Living Lakes CANADA

Water Monitoring Framework for the Upper Columbia Basin

Budget Estimates

Martin Carver and Greg Utzig June 30, 2022 (revised)

Living Lakes Canada (LLC) has developed a structured science-based approach to expanding the water monitoring network of the Upper Columbia Basin (UCB). *Developing a Priority Matrix to Expand Water Monitoring* (April 28, 2021) provides a preliminary eight-step framework for formulating and ranking potential monitoring sites and parameters within UCB Areas of Interest (AoIs). To prepare for application of this framework across the UCB, it will first be piloted within selected areas to test and improve the approach and to better understand its implementation costs. To further prepare for its widespread application across the UCB, costing information is also needed for actual implementation of the outcomes of the framework and its recommendations flowing from the resulting Priority Matrix. In support of these objectives, this document provides preliminary budget information for two potential undertakings:

- Pilot implementation of LLC's *Developing a Priority Matrix to Expand Water Monitoring,* to be implemented immediately to guide monitoring that will then continue for the next decade.
- Distributed coverage of water monitoring across the entire UCB, to be phased in over 10-15 years, with monitoring continuing locally in each area for at least 10 years.

1.0 PILOT IMPLEMENTATION OF FRAMEWORK

Living Lakes Canada (LLC) proposes to develop a Priority Matrix on a pilot basis using its preliminary eight-step procedure (Carver and Utzig 2021). The proposed application of the preliminary framework in selected areas of the Upper Columbia Basin (UCB) would enable LLC to prepare the approach for implementation across the UCB. Developing a Priority Matrix requires the collaboration of a number of parties including three areas of expertise, LLC staff and a range of interests with local knowledge and a focus on local issues. Costing is presented here for the scientific component that leads the process. For the purposes of this costing exercise, it is assumed that the aspects related to citizen engagement are addressed by LLC staff and/or additional consulting capacity.

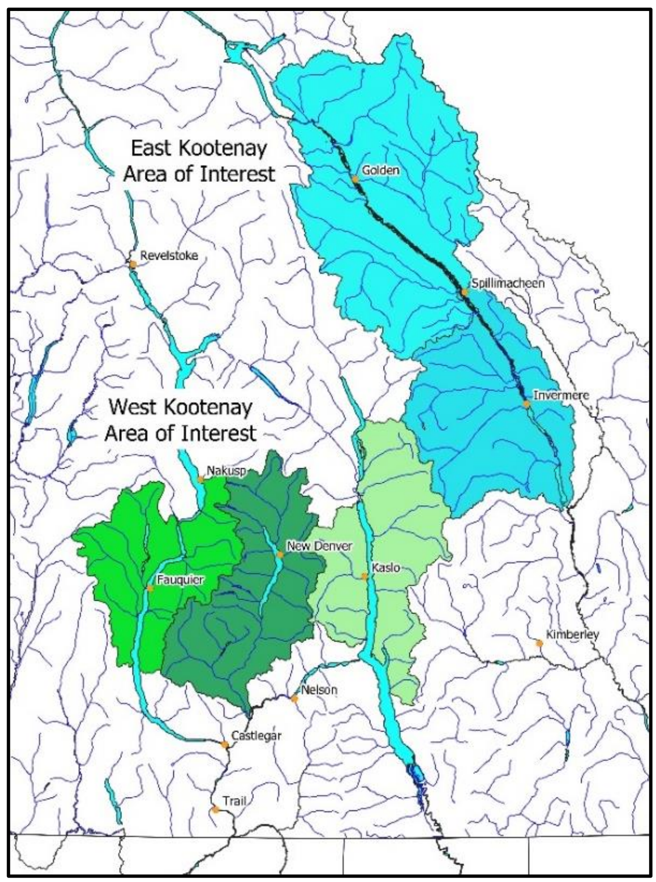

Figure 1. Proposed Areas of Interest for pilot implementation of preliminary procedure to expand water monitoring. Potential sub-areas are shown for planning purposes.

