Water Monitoring and Climate Change in the Upper Columbia Basin - Guidance Information for Planning Monitoring Programs

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

In 2017, the Columbia Basin Trust (the Trust) completed a compilation of water and climate monitoring carried out in the Columbia Basin Trust region (the Basin) entitled *Water Monitoring and Climate Change in the Upper Columbia Basin – Summary of Current Status and Opportunities*. That document, here referred to as the *Trust Water Monitoring Summary*, sheds light on existing understanding of water resources within the Basin. This document draws on the *Trust Water Monitoring Summary* and information gathered during its preparation to provide guidance to those interested in supporting water monitoring for Basin communities and ecosystems. This document seeks to 1) provide guidance for addressing gaps in water (and climate-related) monitoring in a scientifically robust and informed manner, and 2) identify opportunities for complementing data and science to support communities to respond to water-related concerns associated with climate change and land use.

Monitoring in the Basin is considerable but uneven and the data can be tough to access. Many sites have been discontinued since the 1990s peak in monitoring. Various Federal departments and BC ministries provide the bulk of the measurements. The distribution of these sites is not optimal and there are many gaps in location and monitoring parameters. Monitoring effort may reflect a variety of priorities. While not taking away from those criteria, hydrologic regions provide a unified basis on which to evaluate the allocation of monitoring effort. Given the many influences that have evolved government monitoring networks, hydrologic regions offer an objective baseline for site selection. Although of contrasting size, these units represent relatively homogeneous regions of hydroclimate. All other factors being equal, it is desirable to characterize these units equally and, to some degree, regardless of their size.

Detailed assessment of existing monitoring indicates that the sites are heavily weighted toward the larger hydrologic regions. The Upper Kootenay hydrologic region is the most heavily monitored of all regions and, for some parameters, other larger regions are more heavily monitored than others: Northwest Columbia (climate/snow), Lower Columbia Kootenay (climate/snow, water quantity), and Mid Columbia Kootenay (water quantity, water quality). Some regions lack any monitoring for certain parameters of interest. There is no Basin monitoring within the Canoe Reach hydrologic region. A coordinated and well-planned effort is needed to address gaps in monitoring locations by hydrologic region. Station locations also need to be resolved according to other criteria, especially elevation. Given the importance of snow pack, characterizing changes in high-elevation snowpack is a priority among parameters.

In addition to an emphasis on low-elevation locations and putting some hydrologic regions ahead of others, current station locations avoid or under-emphasize wetlands, small streams, smaller lakes, and groundwater quality/quantity. As climate changes, these are sentinels of impacts and are expected to grow in importance for ecosystems and human communities. Smaller surface systems are heavily relied upon in the Basin and subject to great change with climate change. Given the new demands expected on groundwater under future climates, additional groundwater monitoring is recommended to understand its potential as surface water sources become seasonally restricted or of inadequate quality. Wetlands and small lakes are particularly important to water supply and to sustaining environmental flows in rivers.

Designing a monitoring network that is complementary to existing efforts requires consideration of a complex of factors in relation to monitoring objectives. The combined network of the Provincial and Federal governments offer a “backbone” network in place to characterize ecosystems according to hydrologic region and leading identified biophysical criteria. Gaps in the backbone network can then be identified and addressed by other entities planning additional water monitoring, or in collaboration/dialogue with agencies to provide consistent baseline information. Priorities can be identified in sub-regional and local water resources that warrant higher resolution monitoring in relation to aquatic-ecosystem values and community initiative and priorities. The key is to avoid *ad hoc* monitoring and instead tie monitoring to clear Basin-wide objectives. The backbone network can be supplemented strategically with a limited number of regional networks or clusters and sub-networks to address concerns complementary to the backbone and to address issues lacking an associated government mandate.

Larger systems are generally adequately monitored and reasonably understood for water quality, particularly those with industries anchored to specific locations. Water quality monitoring of the larger lakes is improving however progress is constrained by funding and smaller lakes may remain a low priority and thus poorly understood. It is the tributaries and wetlands where the greatest potential exists for improving the monitoring of water quality. It is suggested that monitoring of nonpoint sources should be a focus of new water-quality monitoring because point-source monitoring of water quality is generally considered a regulatory responsibility.

A recognized concern is the difficult access to water data of all kinds. Although data from the BC snow monitoring network and the federal hydrometric network are relatively easily available online, this is not the way with all agency programs and government-mandated data gathering. Data availability can be improved through streamlined archival and retrieval technologies, through building on an existing platform and by creating a new facility within the Basin. Open-access data platforms are an active area of applied technology. Discussion is presented to improve data availability, including data agreements, technical capacity, historic data, community-based monitoring (CBM), and complementary land data.

Potential priority scientific questions and knowledge gaps for consideration are summarized. There is a need to use available data to describe the condition and status of Basin waterbodies, particularly those that might not be included within existing agency mandates which tend to focus on the status of waterbodies downstream of major point source releases and significant waterbodies such as major lakes and reservoirs. Smaller streams, lakes and wetlands get little attention yet many of these serve as "place-based" resources tied closely to and supportive of small communities and distributed rural development.

CBM is community-initiated data collection, yielding data that remain accessible to the community after the collection is complete and no matter who collected the data. Considerable past and ongoing community-based effort and interest have yielded data to help sustain waterbodies which support nearby ecosystems and local communities. Some of these initiatives date back decades. Applying these data sets to inform decision-making is needed. The development of "report cards" is proposed based on data for waterbodies of interest, particularly those with available CBM and other data. CBM data gathering and scientific analysis require resources and appropriate expertise to be implemented successfully. Equipment for monitoring water quantity/quality can be made available to stewardship groups for well-established groups and programs. Regional expertise is needed dedicated to supporting communities as they adapt to climate change and strive to learn more about local water resources. Capacities needed include expertise related to a) water quality and aquatic ecosystems and b) water quantity and natural hazards.

A thirst exists within Basin communities for greater influence over governance of local water resources. Governance includes a range in activities that ultimately contribute to stewardship and management. A key aspect of governance is opportunity to shape adaptation efforts undertaken in support of protecting water resources on which residents depend. A powerful approach to supporting governance is found in the new Water Sustainability Act which enables alternative forms of local watershed governance (see Columbia Basin Trust *et al.* 2018).

A coordinated and systematic approach to water monitoring is proposed to yield monitoring data representative of hydrologic regions, expanded spatial coverage of the network, and expanded monitoring to include inadequately-monitored variables. It is suggested that interested parties strike a cross-sectoral science committee to discuss options for expansion of water monitoring activity and that strong science and community representation be included with expertise in interpreting water-related climate change impact. This collaboration may include Provincial and Federal agencies, First Nations, local government, community groups/organizations, industry, the Trust, and foundations. Through this approach, *ad hoc* patterns of monitoring can be avoided, leading to the design of a complementary monitoring network. An objective structured vetting process can also be applied for selecting which CBM proposals to support and the waterbodies that should be monitored. Living Lakes Canada is currently leading development of a Columbia Basin Water Monitoring Initiative which offers a strong basis for implementing these recommendations.

1.0 INTRODUCTION

In 2017, the Columbia Basin Trust (the Trust) completed a compilation of water and climate monitoring carried out in the Columbia Basin Trust region (the Basin). That document, entitled *Water Monitoring and Climate Change in the Upper Columbia Basin – Summary of Current Status and Opportunities* (Trust Water Monitoring Summary; CBT 2017), has shed light on the strengths and gaps of existing information and knowledge of water resources within the Basin. It was developed for a public audience, however, its detailed findings and their implications are of interest to assist in planning water resource activities particularly those that support water and climate monitoring in relation to climate-change and land-use impacts. This document builds on information provided in the *Trust Water Monitoring Summary* in addition to information gathered during its preparation (but not provided in it) to provide a basis for systematically addressing gaps in water monitoring leading to a lack of key information, rendering Basin communities vulnerable in preparing for the changes underway to hydrologic regimes and aquatic ecosystems.

