data and only data which has been checked and approved be entered into EMS. The decision whether to use data that fail to meet the prescribed data quality objectives is a matter of discretion, but all data must be included in the report – with qualifiers or explanation where necessary. The authors must identify and provide the rationale for the exclusion of any data from interpretation. When exceedances are detected early in the monitoring program then the situation should be addressed prior to continued sampling to reduce further uncertainty.

Summary of QA/QC

The following is a breakdown of the QA/QC sample types.

Sample type	Measures
Laboratory replicates	Analytical precision
Field replicates	Sampling + environmental + analytical precision
Certified reference samples	Analytical accuracy
Certified reference replicates	Analytical accuracy and precision
Spiked samples	Analytical accuracy
Field blank	Contamination (bias and imprecision) introduced during sample handling in the field and laboratory
Trip blank	Contamination (bias and imprecision) introduced by the container, preservative, and/or during transportation
Equipment blank	Contamination (bias and imprecision) introduced through improper cleaning techniques
Filtration blank	Contamination (bias and imprecision) introduced from the filtration apparatus and inadequate cleaning of apparatus
Laboratory blank	Contamination (bias and imprecision) introduced during laboratory analysis

Compiling Data

All data should be summarized in tables that will be incorporated into a report, either in the body of the report (when the number of variables is small), or as appendices. Summary tables for each site should be compiled and include basic statistics (# of values, minimum, maximum, mean, standard deviation, and period of record) for all field and laboratory data. This format allows for easy access to information such as the number of times any one variable was sampled and the range of conditions (worst-case to best-case occurrences). These are general tables that are not intended to partition out seasonal variability or frequency of criteria (or objective) exceedance. When compiling data that focus on seasonal effects such as high or low flow periods and spring overturn events, interpretation of related data is required.

Whenever possible and meaningful, the raw data should be presented in graphical form and not simply described in the summary tables discussed earlier (Chapter 3). Graphical displays

virtually always serve as an aid in the data presentation and interpretation processes; however, there is little to be gained by generation graphs where data are close to the MDL or vary only to a minor degree throughout the year.

A plot of raw data values (for one site) against time is an important preliminary tool to assist in visualizing the data distribution and to provide a check for temporal patterns and extreme values (outliers). When data exist for more than one year, graphical presentation makes seasonal patterns readily apparent. Each seasonal effect (strata) should be partitioned and graphed alone such that trends that develop over the long—term become visually clear.

Statistics

The most reliable method of ascertaining water quality conditions is through statistical analyses of data. The specific analyses performed will have been decided upon during the design phase of the monitoring program. Consultation with a statistician during that initial phase ensures that the monitoring objectives are attainable, and provides guidance on the use of the various statistical tests. A complete discussion of all the statistics that are available for sampling programs is beyond the scope of these guidelines. There are some important analyses that the BCLMN data would be used for. One of which is trend analysis. There are a number of techniques that can be considered e.g., Mann-Kendall tests. Since a main objective of lake sampling is trend detection and analysis, a description about how to statistically analyze trends should be included.

However, the more general statistical tests are discussed in detail below. Under some circumstances, some of the more rigorous and robust tests, such as the ANOVA and non-parametric analyses are more appropriate than the ones discussed here. For a discussion of how these tests are applied, refer to a statistical text. However, the following discussion includes those general statistics that are most likely to be applied in the context of water quality monitoring in British Columbia.

As such, the following statistics will be the minimum required to test null hypotheses:

The Mean — The mean is the most widely used measure of central tendency. The most efficient, unbiased, and consistent estimate of the population mean, [1, is the sample mean, X (read as ‘X bar’). It is calculated by summing the individual observations (Xi) and dividing by the number of sampling units (n). Hence

$$\underline{X= \sum Xi}$$

$$n$$

Deviation — The deviation is the quantity by which each individual data point differs from the arithmetic mean of the sample.

$$Xi= |Xi-X|$$

Variance — The variance is the mean of the squares of the deviations. The most efficient , unbiased estimate of the population variance, is the sample variance s2. It is calculated by first determining the 'sum of the squares of the deviations' (denoted SS) then dividing this value by the 'degrees of freedom' (the sample number, n, minus 1 - denoted V).