LLC has identified two AoIs for use in this pilot implementation (Figure 1). These areas have been selected by LLC to represent a range of climates and a diversity of watershed concerns. They also house population centres, thus providing significant opportunities for engagement with existing groups and processes. These two areas are sufficiently large that consideration could be given to identifying smaller areas within these based on budget capacity for the pilot implementation. Due to travel logistics and localized interests, it may be advantageous to establish three Local Reference Groups in the West Kootenay and two in the East Kootenay (see shading in Fig. 1). There are also ongoing locally-initiated non-governmental water monitoring programs within these areas (*e.g.*, Kootenay Watershed Science, Slocan Lake Stewardship Society, Slocan River Streamkeepers along with other groups in the west and the Columbia Wetlands Stewardship Partners and others in the east).

The Science Lead implements the process with the support of a GIS Technician. Cost estimates for their work are provided in Table 1 and a summary description is provided below on the key tasks involved, excerpted from Developing a Priority Matrix to Expand Water Monitoring.

Table 1. Time requirements to complete scientific component of procedure implementation for each AoI.

#	Preliminary Eight-Step Framework Task Descriptions	Personnel Involved[1]					Time Estimate (day)	
		LLC	SCI	GIS	CEC	LRG	Science Lead	GIS Technician
1	Select and confirm boundaries of Area of Interest	●	●	●			1	0.5
2	Assemble local reference group	●	●		●	●	1	0
3	Determine priorities for monitoring		●	●	●	●	3	1
4	Establish watershed units of interest		●	●	●	●	4	3.5
5	Create database[2] of characteristics and indices		●	●			5	8
6	Stratify into watershed groups with similar runoff response	●	●	●			4	1
7	Apply selection criteria to rank watersheds and choose sites/parameters		●	●	●	●	3	1
8	Finalise monitoring network sites and parameters with rationale	●	●		●	●	3	3
9	Data management and validation[3]	●	●				-	-
10	Analysis/assessment of monitoring data[3]	●	●			●	-	-
						Totals:	24	18

1. CEC – Community Engagement Consultant; GIS – GIS Technician LLC – Living Lakes Canada; LRG – Local Reference Group; SCI – Science Lead (likely a hydrologist)

2. Once we have learned the criteria that are most effective and the GIS routines have been established through the pilot implementation, this step should be much quicker in subsequent applications.

3. These are steps required to prepare the data for use by practitioners; these costs will be shared with the Data Hub and other entities, and therefore are not included in this budget.

Step 1. At a kickoff meeting with LLC, the Science Lead works to confirm the AoI and receive LLC's information about the area (monitoring network information, knowledgeable individuals in the AoI, etc). It is understood that LLC intends to focus this pilot implementation on two areas, one in each of the East and West Kootenay as shown in Figure 1. The Science Lead will also review the proposed members of the Local Reference Group (LRG) and advise LLC accordingly. Initial maps are prepared in advance for use with the LRGs.

Step 2. The Community Engagement Consultant (CEC) meets with LRG[1] to gather as much information as possible about the AoI. The Science Lead attends some (or all) of these meetings and establishes process for technical follow-up. This source of local knowledge about the AoI may include watershed histories, occurrence of past extreme events, water demands, past watershed impacts from development, current and past water monitoring, sources of existing data, access limitations and other matters. The LRG may also offer local priorities for expanded monitoring and, in particular, identifying key questions that need to be addressed by additional monitoring. The Science Lead reviews this information, potentially meeting with the CEC and even directly with the LRG or key members to gain firsthand information on key issues.

[1] If there are two areas being assessed, then two Local Reference Groups would be created.

Step 3. The Science Lead builds a detailed summary about the AoIs showing monitoring sites and data from publicly-available sources, and including the insights and priorities provided by the LRG. Using this inventory and assisted by the GIS Technician, the Science Lead prepares a preliminary spatially-referenced monitoring synopsis to identify where appropriate monitoring sites are already in place, to show where good long-term data sets are available, to summarise expected monitoring priorities, and to highlight resulting first-order gaps in the local monitoring network.