1.1 Objectives

The specific objectives of this document are as follows:

1. <u>Gaps in Water Monitoring and Science</u>. Provide guidance for identifying and addressing gaps in water (and climate-related) monitoring in a scientifically robust and informed manner.

2. <u>Support for Community Response and Adaptation</u>. Identify opportunities for complementing data and science such that communities are supported to adequately respond to water-related concerns associated with climate change and land use.

These objectives are echoed by conclusions reached in the Data Hub conference of 2017 where it was agreed that monitoring priorities need to be identified and a plan developed to support and sustain their implementation (Mountain Labyrinths 2017). Responses to the first of these objectives are presented in sections 2 and 3 of this report. The second objective is addressed in section 4.

1.2 Acknowledgments

This report was prepared after completing preparation of a report entitled *Water Monitoring and Climate Change in the Upper Columbia Basin – Summary of Current Status and Opportunities* (*Trust Water Monitoring Summary*). As indicated in the *Trust Water Monitoring Summary*, many people supported the content and production of that report and thus those people also indirectly supported this report. In addition, I would like to acknowledge the leadership of the Columbia Basin Trust and of Tim Hicks who recognized the value in a compilation of informed guidance to help strengthen water knowledge in the Basin. I also worked closely with Justin Robinson at the Selkirk College Geospatial Research Centre in compiling Tables 1-3 and earlier in creating Figures 1-4 (part of the *Trust Water Monitoring Summary*) and for his contribution I am grateful. Lastly, I would like to express my gratitude to the many residents distributed around the Basin who hold water as a priority, contributing their time to designing water monitoring programs, gathering field data, and managing water data - contributing toward improving water management and governance within the Basin. Their ideas have influenced this document, resulting in stronger content.

1.3 Acronyms

BCH	BC Hydro
CBM	Community-based monitoring
CBSGRN	Columbia Basin Snow and Glacier Research Network
CBT	Columbia Basin Trust
CBWN	Columbia Basin Watershed Network
ECCC	Environment and Climate Change Canada
FLNRO	Ministry of Forests, Lands, Natural Resource Operations
FWCP	Fish and Wildlife Compensation Program
GW	Groundwater
MoE	BC Ministry of Environment and Climate Change Strategy
MoTI	BC Ministry of Transportation and Infrastructure
NKLWMP	North Kootenay Lake Water Monitoring Project
PCIC	Pacific Climate Impacts Consortium
WMQSD	Water Quality Monitoring and Surveillance Division
WSA	Water Sustainability Act

1.4 Limitations

The guidance provided in this document is not intended to be comprehensive. While assembling and writing the *Trust Water Monitoring Summary*, I had occasion to talk with a great many people about water issues and concerns in the Basin. I have also lived and worked in the Basin for twenty years including considerable engagement with communities in a wide range of projects. However, the budget available to prepare this guidance document was limited and, as such, the content must be considered in that light. Ultimately, the content provides my own ideas and perspectives. Any errors and shortcomings are my own.

2.0 A BALANCED NETWORK OF ACCESSIBLE DATA

The *Trust Water Monitoring Summary* demonstrates that considerable monitoring is happening (and has happened) in the Basin. However, it is uneven and the data can be tough to access. These are significant problems that need to be addressed to prepare for the growing impacts of climate change.

2.1 Monitoring Sites and Parameters

The compilation provided in the *Trust Water Monitoring Summary* reveals a significant number of historic and contemporary sites and parameters monitored across the Basin. Although many sites have been discontinued, particularly in Environment Canada and Climate Change (ECCC) since the 1990s peak in monitoring, there still remains a great deal of monitoring in place as illustrated in Figures 1 to 3 (reproduced from Figures 12 to 14 in the *Trust Water Monitoring Summary*) and including long-term sites. Various departments within ECCC and within several BC ministries provide the bulk of these measurements. Closer examination reveals that the distribution of these sites is not optimal and there are many gaps in location and monitoring parameters.

Monitoring effort may reflect a variety of priorities including ecosystem stewardship, rare and endangered species, the value of environmental goods and services and the size of human populations they serve, the magnitude of expected changes in climate and associated ecosystem conditions, the needs of municipal and regional planning, limitations to economic development, adaptation to climate change hazards, and the relative costs involved in monitoring options being considered. While not taking away from these criteria, the hydrologic regions presented in Figure 4 (reproduced from the *Trust Water Monitoring Summary*'s Figure 2) provide an alternative and overarching unified basis on which to evaluate the allocation of monitoring effort. Given the many influences that have evolved the government monitoring networks through time, the hydrologic regions offer an attractive objective baseline for site selection. Although of contrasting areas, these units represent relatively homogeneous regions of hydroclimate and, as such, and all other factors being equal, it would be desirable to characterize them equally and, to some degree, regardless of their size.

Tables 1 to 3 summarize, by hydrologic region and elevation, the information presented graphically in Figures 1 to 3, respectively. It is readily evident that monitoring is dominated within the larger hydrologic regions. In particular, the Upper Kootenay hydrologic region is the most heavily monitored of all regions and, depending on the parameters, other larger regions are more heavily monitored than others: the Northwest Columbia (climate/snow), Lower Columbia Kootenay (climate/snow, water quantity), and Mid Columbia Kootenay (water quantity, water quality) regions. Some regions altogether lack monitoring for certain parameters of interest. There is no Basin monitoring within the Canoe Reach hydrologic region. Note that although beyond the scope of the *Trust Water Monitoring Summary* and this document to ascertain, some of the smaller regions which extend outside the boundary of the Basin may have monitoring sites outside the Basin useful to understanding the area lying within the Basin.

A coordinated and well-planned effort is needed to address gaps in monitoring locations in the Basin's hydrologic regions. While comments in the previous paragraph speak to overall monitoring intensity, it is also necessary to resolve the station locations according to other criteria, depending on the parameters of concern. For example, a priority criterion is elevation. This consideration is of particular concern for climate-related variables addressed in Table 1 because a) climate is very sensitive to elevation and b) climate inputs drive much of the system and deserve added scrutiny. It also pertains to other high-elevation parameters affected by climate – *e.g.*, how are temperatures changing in high-elevation lakes? Because settlements are largely located within valley-bottoms (under ~900 m asl), the monitoring network has traditionally built up in these areas at the expense of the mid-elevation (900-1500 m) and especially high-elevation (>1500 m) locations. This location bias means that when calibrating climate models for the Basin, there is a deficit of precipitation information which is a critical data input in these scientific efforts, creating higher uncertainty in model outputs. Given the importance of the snow pack to the Basin, characterizing changes in high-elevation snowpack *in each hydrologic region* would be a priority among hydrologic parameters.

Figure 1. Climate, snow and glacier monitoring sites within the Basin established by agencies and regulated industry.