Standard Deviation — The standard deviation (denoted s) is the positive square root of the variance.

Percentiles - Percentiles are used for dividing samples into hundredths. For water quality sampling programs, this statistic is typically applied to toxicity testing and bacteriological criteria establishment.

An example of a toxicity percentile would be the expression LD50 (the 50th percentile of the lethal dose). This refers to a scenario in which 50% of the experimental subjects survive the particular dose of the contaminant while 50% do not.

An example of a percentile as it applies to bacteriological criteria establishment is the expression 'fewer than 10 fecal coliform bacteria per 100 mL of water (90th percentile)'. This criteria states that 90% of the samples collected must contain fewer than 10 bacteria per 100 mL of water. For example, if a single sample were collected on each of 30 consecutive days, then 27 of those samples would be required to have fewer than 10 coliform bacteria per 100 mL of water.

Hypothesis Testing (the F-test and the t-test) — As alluded to earlier, hypothesis testing for most water quality monitoring programs will seek to determine if a significant difference exists (either spatially or temporally). One test that is applied to determine if a difference exists is the F-test. This test is most often used in water quality sampling programs to determine if variances are similar between either two sites or at one site between two time periods. In order to definitively state that a change has occurred as a result of human activity (treatment), it is necessary to establish that the variances between the control and treatment do not differ. Use of F-test and t-test are beyond the scope of this short document but are discusses in detail in The Guidelines For Interpreting Water Quality Data and many other standard biometrics or statistical text books.

Appendix C: List of Parameters Sampled by Agency/Organization

Parameter	MOE Lakes	Lake Pulse Lakes	UBCO Lakes
Epilimnion sample	✓		✓
Hypolimnion sample	✓		
Chlorophyll-a	✓		✓
Total N	✓	✓	
NO3	✓		
NO2	✓		
TKN	✓		
Ammonia	✓		
Total P	✓	✓	✓
Dissolved P	✓		
Ortho-P	✓		
Silica	✓		
TOC	✓		✓
Cl	✓		✓ (Cl-)
SO4	✓		✓
Hardness (total)	✓		
Ca (included with hardness)	✓		
Mg (included with hardness)	✓		
Metals (total)	✓		
Metals (dissolved)	✓		
Temperature	Vertical profile	✓	Surface (some profiles)
Dissolved Oxygen	Vertical profile		
Secchi depth	Record depth		
Phytoplankton (1L)	✓	✓	
Zooplankton	✓	✓	✓ (abundance Zoop/L; diversity)
pH		✓	✓
Alkalinity			✓
Conductivity		✓	✓
Turbidity			✓
N4H			✓
NO3-			✓
DOC			✓
TDN			✓

DON			✓
DOC fluorescence			✓
Ca++			✓
Mg++			✓
Na++			✓
K+			✓
d18O, 2H			✓
Bacteria (cells/mL)			✓
Microbial diversity			✓
Carbon (sediment)			✓
Nitrogen (sediment)			✓
% organic matter			✓
Diatom community composition			✓
Cladoceran community composition			✓
Core samples		✓	
Pesticides & pharmaceuticals		✓ (1/2 of lakes)	

Appendix D: Indigenous Peoples: Indian Bands and Nation-Based Organizations

The following was provided by Living Lakes Canada and Michelle Sam of the Ktunaxa First Nation.

Indigenous Knowledge and culture in Canada, includes a way of life rich with songs, stories, ceremonies, values, beliefs and languages. Each First Nation has a different protocol with how Traditional Knowledge is held and transferred. Local and Traditional Knowledge provide key insights and observations to lake water quality monitoring and water stewardship including historical and current land-use practices that could impact water quality. Through collaborating with local First Nations within the traditional territory where monitoring is to occur, issues of concern including potential point source pollution areas, appropriate site reconnaissance and establishment of monitoring locations are driven by community involvement. This community involvement builds capacity and local relevance for the project, thus making the project more sustainable.