Step 4. The Science Lead works with the GIS Technician to create Watershed Units of Interest to be used as the basis for organizing and assessing changes to the monitoring network. This work involves modifying BC's Assessment Watersheds to distinguish nested and aggregated Assessment Watersheds and to pull out smaller watersheds not delineated within this provincial coverage of off-the-shelf boundaries. The initial Watersheds Units of Interest map is revised based on feedback from the LRG (through the Community Engagement Consultant) to ensure consistency with local context and to capture and properly represent all relevant watersheds on the final Watershed Units of Interest map.

Steps 5-6. Detailed analytical work follows as a database is created of characteristics and watershed indices for each of the Watersheds of Interest. Data are assembled from a wide range of sources and used to create metrics that form the basis for statistically stratifying the watersheds into runoff regimes. Using these groupings and an understanding from LLC of the scope of funding available for new monitoring, the Science Lead identifies an appropriate suite of options (gaps) that can be considered for new monitoring strictly on a scientific basis.

Steps 7-8. Facilitated by the Community Engagement Consultant, LRG application of selection criteria sets the stage for the Science Lead to rank the candidate monitoring options (sites, parameters and objectives) for final consideration by all parties.

Further Analysis and Assessment. Once implemented, LLC may ask the Science Lead to participate in a periodic review of monitoring data in relation to objectives established during the rankings. This work is incremental to that shown in Table 1.

Total costs are estimated based on $1200/day for the Science Lead and $600/day for the GIS Technician, however, these rates will vary depending on the experience and skills of the individuals. Assuming these day rates and the time requirements shown in Table 1, the total estimated cost for pilot application of the procedure is $39,600+GST per AoI, plus administrative and community-engagement costs borne by LLC.

2.0 DISTRIBUTED MONITORING ACROSS UCB

The pilot implementation described in the previous section lays the foundation for a wider, staged implementation of expanded monitoring across the UCB. Shown in Figure 2 and subject to local variation, the UCB's Regional Landscapes (RLs) each represent a consistent regional climate while varying in size, topographic and bedrock complexity, glacial coverage, the degree of human disturbance and water demand, and current and historic water and water-related monitoring. Based on a review of the preliminary findings from the LLC Hydrology Workshop held June 8th 2020, it is estimated that the number of watersheds required to cover variation in watershed response ranges from 3 to 12 for each RL. Smaller, less complex RLs with minimal human disturbance and water demand require less monitoring (*e.g.*, RLs 16 and 20). In contrast, larger ones with more landscape diversity and human development issues require more (*e.g.*, RLs 5 and 10). In some cases, it is appropriate to combine RLs for establishing watershed groups where watershed boundaries overlap RLs (*e.g.*, RLs 14 and 15). For examples, the two pilot areas include a single RL in the West Kootenay (RL 5) and combined RLs in the East Kootenay (RLs 14,15,17,18, and parts of 20 and 26). For planning purposes in estimating costs associated with building out an expanded network throughout the entire UCB, an estimated mean value of five monitored watersheds is used here for each RL. These five hydrometric stations are focused on smaller streams (watershed areas of ~1-100 km^2) because existing stations tend to focus on larger systems and are generally adequate at that scale (though exceptions exist). Depending on the interests and recommendations of the LRGs, additional hydrometric stations may be suggested to address high-priority uses, exploratory questions, research objectives, Indigenous needs, and other guidance related to specific RLs.

To characterize the water balance upstream of watershed outlets, parameters in addition to discharge are monitored. Monitoring of water-balance parameters within a selected group of watersheds in each RL can serve to describe the range of watershed responses throughout the RL. Monitoring of climate (including snow), lakes, groundwater and wetlands is generally required, though one or more parameters may be better covered by existing monitoring in some RLs.