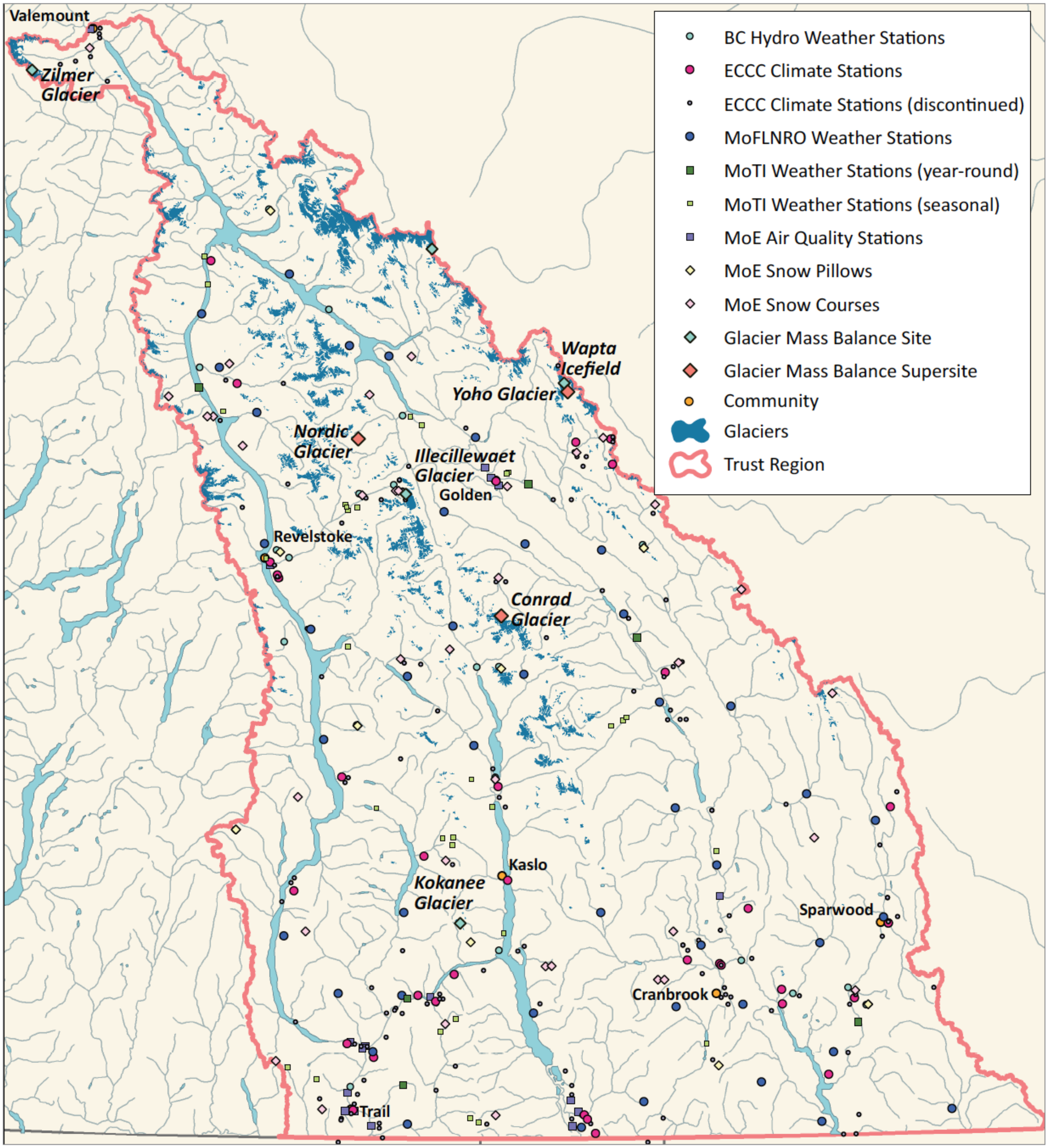

Figure 2. Hydrometric stations and lake/reservoir and groundwater monitoring sites within the Basin, established by agencies and regulated industry.

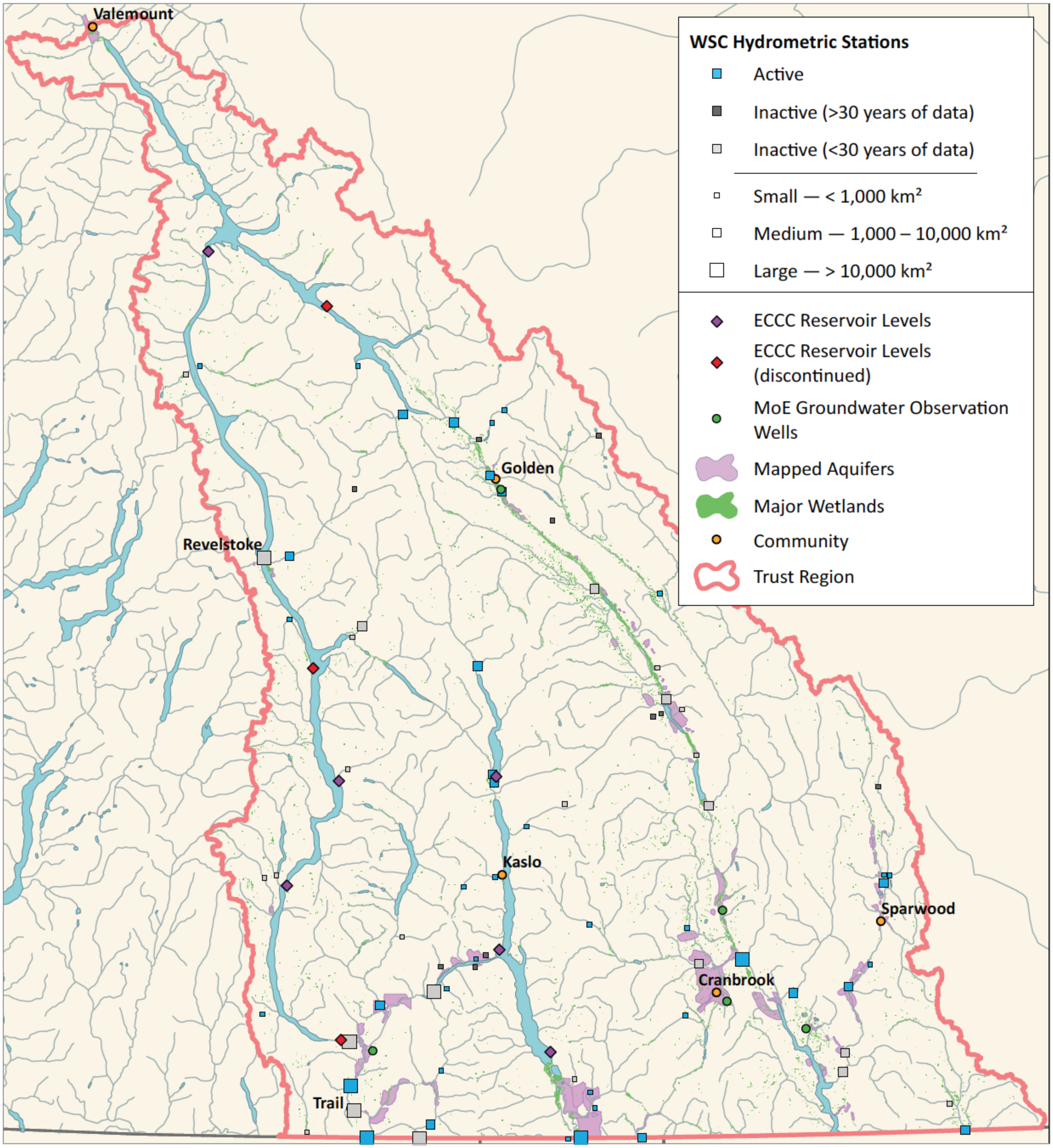

Figure 3. Water quality monitoring sites within the Basin, established by agencies and regulated industry.