There are many resources available for identifying relative locations of traditional territories including native-land.ca, INAC Map of First Nations in British Columbia, INAC First Nations Profile Interactive Map. Contacting the Nation, band office or local governing body of the traditional territory to find out appropriate contacts and protocol to follow is the first step for collaborative water stewardship projects. The Centre for Indigenous Environmental Resources (CIER) released a series of Watershed Guide Books for partnering with local First Nations and watershed planning and management. Many Nations also have toolkits or guidebooks prepared for their citizens to understand governance, roles, rights and responsibilities that provide important background information for a foundation of trust and understanding. Other important background information includes the Truth and Reconciliation Calls to Action and Canada's commitment to the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) to be used as a framework to reach true reconciliation through the help of initiatives like #Next150.

The Centre for Indigenous Environmental Resources (CIER), is a national First Nation directed environmental non-profit organization that offers research, advisory, and education and training services to Indigenous communities, governments and private companies through four program areas: Taking Action on Climate Change, Building Sustainable Communities, Protecting Lands and Waters, and Conserving Biodiversity www.cier.ca

CIER (2011), emphasize that First Nations have a unique, complex relationship with water that extends beyond using water for their personal or community needs or as the life support system for the food they harvest and consume. First Nations' relationships with water include cultural, spiritual, economic, stewardship, governance and rights - based aspects. In addition, many First Nations indicate that water also has responsibilities given by the Creator to provide for people and nature (CIER, 2011).

CIER has a guidebook for First Nations Integrated Watershed Planning (CIER, 2011), as well as a number of other guidebooks and resources.

Further First Nations perspective has been provided by Michele Sam of the Ktunaxa First Nation (2018) as follows:

Water stewardship to many First Nations is based on of a theme of reciprocity, trust and sacredness[18]

> *"Our relationship with our lands, territories and water is the fundamental physical cultural and spiritual basis for our existence. This relationship to our Mother Earth requires us to conserve our freshwaters and oceans for the survival of present and future generations. We assert our role as caretakers with rights and responsibilities to defend and ensure the protection, availability and purity of water. We stand united to follow and implement our knowledge and traditional laws and exercise our right of self-ˇdetermination to preserve water, and to preserve life."*[19]

Because jurisdictional issues exist, there is no 'one voice' in current approaches, to represent Indigenous peoples' perspectives and needs. Indian band administrations (First Nations) whose jurisdiction upon reserve lands can include fresh water lakes, can only consider lakes within reserve communities boundaries despite source waters originating off reserve as well as run off. Off reserve Nation based organizations are often expected to respond to, or be included/consulted within non-First Nations community and organizations processes and projects but are however influenced by a lands and resources lens, which is determined by external entities, through treaty and land claims, mining and other industry social responsibilities. A systematic approach to water monitoring undertaken over the past number of years has unwittingly perpetuated a knowledge gap of those Band Administrations and Nation based organizations—those with capacity and those without. But the issue is more than just politics because water runs across man made boundaries and jurisdictions---it can sit invisible with a story to tell but inaudible due to jurisdictions and definitions that limit relationships in which to transform and transfer knowledge for health and well being. Often what happens on the reserve 'stays on the reserve' until it flows downstream. Because of the location of most reserves, band administrations are 'front line' witnesses to what is occurring and often have place based historical memory to draw upon to contextualize changes over time.

[18] Perspectives on the BC Water Sustainability Act: First Nations Respond to Water Governance Reform in British Columbia. Program on Water Governance, UBC 2017.
[19] From the Simpcw First Nation (a Shuswap Nation member) Water Declaration (2010), cited in Shuswap Nation Tribal Council, 2013, p.1

Water as an issue, is not only limited to drinking water, but also downstream impacts and cumulative impacts of development over the past 100-150 years that now impact Band administrations. Federal legislation and local access to membership and community members provide Band administrations with information sources not always consulted. Lake monitoring as a system has not been integrated into the governance and research infrastructure of band or Nation based organizations. Often times it is because non-Reserve communities, municipalities and organizations just do not know the jurisdictional issues or authorities involved with 'getting the right minds to the thinking'. A capacity issue exists in band administrations and Nation based organizations as well, as water is currently constructed into 'issues' rather than according to place based understanding of the complex and interconnected relationship of all living beings. This is apparent in current Lake monitoring limited to drinking water source surface water.