Costing out UCB implementation of this approach requires a series of assumptions to address variabilities in landscape characteristics, population distribution, options and standards in monitoring and other factors. Whereas the underlying variability in landscape characteristics is addressed by organizing monitoring according to RLs, program planning is best organized by AoIs which identify groupings of RLs reflective of their spatial layout in relation to social and other practical considerations. Figure 2 shows how the RLs could be grouped to form AoIs. In the UCB, there are about 24 RLs and, in this example, there are 12 AoIs. Although the ratio between them varies (from 1 to 4.5), the costing exercise provided below assumes that each AoI typically has two RLs, the average in this example. Departures from this mean ratio can be taken into account on a case-by-case basis once the AoI has been selected for implementation.

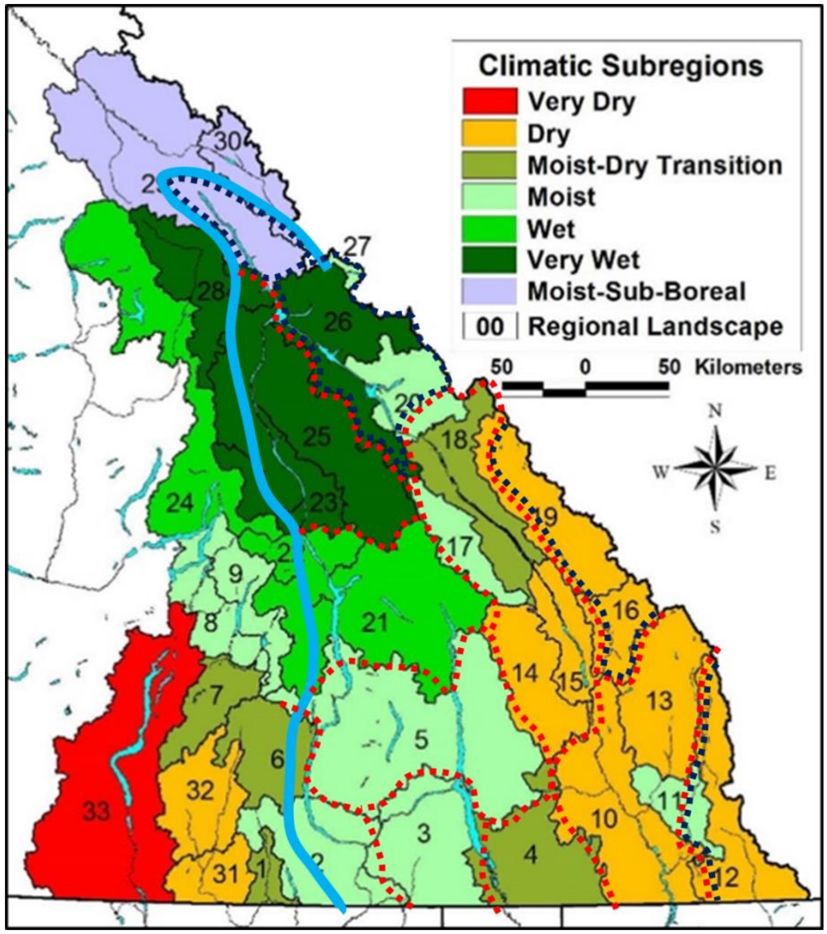

Figure 2. Regional Landscapes of the Upper Columbia Basin. Also shown in red and blue are potential Areas of Interest based on RL groupings (red - front-country; blue - back-country)

Costs of installation and operation of the monitoring program are also shaped by both the proximity of a site to the road network and the distance between the road access point and the nearest population centre where most contractors and volunteers are typically based. In general, sites that are within a short walk (~20 minutes) of a drivable road are deemed "accessible" sites, otherwise they are considered "remote" sites. Remote sites are candidates for helicopter access which is assumed to cost, on average, $500 in each direction. However, if the site is in a back-country AoI (one that is sparsely populated, or sites are generally distant from population centres), it may also be considered a remote site even if it is close to a drivable road – for example, if it over a three-hour drive from a population centre. These distinctions are provided to better allocate resources for accessing sites according to their locations. For example, sites adjacent to a resource road on the east side of the Kinbasket Reservoir and sites situated more than a couple-hour walk away from a road near Kimberley could both be considered remote sites.