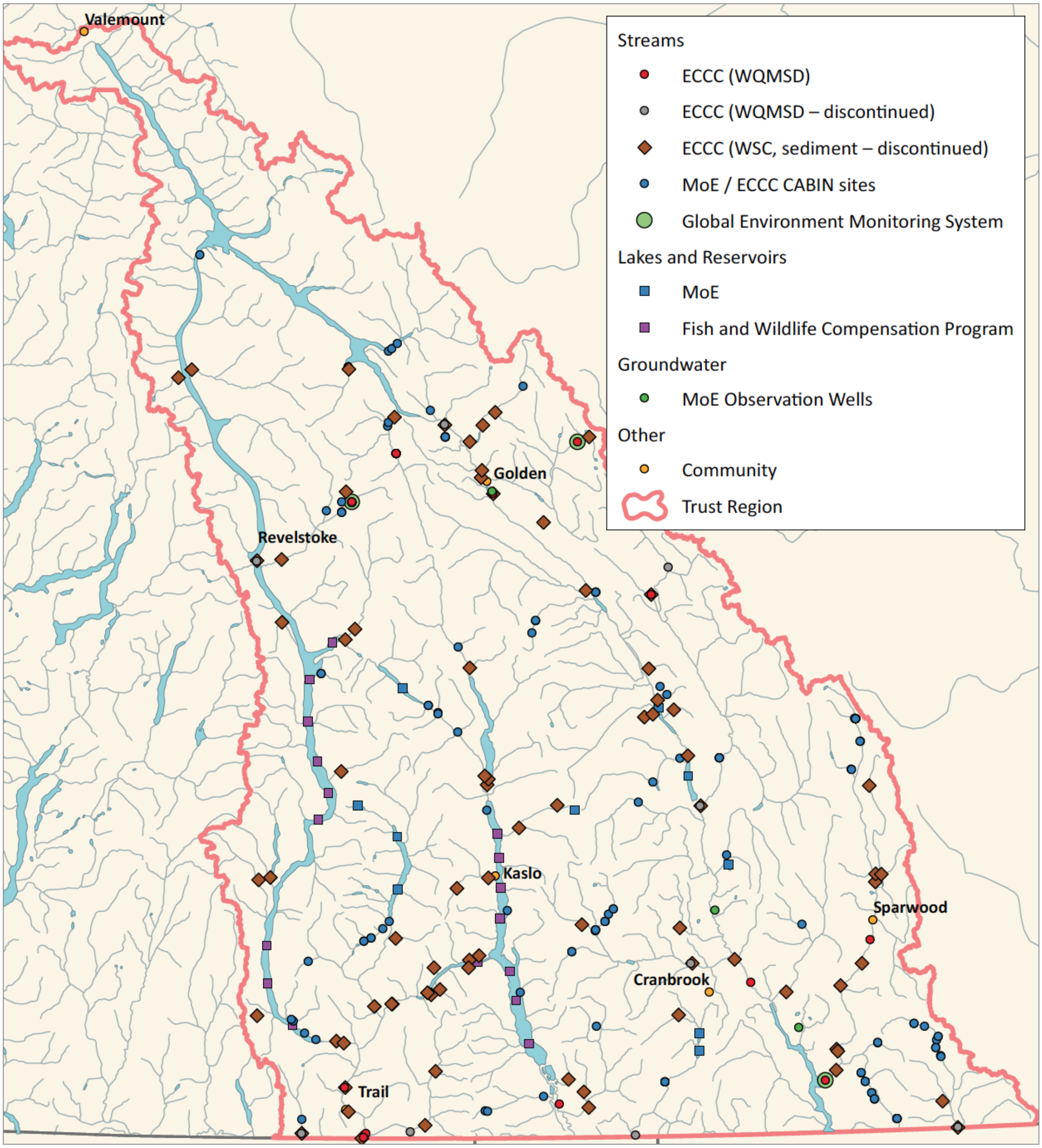

Figure 4. Basin hydrologic regions as indicated by patterns of climate and surface runoff.

Table 1. Active and discontinued climate, snow and glacier monitoring sites.

Data Group	**Provider**	**Status /Type**	**Hydrologic Region**[1]											**Elevation Range**[2]		
			All	**CKH**	**UPK**	**UPC**	**NEC**	**NWC**	**MCK**	**LCK**	**SMM**	**CR**	**KI**	**lo**	**mid**	**hi**
Climate	All	Annual	122	13	28	7	6	25	10	29	3		1	60	40	22
	All	Seasonal	32	5	1	1		11	6	7	1			8	8	16
	ECCC	Annual	35	4	11	1		5	5	9				15	13	7
	ECCC	Discontinued	147	25	33	4	4	18	16	37	3	7		46	66	33
	FLNRO	Annual	43	6	11	3	2	10	3	5	3			14	22	7
	MoTI	Annual	6	2	1			1		2				4	2	
	MoTI	Seasonal	32	5	1	1		11	6	7	1			8	8	16
	MoE	Annual	17		1	3		1		12				17		
	BCH	Annual	21	1	4		4	8	2	1			1	10	3	8
Snow	All	All	53	8	3	4	2	15	6	7	5	1	2	4	11	37
	MoE	Pillows	9	1		2	1	3	1				1			9
	MoE	Courses	39	7	3	2	1	11	4	4	5	1	1	3	10	26
	Resort	Pole	3					1		2				1	1	1
	CBM	Course	2						1	1						1
Glacier	CBSGRN	Mass Balance	5			2	1		1			1				5
	CBSGRN	Supersite	3	1				2								3

1 CKH-Columbia-Kootenay Headwaters; UPC-Upper Columbia; NEC-Northeast Columbia; CR-Canoe Reach; NWC-Northwest Columbia; MCK-Mid Columbia-Kootenay; KI-Kettle Inonoaklin; UPK-Upper Kootenay; SMM-St. Mary-Moyie; LCK-Lower Columbia-Kootenay

2 Lo - < 900 m: Mid: 900-1500 m; Hi: > 1500 m

Table 2. Active and discontinued water-quantity monitoring sites for streams, lakes, reservoirs and groundwater wells.

Group	**Provider**	**Status**	**Hydrologic Region**											**Elevation Range**		
			All	**CKH**	**UPK**	**UPC**	**NEC**	**NWC**	**MCK**	**LCK**	**SMM**	**CR**	**KI**	**lo**	**mid**	**hi**
Stream discharge	All	Active	45	2	20	6	2	4	17	14	3			49	17	2
	ECCC	Active	45	1	10	5	2	4	7	13	3			29	16	
	ECCC	Discontinued	38	9	5	3	1	4	4	11			1	28	6	4
	CBM	Active	23	1	10	1			10	1				20	1	2
	CBM	Discontinued	56	2	7	4	1	3	29	6	4			37	19	
Lake level	All	Active							2					2		
	ECCC	Active							2					2		
Reservoir level	All	Active	4					1	2	1				6		
	ECCC	Active	6					1	4	1				6		
	ECCC	Discontinued	1				1							1		
Ground-water	All	Active	6	1	3	1				1				5	1	
	MoE	Active	5		3	1				1				4	1	
	CBM	Active	1	1										1		

1 CKH-Columbia-Kootenay Headwaters; UPC-Upper Columbia; NEC-Northeast Columbia; CR-Canoe Reach; NWC-Northwest Columbia; MCK-Mid Columbia-Kootenay; KI-Kettle Inonoaklin; UPK-Upper Kootenay; SMM-St. Mary-Moyie; LCK-Lower Columbia-Kootenay

2 Lo - < 900 m: Mid: 900-1500 m; Hi: > 1500 m

Table 3. Active and discontinued water-quality monitoring sites for streams, lakes, reservoirs, wetlands, and groundwater wells.