- *Consider Reserve administrations in proximity to Lake monitoring programs[20];*
- *Consider Reserve administrations whose reserve lands include 'lakes';*
- *Consider criteria for 'on reserve' lake monitoring—water issues on reserves are not just in wells or drinking water but 'bodies of water' often cited in creation stories and identity;*
- *Consider Indigenous Peoples knowledge, historical relationship to "bodies of water" over time;*
- *Consider the role of water in current Comprehensive Community Planning approaches from INAC for Band reserve administrations;*
- *Consider what 'community engagement' means in the context of community governance models;*
- *Consider the omission of research and intellectual sovereignty over time, and the need to invest in research relationships with Reserve administrations and Nation based organizations as well as provincial organizations need for local place based knowledge in policy development;*
- *Consider criteria set for inclusion into projects or programs—is it representation or perspective sought? Is it technical ability or decision making ability needed to move into action? Is it band administration AND nation based? Or band administration OR nation based?*
- *Consider a complement of key roles and responsibilities, and human capacity development from within band and nation level, and provincial organizations;*
- *Consider the ways in which the following programs and research consortiums conceptualize "inclusion" of Indigenous Peoples into already in progress or pre-designed projects;*

[20] https://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-BC/STAGING/texte-text/inacmp_1100100021016_eng.pdf
An INAC sanctioned map of Indian Bands (First Nations in BC)

- *Consider building upon First Nations Water Operators Network capacity—band administrations have water monitoring for drinking water specifically done by band staff—this could be expanded;*
- *Consider First Nations Health Authority Water Monitoring program;*
- *Consider research relationships with organizations such as IC IMPACTS and Res'Eau WaterNet whose mandates are to address water research with Indigenous populations.*

These considerations are offered as a means of furthering meaningful conversation towards action. First Nations administrations are active in revitalizing their self-development and water stewardship, for many is a natural law and guiding principle to be reactivated. The above collection of considerations are not limited although they are in most cases, place based and require investment of time, into people and their relationships.

Appendix E: GPS Coordinates for 2018 BCLMN Lakes, Potential BCLMN Lakes, and non-BCLMN Lakes

Region	Lake Name	GPS Coordinates	
Okanagan	Christina	-118.22404	49.082123
	Kalamalka	-119.32736	50.17280
	Mabel	-118.712	50.57243
	Mara	-119.017348	50.786281
	Okanagan	-119.579779	49.802029
	Osoyoos	-119.457579	49.045655
	Skaha	-119.585394	49.410032
	Sugar	-118.5399936	50.3980671
	Wood	-119.389786v	50.081728
	Ellison	-119.396668	49.993201
	Shannon	-119.612226	49.856841
	Vaseux	-119.531572	49.288771
	Sunday	-120.275754	49.789161
	Peachland	-119.967949	49.830431
	Robert	-119.409356	49.936496
	St. Margaret	-118.846684	49.952015
	Unnamed (near Vernon)	-119.365207	50.196647
	Swan	-119.256051	50.318409
	Chain	-120.2703	49.7019
	Twin	-119.7208	49.3277
	Jewel	-118.6096	49.1736
Vancouver Island	Cowichan	-124.27549	48.86604
	Elk	-123.39876	48.52852
	Langford	-123.52745	48.44838
	Quamichan	-123.65403	48.80064
	Bainbridge	-124.73168	49.20071
	Brannen	-124.06491	49.2034
	Lizard	-124.6743	49.13942
	Quatse	-127.56169	50.63047
	Shawnigan	-123.64492	48.63499
	Comox	-125.18038	49.6257
	Sproat	-125.03701	49.27619
	Buttle	-125.55928	49.70826
	Maxwell	-123.53114	48.82177
	St. Mary	-123.54693	48.88657
	John Hart	-125.38123	50.0445
	Gunflint	-124.953979	50.069889