Table 2 estimates typical equipment and installation costs by parameter and site type. Equipment costs reflect products known to be in common use - for example, HOBO MX2001 for wireless water level/temperature measurements. (Major government agencies often use more expensive equipment to meet equivalent monitoring standards. Associated cost estimates are only slightly higher as discussed in Appendix A1.) Day rates (8 hours) are set as follows: a professional rate for science and supervision at $1200/day and a technical rate at $600/day. Hydrometric costs assume a ten-year average of 5 visits/year/site and 2 site-visits/day (the first few years will likely be greater, the latter years less). These visits include servicing the site in the spring and fall, carrying out salt-dilution flow measurements through the freshet and downloading the water level data frequently enough to avoid significant data gaps. (Larger streams are generally out of scope in this costing exercise because they require a cable way and monitoring at high flow or other sophisticated systems.) Flow measurements typically include monitoring of water temperature. CABIN (Canadian Aquatic Biomonitoring Network) costs include sample analyses. Stream grab sampling includes analysis of two types – metals and turbidity/TSS[2]/conductivity. Lake/wetland level monitoring uses similar equipment to the hydrometric stations but do not require flow measurements. Site visits to climate stations must be frequent enough to address issues as they arise so as to avoid significant data gaps. Snow courses are estimated based on a two-person team making five site visits each year. Snow courses are best located along higher-elevation roads such as those that access ski hills. (Snow pillows are not considered here for implementation due to their complexity and maintenance requirements.) Groundwater costs are based on using existing wells only and include equipment, well assessment and installation, and minor well upgrades to make well suitable for monitoring. Given access costs to remote sites and the servicing frequency required of automated sampling equipment, water quality sampling is assumed to take place only at accessible sites. Unlike the sites focused on water quantity, the water-quality sites are not meant to be representative of the entire RL but instead address priority issues in the AoI (community concern, research questions, etc.).

Contingency is estimated at between 10% and 12% of equipment cost, implying that all equipment is eventually replaced on average once every eight to ten years. The use of volunteers, either alone or teamed up with a field tech, can substantially reduce labour costs associated with these estimates (we have assumed no volunteers in these estimates). All estimates exclude taxes and administration fees.

The information provided in Table 2 is assembled from a number of sources:

- Frank van der Have, Environmental Sales – Hydrology & Meteorology, Hoskin Scientific
- Carol Luttmer, LLC Groundwater Program Manager
- Natasha Neumann, FLNRORD Research Hydrologist
- Authors' experience initiating and operating the Kootenay Watershed Science (LLC monitoring program)
- Camille LeBlanc, Friends of Kootenay Lake Stewardship Society, Program Manager

Table 3 estimates total costs of network installation and operation based on the following number of stations per RL:

- 5 hydrometric
- 1 year-round climate
- 2 snow course
- 2 seasonal climate
- 4 lake/wetland level
- 1 or 2 groundwater level (using existing wells only)[3]
- 1 to 4 CABIN (benthic macroinvertebrates)
- 1 water quality, stream (accessible only)
- 1 water quality, lake (accessible only)

The number of stations costed as accessible and remote sites varies according to status of the AoI in which they are located (ie, back-country versus front-country). Back-country AoIs involve a greater number of remote sites and thus are more costly to implement. Operation and contingency costs are annual costs. Minimum network size may be required to achieve costs shown. Telemetry would add further costs to these estimates but may result in additional buy-in from communities and other data users where the technology is possible.