Group	Provider	Status	Hydrologic Region											Elevation Range		
			All	**CKH**	**UPK**	**UPC**	**NEC**	**NWC**	**MCK**	**LCK**	**SMM**	**CR**	**KI**	**lo**	**mid**	**hi**
Stream	All	Active	66	5	28	3	1	6	10	6	7			35	24	7
	MoE/ECCC	Active	26	2	10	1		5		1	7			7	14	5
	WQMSD	Active	12	2	3	1	1	1		4				8	4	
	CBM	Active	28	1	15	1			10	1				20	6	2
	CBM	Discontinued	56	2	7	4	1	3	29	6	4			37	19	
	WQMSD	Discontinued	9	2	2	1		1		2	1			7	2	
	ECCC-sedm	Discontinued	79	10	15	8	3	8	11	21	2		1	53	22	4
Lake	All	Active	32	5	6			1	10	7	3			25	6	1
	MoE	Active	10	2	1			1	4		2			7	2	1
	CBM	Active	14	3	5				1	4	1			10	4	
	FWCP	Active	8						5	3				8		
Reservoir	FWCP	Active	9					4	3	2				9		
GW	MoE	Active	3		2	1								2	1	
Wetland	CBM	Active	21						20	1				13	5	3

1 CKH-Columbia-Kootenay Headwaters; UPC-Upper Columbia; NEC-Northeast Columbia; CR-Canoe Reach; NWC-Northwest Columbia; MCK-Mid Columbia-Kootenay; KI-Kettle Inonoaklin; UPK-Upper Kootenay; SMM-St. Mary-Moyie; LCK-Lower Columbia-Kootenay

2 Lo - < 900 m: Mid: 900-1500 m; Hi: > 1500 m

In addition to an emphasis on low-elevation locations and putting some hydrologic regions ahead of others, current station locations avoid or severely underemphasize wetlands, small streams, smaller lakes, and groundwater quality and quantity. As climate changes, these will be important sentinels of impacts and are expected to grow in importance for ecosystems and human communities. Smaller surface systems are heavily relied upon in many parts of the Basin and are subject to significant adjustments with climate change. Given the new demands likely to be placed on groundwater under future climates, additional groundwater monitoring is recommended to better understand its potential as surface water sources become seasonally restricted or of inadequate quality. Escalating demands on surface water may also lead to increased drawdown of groundwater in those situations where significant surface-water/groundwater interactions occur. Wetlands and small lakes are particularly important to water supply and in sustaining environmental flows in river systems. Given the historic and extensive loss of major wetlands and expected increases in episodes of water scarcity, mapping and tracking small wetlands, including high-elevation sites, would increase understanding of water storage and supply reliability under future seasonal dry periods. This knowledge would be directly useful in safeguarding aquatic habitats and maintaining community water supplies during periods of water scarcity. Monitoring the extensive and relatively less-disturbed Columbia River Wetlands is a priority given their international status and significance. Monitoring of natural lake levels may provide important information about rates of evaporation. Recent work on high-elevation lakes led by John Pomeroy highlights dynamic changes in their water temperature and surrounding soil moisture, pointing to monitoring in these areas to better understand these components of basin water balance and energy budgets (Kat Hartwig personal communication).

In addition to the monitoring of small streams, small lakes, wetlands and groundwater, additional notable (non-elevation) considerations include selection of representative or, at least, a wide cross-section of:

- streams (bedrock/alluvial, glacial/nonglacial, range in watershed roughness),
- wetlands (size, type) and
- lakes (size, nutrient/oxygen status).

While it was beyond the scope of the *Trust Water Monitoring Summary* to evaluate whether the existing monitoring stations provide a representative sample of these types, *it is highly likely that they do not*.

On a sub-regional basis, additional considerations come into play. For example, human dependencies may have arisen in certain locales around specific available goods and services. These values may warrant focused monitoring. A concept known as “regional landscapes” has been developed through direct application to the Basin. Regional landscapes are areas of similar elevational sequences of biogeoclimatic units (Holt *et al.* 2012). For example, the North Kootenay Lake Water Monitoring Project (NKLWMP 2017) has designed its monitoring network to provide climate and water-quantity data sufficient to support the characterization of the changes in behaviour of two regional landscapes that cover the area around the north end of Kootenay Lake, and in the coming decades of climate change. While it is unlikely that NKLWMP’s monitoring intensity can be sustained for all regional landscapes, this example provides a template for “drilling down” to spatial scales appropriate to the adjustments anticipated with climate change and may enable effective modelling to project overall change in water supply, particularly in relation to important local water sources.

Tiered Approach

Designing a monitoring network that is complementary to existing efforts requires consideration of this complex of factors in relation to monitoring objectives. In addition to identifying the monitoring type (baseline, trend, compliance, *etc.*), key biophysical and socioeconomic considerations should be identified so that priorities and tradeoffs can be established. It is suggested that the combined network of the provincial and federal governments be seen as the “backbone” network in place to characterize ecosystems according to hydrologic region and leading identified biophysical criteria. Gaps in the backbone network can be identified and addressed by those planning additional water monitoring, or in collaboration/dialogue with agencies, or both, to provide consistent baseline information. It is also suggested that monitoring agreements be sought with leading government data providers to leverage funds to complete the Basin-wide backbone network and structured according to the hydrologic regions. Within such a framework, gaps in hydrometric and climate monitoring can then be addressed such that suggested priorities for monitoring (*i.e.*, wetlands and groundwater) can be identified by hydrologic region and building on whatever sites may already be in place. Given the importance of the two Ramsar sites within the Basin and the absence of monitoring of those areas, it would also be appropriate to initiate wetland monitoring in those areas, and especially in the Columbia River Wetlands. Additional glacier monitoring sites, including super sites in representative locations, are also needed to better understand the pace of decline of glaciers by hydrologic region and particularly in relation to the concept of "peak melt" which is variable across the Basin, as discussed in the *Trust Water Monitoring Summary*.

In addition to filling these gaps in the backbone network, priorities can be identified in sub-regional and local water resources that warrant higher resolution monitoring in relation to aquatic-ecosystem values and community initiative and priorities. The key here is to avoid *ad hoc* monitoring and instead tie monitoring to clear Basin-wide objectives. Given the vast scope of monitoring that can be envisioned, a workable approach would be to establish Basin-wide objectives through a science committee composed of experts in the field able to use the existing information (including this report) to guide and provide rationale for proposed monitoring priorities and specifics. A call for CBM proposals aligned with such objectives can integrate them with community capacity and interest and under the guidance of a larger framework (e.g., the Columbia Basin Water Monitoring Framework – see section 4.1.1). . In this way, the backbone network can be supplemented strategically with a limited number of feasible targeted regional networks or clusters and sub-networks to address concerns complementary to it and to address issues that do not have an associated government mandate. For example, the complementary function may be to support the development of municipal, business and community adaptations to climate change. In this way, funders can further leverage their resources through CBM and citizen science (see section 4).

Water-Quality and Other Parameters

With respect to water quality, the larger systems are generally adequately monitored and reasonably understood, particularly those with industries anchored to specific locations. Water quality monitoring of the larger lakes is improving however progress is constrained by funding and smaller lakes may remain a low priority and thus poorly understood. It is the tributaries and wetlands where the greatest potential exists for improving the monitoring of water quality. On the one hand, a focus on those systems with significant current levels of human activities, particularly forestry and range activities, could yield immediate benefits in terms of identifying strategies to improve water quality. On the other hand, greater study of those waterbodies most vulnerable to climate change, with a focus on those that are currently *less* influenced by human activities, would provide critical information needed to manage these areas as the climate warms. Regardless, it is suggested that monitoring of nonpoint sources should be a focus of new water-quality monitoring because point-source monitoring of water quality is generally considered a regulatory responsibility.