Region	Lake Name	GPS Coordinates	
Vancouver Island (cont.)	Hague	-124.953979	50.062308
	Prospect	-123.4392	48.5183
	Cusheon	-123.4681	48.815
	Weston	-123.4252	48.7843
	Glen	-123.5225	48.4374
	Florence	-123.5111	48.4583
	Spider	-124.626	49.3486
	Cameron	-124.5854	49.2911
	Fork	-123.4842	48.5186
	Enos Lake	-124.158222	49.281806
	Killarney	-123.456389	48.528333
	Maltby	-123.4522	48.4967
	Somenos	-123.7031	48.8008
Lower Mainland	Deer	-122.97138	49.23613
	Alta	-122.98153	50.11678
	Brohm	-123.13504	49.82123
	Chilliwack	-121.40702	49.05923
	Sasamat	-122.88895	49.32215
	Cultus	-121.97621	49.0679
	Como	-122.85636	49.26051
	Burnaby	-122.94411	49.24203
	Alpha	-123.00414	50.09438
	Nita	-122.99491	50.09882
	Lost	-122.93723	50.12876
	Green	-122.93729	50.15303
	Sakinaw	-124.01546	49.6781
	Lois	-124.22977	49.86387
	Buntzen	-122.85986	49.35063
	Stave (3 stations)	-122.24421	49.36976
	Alouette (3 stations)	-122.41814	49.33374
	Harrison	-121.86241	49.55435
	Pitt	-122.64146	49.38452
	Cat	-123.109167	49.799167
	Alice	-127.4219	50.4732
Kootenays	Columbia	-115.83564	50.18126
	Windermere	-116.00207	50.4902
	Moyie	-115.82362	49.34782
	Slocan	-117.393343	49.932197
	Premier	-115.66477	49.9396
	Trout	-117.45621	50.61145
	Whiteswan	-115.47924	50.14164
	St Mary's	-116.1818609	49.6145958

Region	Lake Name	GPS Coordinates	
Kootenays (cont.)	Wasa	-115.735367	49.779694
	Summit (Nakusp)	-117.64529	50.15722
	Jimsmith	-115.84885	49.4821
	Kootenay	-117.29521	49.49676
	Tie	-115.313086	49.418026
	Koocanusa	-115.227437	49.197899
	Arrow	-117.82228	50.24881
	Surveyors	-115.235655	49.245774
	Unnamed (Columbia Wetlands at Golden)	-118.992075	49.418436
	Pingston (Revelstoke)	-118.122669	50.670967
	Rosen	-115.254167	49.394167
	Lillian	-116.0972	50.5081
	Kimbol	-117.63618	50.273978
	Horseshoe	-117.661183	50.247264
	Hird	-117.735316	49.85563
	Rocky	-117.735572	49.84586
	Gwillim	-117.745565	49.81607
	Valhalla SE	-117.674141	49.78607
	Coven	-117.662635	49.824319
	Gibson	-117.158046	49.723978
	Kokanee	-117.174318	49.74673
	Keen	-117.188905	49.761188
	Kaslo	-117.19514	49.769183
	Helen Deane	-117.172479	49.774537
	Little Helen Deane	-117.171205	49.772671
	Helen Deane South	Not available	Not available
	Kalmia	-117.180003	49.770222
	Hamling	-117.523052	50.263798
	New	-116.513437	50.609333
	Buster	-116.51018	50.614835
	Welsh (lower)	-116.493585	50.624034
	Welsh	-116.495359	50.61836
	Aberystwyth	-116.505806	50.625951
	Thunderwater	-116.582943	50.654067
	Whirlpool	-116.595528	50.656622
	Joker (upper)	-117.138859	49.771918
	Joker (lower)	-117.140684	49.775066
	Kokanee Toe	-117.13992	49.764459
	Walton	-117.20772	50.202534
	Sky Pilot	-117.244816	50.2426
	Poplar Baby	-117.287999	50.296624