Based on these assumptions and inputs, the ten-year cost to implement this approach throughout the entire UCB would be $3.1 million for initial installation and $26.0 million for 10 years of operation.

[2] TSS = total suspended solids
[3] This minimal level of effort is based on the assumption that it is only augmenting LLCs existing groundwater program

Table 2. Estimated station costs for equipment, installation and operation of water monitoring stations.

	Start-Up Costs (One Time)					Annual Operating Costs				Required # of 8-Hour Days (used in 2 left panels)		
Monitoring Type	Equipment On-Site ($k/site)	Equipment Off-Site ($k/AoI)	Science Start-Up ($k/site)	Installation (accessible) ($k/site)	Installation (remote) ($k/site)	Operation (accessible) ($k/yr/site)	Operation (remote) ($k/yr/site)	Contingency (~8-10 year equipment replacement)	Science & Oversight ($k/yr/AoI)	Operations Science & Oversight (days/yr/site)	Operations Technician (accessible) (days/yr/site)	Start-Up Science & Oversight (days/site)
Hydrometric	2	3.5	3.6	1.5	2.5	3	8	10%	2.4	2	5	3
Climate year-round	25	0.5	3.6	4	6	2.4	4	12%	2.4	2	4	3
Snow	0	5	2.4	1.5	2.5	12	15	10%	1.2	1	20	2
Climate seasonal	2	0.5	1.2	1.5	2.5	1.2	2	12%	1.2	1	2	1
Lake/wetland level	2	0.5	0.6	1.5	2.5	1.0	2	10%	1.2	1	1.7	0.5
Groundwater level	5	0.5	0.6	2.5	3.5	2.4	6	12%	1.2	1	4	0.5
CABIN	0	0	1.2	0.5	0	4.8	0	0	1.2	1	8	1
Water quality strean	0	0	0.3	0	0	12	0	0	1.2	1	20	0.25
Water quality, lake	0	0	0.3	0	0	12	0	0	1.2	1	20	0.25

Table 3. Estimated total costs associated with creating and operating monitoring stations across the Upper Columbia Basin.

	Front Country AoIs		Back Country AoIs		Costs per AoI (2 RLs/ AoI)				Installation Cost for CBT Basin			10 Years Operational Cost for CBT Basin		
Monitoring Type	Accessible Sites/RL	Remote Sites/RL	Accessible Sites/RL	Remote Sites/RL	Installation FC AoI	Installation BC AoI	Annual Operation FC AoI	Annual Operation BC AoI	8 FC AoIs	4 BC AoIs	Total	8 FC AoIs	4 BC AoIs	Total
Hydrometric	4	1	1	4	77	83	45	75	612	330	942	3,608	3,004	6,612
Climate year-round	1	0	0	1	66	70	13	17	526	279	804	1,066	661	1,726
Snow	1	1	0	1	23	15	56	32	181	59	240	4,496	1,288	5,784
Climate seasonal	1	1	1	1	21	21	9	9	170	85	256	694	347	1,042
Lake/wetland level	3	1	1	3	35	39	13	17	282	157	440	1,042	678	1,719
Groundwater level	2	0	1	0	33	17	13	7	263	67	330	1,066	293	1,358
CABIN	4	0	1	0	14	3	40	11	109	14	122	3,168	432	3,600
Water quality stream	1	0	0	0	1	0	25	1	5	0	5	2,016	48	2,064
Water quality, lake	1	0	0	0	1	0	25	1	5	0	5	2,016	48	2,064
Total ($k) - REVISED JUNE 30, 2022					**269**	**248**	**240**	**170**	**2,153**	**991**	**3,144**	**19,171**	**6,798**	**25,970**

REFERENCE

Carver M and G Utzig 2022. *Developing a Priority Matrix to Expand Water Monitoring in the Upper Canadian Columbia Basin: Steps for Pilot Implementation* (revised May 30, 2022). Prepared for Living Lakes Canada, 12 p.