In addition, note:

- With respect to the water quality sites where the CABIN methodology is applied, it would be beneficial to also monitor discharge at those sites. Given the cost of monitoring discharge, criteria would have to be developed to choose from the many sites.
- The magnitude of short-term (10-minute) rainfall intensity is expected to increase as the climate changes. The extent of monitoring of this parameter could be increased.

- It is of value to monitor undisturbed (or less disturbed) watersheds to provide baseline data against which to compare data from disturbed areas.
- Systematic monitoring of aquatic invasives is limited. This topic was beyond the scope of the *Trust Water Monitoring Summary*.
- There is a deficit in monitoring of pharmaceuticals and airborne contaminants, however, the importance of monitoring these would have to be carefully assessed in relation to the cost.

2.2 Data Management

A widespread and often-quoted concern is the difficult access to water data of all kinds. Difficult data access can impair the ability of a proposed monitoring project to choose appropriate new sites and parameters or of a proposed modelling or analysis initiative to achieve its objectives on a limited budget. In a nutshell, once data are gathered, an effective open-access data hub is needed if the effort of monitoring is to reach fruition. Although data from BC's snow monitoring network and Environment Canada's hydrometric network are easily available online, concerns can be noted about data access from other agency programs. Water quality data associated with the federal-provincial CABIN program are not made available except by release by staff upon request and approval. Data from ECCC's climate stations can be awkward or expensive to access. Glacier data are essentially unavailable. Data from CBM are available only upon request to those who are gathering the data. CBM data sets may not be provided in a standardized format, when made available. Data gathered in support of development proposals (Environmental Assessments) are generally not ever made publicly available.

The data-access situation contrasts with that of other jurisdictions where a broader range of data are easy for the public to access. Although beyond the scope of the *Trust Water Monitoring Summary* to document data hosting and distribution platforms, it is known that many USA data sets are generally well archived and easily accessed. In general, data availability can be improved through streamlined archival and retrieval technologies, through building on an existing platform (*e.g.*, the Pacific Climate Impacts Consortium's station data portal) or by creating a new facility within the Basin. "Water portals[1]" are being developed by the provincial government (*e.g.*, the Northeast Water Portal) including one currently under development for the Columbia Basin. A Canadian example is provided by DataStream which is an open-access platform that shares water data in the Mackenzie Basin[2]. We can learn from and build on this approach in creating a similar service for the Basin. As part of a warehouse for Basin water data, the opportunity exists to maintain an up-to-date map of all monitoring sites including data from discontinued sites. This map could be similar to the BC-wide monitoring site map maintained by the Pacific Climate Impacts Consortium (PCIC) but focused exclusively on the Basin and including monitoring sites of all types of water data and associated meta-data (owner, years of record, where the data can be acquired, *etc*.). Open-access data platforms are an active area of applied technology (including phone Apps) and the appropriate expertise should be consulted. As part of the Columbia Basin Water Monitoring Framework, currently being facilitated by Living Lakes Canada, a sub-committee is beginning to address open-source data storage and access for basin water data. That sub-committee is working with governments and the Mackenzie DataStream to explore hybrid options to address data-storage needs.

In addition to establishing a hub of Basin water data, the following actions can also be considered to further improve data availability:

1. Negotiated data agreements. Pursue negotiated data-sharing / cost-shared agreements with leading data providers (ECCC, BC Ministries including the BC Environmental Assessment Office) to make all water data open-access and uniformly available.

[1] http://waterportal.geoweb.bcogc.ca/#6/56.208/-126.721
[2] http://mackenziedatastream.ca/

2. Technical capacity. Establish dedicated time for managing updates and outreach concerning the data warehouse and to support data-management aspects of community-based monitoring initiatives.
3. Assembly of historic data. Historic and ongoing data can be captured and archived so that they can be included in the data warehouse. This would involve outreach to various agencies holding data in "filing cabinets".
4. Community-based monitoring. Increase engagement with existing institutions (*e.g.*, colleges) and non-governmental organizations (eg, the Columbia Basin Watershed Network) to support expanded technical capacity and other support for CBM programs the goals of which are to provide legitimate long-term data for inclusion in the new data warehouse. (*e.g.*, training and mentorship support).
5. Complementary land data. In the data warehouse, include information guidance on finding and securing land-based data complementary to the (primary) water data.

3.0 SCIENTIFIC UNDERSTANDING

3.1 Knowledge Gaps

The *Trust Water Monitoring Summary* includes findings from a number of scientific studies relevant to water in the Basin. Potential additional work is effectively infinite, however some key questions arise that are a higher priority than others. In general, these pertain to changes in hydrologic behaviour that suggest deeper impacts to come in the near future. The following is a short list of potential scientific questions and knowledge gaps for consideration due to their combined relevance to community sustainability and their support in identifying the status of hydrologic impacts of climate change.

1. <u>High-elevation data.</u> The station review in section 2 has indicated that it is the high-elevation data that are in deficit in the Basin. Yet, it is the water stored as snow and ice in these areas that determines much of what happens in the low-elevation areas. Acquiring more high-elevation data is a priority in the Basin.

2. <u>Peak glacial melt.</u> There is evidence that many glaciers in the Basin are at or near their periods of peak melt. On the lead up to peak melt, glaciers deliver more water to downstream waterbodies whereas in the recession after peak melt, their contributions drop off, often sharply. The status of glaciers across the Basin varies significantly with some approaching peak melt while others are past it. These differences are significant for downstream water resources and aquatic ecosystems and in the priorities that are allocated to adaptation. Determining more about the distributed status of peak melt is a priority scientific question in the Basin.

3. <u>Basin annual water yield.</u> As the *Trust Water Monitoring Summary* details, there are conflicting signals in hydrometric data regarding changes in water yield from watersheds throughout the Basin. It is accepted that climate change is leading to a number of process changes in runoff that will collectively alter the nature of catchment water yield (amount and timing). These dynamics are complex and not fully understood. Further work on this would be beneficial to create a better understanding of how annual hydrographs are evolving in response to changes in climate. This is of direct use in the management of downstream aquatic ecosystems and in community adaptation.

4. <u>Snow trends.</u> The *Trust Water Monitoring Summary* describes an analysis of changes in snowpack that identifies declines up to 2005. This work needs to be updated to clarify the extent of changes since 2005. Again, this is important because the snowpack is central in the makeup of Basin aquatic ecosystems and the environmental goods and services which they provide to downstream communities. This analysis would include core data provided by BC’s Snow Survey and Automated Snow Pillow networks, as well as data from other sources such as BC Hydro’s network. Bringing together all the snow data would also inform site selection of new high-elevation monitoring sites. Thompson Rivers University is carrying out a similar analysis for another region thus it may be efficient to partner with that university to get the analysis done for the Basin.

5. <u>Wetlands.</u> Barely monitored, wetlands provide environmental goods and services disproportionate to their size and in terms of water supply and aquatic habitat. Small wetlands are particularly vulnerable to climate change. There is a great need to establish plots around the Basin to track change. Such plots could serve as additional front-line indicators of hydrologic effects of climate change.

Additional questions that warrant study due to their growing importance are as follows:

1. Groundwater. As surface water sources become affected by climate change, many may no longer be suitable as water supplies for communities. Increasingly, it is expected that groundwater will be sought out, particularly in populated areas where pressures are likely to occur earlier. Establishing a groundwater working group to create a made-in-the-Basin science plan would offer a valuable opportunity to begin to address priority groundwater information gaps and go beyond gathering data (which is also needed).

2. Evaporation rates. Hydrologic modelling requires a variety of inputs of process rates. As the climate warms, these rates change. Evaporation, in particular, is sensitive to warming and is often a major source of uncertainty in hydrologic model outputs. Determinations of evaporation rates, including from smaller lakes and wetlands, may be an effective way to improve the accuracy of model outputs so that communities have a stronger information base on which to reach decisions as climate change advances.