Region	Lake Name	GPS Coordinates	
Kootenays (cont.)	Poplar Camp	-117.291728	50.296606
	Cascade Blue	-117.231887	50.302009
Skeena	Lakelse	-128.54792	54.37551
	Diana	-130.16553	54.22089
	Morice	-127.45271	54.01756
	Burns	-125.74656	54.2047
	Babine	-126.09052	54.7775
	Kathlyn	-127.20818	54.8247
	Tyhee	-127.03822	54.7082
	Francois	-125.73466	54.01505
	Decker	-125.83578	54.29425
	Round	-126.93587	54.65677
	Seymour	-127.15999	54.74809
	Dease	-130.03244	68.51892
	Meziadin	-129.31903	56.08078
	Tchesinkut	-125.6156	54.0949
Thompson	Shuswap	-119.27292	50.75085
	Adams	-119.60005	51.17337
	Pennask	-120.137292	49.995785
	Stump	-120.372613	50.362117
	Nicola	-120.51514	50.1773
	White	-120.06797	50.5478
	Monte	-119.83451	50.50565
	Roche	-120.152112	50.472202
	Peter Hope	-120.31098	50.29847
	Big Bar	-121.79373	51.30935
	Bonaparte	-120.65696	51.27832
	Gun	-122.87093	50.86867
	Heffley	-120.05054	50.83433
	Lac Le Jeune	-120.47564	50.48769
	Loon	-121.30173	51.08162
	Dutch	-120.06066	51.64957
	Kamloops Lake	-120.57052	50.74931
	Kentucky Lake	-120.564311	49.896608
	Paradise Lake	-120.276885	49.915253
	Palmer Meadows	-120.175492	50.380147
	Otter	-119.250017	50.411543
	Round	-119.328795	50.426909
	Madeline	-119.356749	50.438902
	Gardom	-119.204994	50.601723
	Upper Buse	-120.049703	50.621076
	Little Shuswap	-119.646343	50.85027

Region	Lake Name	GPS Coordinates	
Thompson (cont.)	Little White	-119.313452	50.876887
	Unnamed (Columbia-Shuswap A)	-116.938997	51.257591
	Hidden	-118.8208	50.5708
	Lajoie	-122.9076	50.8379
	Lac Des Roches	-120.5934	51.4917
	Birch	-120.503075	51.453128
	Little Lac Des Roches	-120.625475	51.499514
	Phinetta	-120.4939	51.4739
	Logan	-120.809	50.4951
	Green	-121.2925	51.3614
	Watch	-121.1264	51.4525
	Heffley	-120.05054	50.83433
	Pavilion	-121.74191	50.86677
	Paska	-120.6548	50.5247
Omineca-Peace	Nadsilnich (West)	-122.86947	53.71376
	Tabor	-122.54472	53.9177
	Clucultz (2 sites, 1 in 2019)	-123.5767	53.87914
	Fraser	-124.76101	54.09111
	Stuart	-124.49676	54.56793
	Moberly	-121.73241	55.83405
	Swan	-128.658165	55.787169
	Charlie (2 sites, 1 in 2019)	-121.00861	56.33604
	One Island	-120.285	55.31176
	Naltesby	-123.49174	53.63771
	Purden	-121.88435	53.90418
	Summit	-126.68229	54.48566
	Carp	-123.24089	54.76136
	Ness	-123.1331	54.0269
	Bednesti	-123.3473	53.8531
	Berman	-123.3333	53.8583
	Nukko	-123.0078	54.0689
	Norman	-123.3547	53.7811
Cariboo	Williams	-122.08548	52.12216
	Chimney	-121.95157	51.91701
	Dragon	-122.42958	52.95257
	Horse	-121.10529	51.58267
	Puntzi	-124.0376	52.19694
	Quesnel	-121.10836	52.52043
	Polley (north)	-121.617	52.564
	Bowron	-121.41016	53.25843

Region	Lake Name	GPS Coordinates	
Cariboo (cont.)	Big	-121.45856	51.66019
	Bridge	-120.75053	51.4974
	Horn	-124.7095	51.80116
	Lac La Hache	-121.53931	51.82831
	McLeese	-122.29414	52.41388
	Spanish	-121.42346	52.58278
	Tatla	-124.39903	51.97563
	Canim	-120.74664	51.84725
	Quesnel	-121.10836	52.52043
	Chilko	-124.01586	51.43157
	Mahood	-120.4717	51.8906
	Rose	-120.7631	52.2444
	Ruth	-121.06	51.8325
	Charlotte (west)	-125.35006	52.200159