APPENDIX – COSTS ASSOCIATED WITH AGENCY NETWORKS

Federal and provincial agencies often employ a higher quality of instrumentation and may also use alternative monitoring methodologies. Reasons for these differences may be associated with reliability needs and due to the higher access and labour costs often associated with government institutions. Tables 4 and 5 provide equivalent information from Tables 2 and 3, with adjustments made for some known differences in equipment and approach. The resulting costs are only slightly higher and may be preferable or applicable in the LLC implementation under some circumstances.

Table 4. Estimated station costs for equipment, installation and operation of water monitoring stations and assuming equipment and methodologies typical of government agencies.

	Start-Up Costs (One Time)					Annual Operating Costs				Required # of 8-Hour Days (used in 2 left panels)		
Monitoring Type	Equipment On-Site ($k/site)	Equipment Off-Site ($k/AoI)	Science Start-Up ($k/site)	Installation (accessible) ($k/site)	Installation (remote) ($k/site)	Operation (accessible) ($k/yr/site)	Operation (remote) ($k/yr/site)	Contingency (~8-10 year equipment replacement)	Science & Oversight ($k/yr/AoI)	Operations Science & Oversight (days/yr/site)	Operations Technician (accessible) (days/yr/site)	Start-Up Science & Oversight (days/site)
Hydrometric	3	3.5	3.6	2	3	3	8	10%	2.4	2	5	3
Climate year-round	25	0.5	3.6	4	6	2.4	4	12%	2.4	2	4	3
Snow	0	5	2.4	1	2	12	15	10%	1.2	1	20	2
Climate seasonal	12	0.5	1.2	2	3	1.2	2	12%	1.2	1	2	1
Lake/wetland level	3	0.5	0.6	2	3	1.0	2	10%	1.2	1	1.7	0.5
Groundwater level	5	0.5	0.6	2.5	3.5	2.4	6	12%	1.2	1	4	0.5
CABIN	0	0	1.2	1	0	4.8	0	0	1.2	1	8	1
Water quality strean	0	0	0.3	0	0	12	0	0	1.2	1	20	0.25
Water quality, lake	0	0	0.3	0	0	12	0	0	1.2	1	20	0.25

Table 5. Estimated total costs associated with creating and operating monitoring stations across the Upper Columbia Basin and assuming equipment and methodologies typical of government agencies.

	Front Country AoIs		Back Country AoIs		Costs per AoI (2 RLs/ AoI)				Installation Cost for CBT Basin			10 Years Operational Cost for CBT Basin		
Monitoring Type	Accessible Sites/RL	Remote Sites/RL	Accessible Sites/RL	Remote Sites/RL	Installation FC AoI	Installation BC AoI	Annual Operation FC AoI	Annual Operation BC AoI	8 FC AoIs	4 BC AoIs	Total	8 FC AoIs	4 BC AoIs	Total
Hydrometric	4	1	1	4	92	98	46	76	732	390	1,122	3,688	3,044	6,732
Climate year-round	1	0	0	1	66	70	13	17	526	279	804	1,066	661	1,726
Snow	1	1	0	1	21	14	56	32	165	55	220	4,496	1,288	5,784
Climate seasonal	1	1	1	1	63	63	13	13	506	253	760	1,078	539	1,618
Lake/wetland level	3	1	1	3	47	51	14	18	378	205	584	1,106	710	1,815
Groundwater level	2	0	1	0	33	17	13	7	263	67	330	1,066	293	1,358
CABIN	4	0	1	0	18	4	40	11	141	18	158	3,168	432	3,600
Water quality stream	1	0	0	0	1	0	25	1	5	0	5	2,016	48	2,064
Water quality, lake	1	0	0	0	1	0	25	1	5	0	5	2,016	48	2,064
Total ($k) - REVISED JUNE 30, 2022					**340**	**317**	**246**	**177**	**2,721**	**1,267**	**3,988**	**19,699**	**7,062**	**26,762**