3. Permafrost. Permafrost has been given little attention in the Basin and is essentially unmapped. Are there high-elevation permafrost sites? If so, are they melting and can they be a source of increased local geomorphic hazards?

4. Climate modes. The *Trust Water Monitoring Summary* provides an overview of climate modes that affect the Basin and a discussion of some current scientific thinking about their interactions (supported by information from Dr. Faron Anslow at PCIC). This discussion raises questions concerning the linkage between warming and climate modes and warrants further investigation. The most affordable approach may be to undertake a more comprehensive review of the scientific literature with respect to how climate modes may be affecting Basin climate/hydrology including how climate warming may be affecting the behaviour of any climate modes relevant to the Basin. Without this information, projections within the Basin can be confused by the effects of climate modes. Primary research in this field may be prohibitively costly, hence the suggestion to pursue a science review.

3.2 Status Assessments

There is a need to use available data to describe the condition and status of Basin waterbodies, particularly those that might not get included under agency mandates. Agencies and other agents are generally attentive to addressing the status of waterbodies downstream of major point source releases and for significant waterbodies such as the major lakes and reservoirs in the Basin. However, a host of other waterbodies are also of significance to Basin communities and ecosystems, for example, smaller streams, lakes and wetlands. Many of these waterbodies serve as “place-based” resources tied closely to and supportive of small communities and distributed rural development.

Considerable past and ongoing community-based effort and interest have yielded data and information to help sustain the waterbodies which support nearby ecosystems and local communities. Some of these initiatives date back decades. A parallel effort to use the data to inform decision-making could be improved in the Basin through application of monitoring data in condition and implementation evaluations (*e.g.*, see report discussion below). Without such complementary action, the value of the data sets is not realized. In fact, because distributed local and site-specific monitoring programs can create the impression of engaged active stewardship, they can have the unintended effect of creating complacency when water resource value may actually be declining while potential deterioration remains unidentified and unaddressed.

One response to this gap is the development of “report cards” based on data for waterbodies of interest, particularly those with available CBM and other data. Report cards can range from descriptions of the state of data availability to simple statements of current condition, to more comprehensive analyses of trends in ecosystem integrity and its delivery of community goods and services. They can also include forward-looking assessments that consider climate change projections. Production of report cards for water sources within the Basin can build on WWF-Canada’s Freshwater Health Assessment of the major basins across Canada, particularly with respect to its findings for the Columbia Basin. For smaller sources which are typically of interest to local communities, the emphasis currently is on data gathering and often does not include data analysis. As the period of record for available monitoring data grows, it presents a strategic opportunity for increased analysis to determine trends and improve existing monitoring programs. Report cards could examine clusters of sources within nearby regional landscapes (see section 2.1) to enable stronger insights that build on the strengths of various data sets and better overcome gaps and deficiencies in data sets derived for single sites. In addition to reporting on water status, report cards could also address the success of implementing the relevant monitoring framework components, based upon agreed upon priorities. These integrated assessments could be facilitated to make available relevant agency and industry data such as the Forests Land and Natural Resource Operations’ Forest and Range Evaluation Program, the Interior Health Authority and potentially forest-licensee data. Analysis of combined data from both community-based programs and long-term government networks may also provide important insights on hydrologic changes.

Various destinations exist for report-card information. They would be of direct value to decision-makers in their determinations regarding allocations for tenures and resource extraction. Communities reliant on small water sources benefit from a deeper understanding of the status of their water supply particularly in those situations where they do not have alternate sources in place. Existing watershed groups are generally keen to see analysis of available data sets to potentially inform their CBM initiatives. This type of information may enhance engagement by Columbia Basin Watershed Network (CBWN) with local groups and communities. The Kootenay Conservation Program may be interested in learning of trends in ecosystem status to better inform their conservation efforts, particularly where rare and endangered species and ecosystems are involved. In those situations where cumulative effects are of concern, report cards could include cross-cutting consideration of stressors including distributed non-point sources.

4.0 A STRENGTHENED CAPACITY FOR COMMUNITY RESPONSIVENESS

Accelerating impacts from climate change and increased awareness and capabilities at the community level highlight the need to support increased capacity for communities to respond effectively to the threats before them. Given the extent of scientific work that now needs to be done, leveraging the interest of local communities is highly recommended.

4.1 Integration of Community-Based Initiatives across Scales

Where threats exist to essential community water resources, communities tend to self-organize to create and implement solutions. Two leading responses involve water/watershed monitoring and efforts to increase local involvement in decision-making. In those situations where a community is heavily reliant on smaller watersheds or waterbodies (*e.g.*, small streams, wetlands and lakes), there may be little or no stewardship available other than that provided by the local community. Given these gaps, it points to opportunities to step up and provide initiative support for increased local stewardship.

4.1.1 Monitoring and Analysis

Communities typically have close relationships with their local environments. In addition, many citizens also want to increase their own scientific understanding of the water sources upon which they depend. Widespread awareness of the need to adapt to climate change, including residents being witness to its early impacts, has increased the impetus for many Basin residents to expand their knowledge of and responsibility toward their local water resources. This heightened interest has led to increased pursuit of CBM and opportunities to assess the current state of local water resources (see section 3.2). However, data gathering and scientific analysis require resources and appropriate expertise to be implemented successfully. Also, there may be a need to carefully select representative sites because not every watershed of concern can support the infrastructure and effort to justify the standards (and thus costs) required of water monitoring.

CBM is community-initiated data collection, yielding data that remain accessible to the community after the collection is complete and no matter who collected the data. Integration of CBM effort is widespread throughout North America. For example, the Northwest Territories government funds and relies upon CBM data to deliver on its stewardship mandate. There are various community-based organizations (*e.g.* non-profit organizations) carrying out water monitoring across the Basin with support from various sources. Whereas such groups have engaged in CBM over time, it is difficult for communities to sustain this work because of the costs and the need for continuity. A collaborative approach with efficiencies of scale is important to the success of CBM because it is generally too demanding for individual communities to each work through the challenges of mounting a scientifically defensible program. In some situations, local residents act as citizen scientists while in other situations, professional scientists are engaged to deliver the objectives of CBM. Regardless of the particular design of the CBM activity, there exists a great need to advance the role of CBM in the Basin, and complement the contributions of higher-level governments, including First Nations. Specifically, an objective and structured vetting process is recommended for selecting which CBM proposals to support and the associated waterbodies that should be monitored. A framework is currently being built as part of the Columbia Basin Water Monitoring Framework Initiative (led by Living Lakes Canada) to serve as a guiding document.

Whereas primary data collection by community members delivers critical information for improved stewardship of water resources, there is also a need to support additional capabilities within communities to enable motivated Basin residents to contribute to the processing and analysis of the expanding information base. It is not uncommon in the Basin for there to be considerable relevant expertise within communities that goes well beyond data collection. Many residents are keen to grow and apply their skills to better understand the water resources on which their communities depend and how they are being impacted by climate change. Expanded targeted education and outreach to grow scientific capabilities at the community level would be valuable in advancing the objective of increasing community capacity to take increased responsibility for the stewardship of the water resources on which they depend. For those communities with existing CBM projects in place, and where there is interest in going further, support for data management and Geographic Information System (GIS) capability can increase community capacity to steward water resources and engage productively with agencies and industry that may have their own responsibilities in relation to these water sources. For example, the Duhamel Watershed Society (on the North Shore of Kootenay Lake) has developed in-house capabilities using open-source GIS software (QGIS) to improve its ability to respond to water quality impacts in that watershed. This technical capacity can lead to further capabilities in evaluating resource condition and could also support additional - virtual or actual - collaborations in relation to a potential Columbia Basin Centre for Water Excellence.

Growing community-based technical capacity can be delivered through programs already in place with the Selkirk College Geospatial Research Centre (SGRC) and the CBWN. For example, community development of map products is already in place through SGRC and CBWN. The explosion of smart phones and App technologies appears to be a natural fit with community-based capacities, however there is a learning curve and the devices and software are needed, with cost and training implications. These innovations could be enabled through support for Basin residents to learn about the technology and apply it in local stewardship. Capacity building through loans of current technology (*e.g.*, devices) and advice on its use would help citizen scientists bridge the gap and get them up and running. Equipment for monitoring water quantity and water quality could be made available to stewardship groups (*e.g.*, salt dilution flow-monitoring equipment) for well-established groups and programs.

4.1.2 Governance and Adaptation

There exists a thirst within many Basin communities to have greater influence over the governance of local water resources. Gaps in the ability and preparedness of communities to respond to the rapid changes underway in water resources do not centre only on data availability and scientific understanding, but also include systems of water governance which can limit opportunities for communities to move forward in transforming their adaptive capacity. A greater role in water governance is a frequent request from communities and does not need to be in conflict with existing decision-making structures. Governance includes a wide range in activities that ultimately contribute to stewardship and management of water resources and go beyond endpoint decisions. Many community members and groups wanting to engage in governance may be satisfied with meaningful input into decisions. For many Basin residents, a critical aspect of governance is the opportunity to shape adaptation efforts undertaken in support of protecting water resources on which they directly depend.

During 2015-2018, Living Lakes Canada, the Trust and the POLIS Water Sustainability Project conducted research with the intent of offering residents of the Upper Columbia River Basin a useful resource for understanding how community-based groups engage in watershed governance. Background for the resulting research report, POLIS *et al.* (2018) and the identification of the case studies were informed by the 2013 *Think Like a Watershed Symposium*, hosted in Fairmont Hot Springs by CBWN and Living Lakes Canada. Its case studies and key messages highlight the value of community watershed groups in enhancing watershed governance and informing decision-making.

A powerful approach to supporting governance can be found in the new Water Sustainability Act (WSA) which enables alternative forms of local watershed governance. There is considerable guidance information available from the Polis Project on Ecological Governance at the University of Victoria (*e.g.*, see Brandes and Morris, 2016). As government water monitoring efforts have decreased over the last few decades, there has been increasing interest from some British Columbia residents to be involved in responding to serious threats in their watersheds, particularly ones that involve adapting to climate change. Collaborative governance structures can enhance decision-making. Collaboration provides many benefits, including opportunities to share knowledge, leverage local capacities, and expand access to resources and serves as an opportunity for developing trust and support for co-governance arrangements between First Nations, the Province and local communities.

The WSA provides the potential for new "watershed entities" to take on more responsibility and decision-making authority. Watershed entities include boards, trusts, regional bodies, and other watershed partnerships and arrangements. They have formal support and a recognized governing mandate as well as identified role and responsibilities relating to watershed health and function. They are consistent with what is in the WSA (Brandes *et al.* 2014). Although beyond the scope of the *Trust Water Monitoring Summary*, there are examples available to examine and learn from (*e.g.*, Yukon Intertribal Watershed Council, Mackenzie Keepers of the Water, and groups in the USA). Basin networking groups remain an important component of water governance however there is a need now to go beyond networking to the establishment of pilots of complementary local governance and in light of opportunities made possible within the WSA.

4.2 Regional Expertise and Community Guidance

There is a need in the Basin for regional expertise dedicated to supporting communities as they adapt to climate change and strive to learn more about their local water resources. For example, existing initiatives such as the Science Committee of the Columbia Basin Watershed Network could be used as a model to build an expanded consortium of science interests to create a Columbia Basin Centre for Water Excellence. Specific capacities that are called for include:

Water Quality and Aquatic Ecosystems. Provide advice on CABIN methodology and other water-quality monitoring approaches. Analyse regional water quality data (biological and chemical parameters). Understand and communicate climate change impacts on aquatic ecosystem function.

Water Quantity and Natural Hazards. Provide advice and training on discharge measurements and the monitoring of physical water parameters (sediment and temperature). Analyse regional water quantity and sediment data. Understand and communicate climate change impacts on natural hazards including fire, floods, drought and landslides. Maintain strong connection with PCIC and glacier research.

The potential for the Basin to serve as a research focal point in understanding water resources and their management is immense and invaluable to Canada and the international community. A Columbia Basin Centre for Water Excellence could provide the hub for these opportunities and serve to generate and multiply further interest for water research in the Basin. There is a strong precedent for this in the USA with the Long Term Ecological Research Network and the National Ecological Observation Network, groups which partner with universities and federal and state programs.

These initiatives could be integrated with the provision of capacity detailed elsewhere in this document in support of citizen science and CBM. Building citizen science serves to directly increase scientific capacity while simultaneously providing a collateral benefit of expanding citizen awareness of the issues involved. In fact, because there are facets of scientific data collection and ecosystem observation that can be provided best by place-based local residents, a deep involvement in citizen-science and CBM initiatives is a mutually beneficial collaboration. The Northwest Territories may offer a good example.

5.0 NEXT STEPS

The *Trust Water Monitoring Summary* provides a compilation of water monitoring sites carried out in the Upper Columbia Basin. The need to fill gaps in monitoring and to undertake associated scientific analysis has never been greater given the hydrologic non-stationarity (Milly *et al.*, 2008) brought about by climate change. We need to learn more about current change if we are to adequately prepare ourselves for it. This brief document has added to and unpacked the information provided in the *Trust Water Monitoring Summary* to offer a basis for systematically addressing gaps in water monitoring that currently render Basin communities vulnerable to a lack of key information needed to plan for the change already underway.

A coordinated and systematic approach to water monitoring is proposed to yield monitoring data representative of hydrologic regions, expanded spatial coverage of the network, and expanded monitoring to include inadequately-monitored variables among other benefits. To maximize efficiencies and benefits, such an approach would involve collaboration with a range of organizations. Given the unlimited scope for additional monitoring that this document has highlighted, it is recommended that new efforts to enhance water monitoring begin by closely examining the gaps as presented in this document (section 2.1) using the recommended approach, based on hydrologic regions and elevation. These overviews can be further broken down, depending on targets parameters, by other site characteristics such as location within hydrologic region, the period of monitoring record, landscape characteristics, *etc*.

In addition to new primary field monitoring, application of systems and technologies is needed to make data freely and easily accessed thereby facilitating scientific analyses and community examination of available options. These expanded services may be offered by different providers.

It is suggested that interested parties strike a cross-sectoral science committee to discuss options for expansion of water monitoring activity and that strong science and community representation be included with expertise in interpreting water-related climate change impact. This collaboration may include Provincial and Federal agencies, First Nations, Regional Districts, local government, community groups/organizations, Columbia Basin Trust and foundations such as those involved in the BC Water Funders Collaborative, as introduced above. Through this approach, *ad hoc* patterns of monitoring can be avoided, leading to the design of a complementary monitoring network. Living Lakes Canada is currently leading the Columbia Basin Water Monitoring Framework, emerging from a conference held in Invermere (Nov 29-30, 2017) entitled *Water Data Hub Cracking the Code; An Open Source Data Dialogue Toward a Columbia Basin Water Monitoring Framework*. Systematic inclusive approaches such as these can assist in identifying an objective basis for site selection, ultimately rooted in recognized scientific gaps and optimized to reflect community needs and priorities. Integrating and coordinating an expanded water-monitoring role may offer opportunities for efficiencies and added leverage. Existing networking organizations such as the CBWN provide opportunity to efficiently solicit and engage communities.

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