MacHydro

Geospatial Analysis for the Pilot Priority Matrix to Expand Water Monitoring in the Upper Columbia Basin

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Pilot Priority Matrix to Expand Water Monitoring in Upper Columbia Basin

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Contents

List of Figures

List of Tables

1 Introduction

1.1 Geospatial Analysis of the Pilot Implementation for the Columbia Basin Water Monitoring Framework

In 2017, Living Lakes Canada (LLC; LLC, 2017) hosted a conference that brought together 120 water experts to discuss needs for an expanded water monitoring network and an accompanying open-source water data hub for the Upper Columbia Basin (UCB). In June 2020, LLC facilitated a hydrologist workshop with the purpose of developing recommendations for a phased expansion of the water monitoring network within the UCB (Carver and Utzig, 2020). This led LLC to commission the development of a Terms of Reference and budget (Carver and Utzig, 2021a; 2021b).

Living Lakes Canada is leading the implementation of the methods outlined in the Terms of Reference through the program called the Columbia Basin Water Monitoring Framework (CBWMF). The goal of the CBWMF is to "establish a unified monitoring scientific framework based on a Priority Monitoring Matrix that reflects local priorities within a scientific water balance approach to support future water allocation based on priority needs" and considers climate change within the UCB (LLC, 2022a). This comprehensive, scaled, and nested approach for water monitoring is intended to support efforts of decision makers to better address community and ecosystem climate adaptation options. This comprehensive approach may also provide a template for other watershed groups to support local and regional efforts to increase climate change adaptation options and to support the longer-term viability of natural ecosystems and ecosystem services.

The Priority Monitoring Matrix process was initiated by delineating a study area of relatively homogeneous hydroclimatic regions to consolidate a major source of variation in watershed behavior. The second step was to select an appropriate range of watershed sizes to focus on (in this case the Freshwater Atlas; BC Data Catalogue, 2022a). Priority watersheds were then stratified into groups based on criteria related to hydrologic processes. From there, specific watersheds were selected for monitoring based on gaps in historic and current monitoring and priorities identified by Local Reference Groups (Figure 1; Carver and Utzig, 2021a). The intent was to identify monitoring sites that are representative of other locations across the UCB so that information could be used to make inferences about hydrologic conditions at multiple spatial and temporal scales. This eight-step approach, summarized in Figure 2, was used to formulate and rank potential monitoring sites and parameters to be collected.

The three pilot Areas of Interest implemented in 2022 are the Columbia-Kootenay Headwaters, the Mid-Columbia Kootenay, and the Elk River Watershed. These areas have population centers that provide opportunities for engagement with existing Local Reference Groups and processes, which include ongoing locally initiated non-governmental water monitoring programs (Carver and Utzig, 2021b). The Elk River Alliance is also actively monitoring water quality within the Elk River Watershed and were interested in expanding their monitoring program, so this process was used to help expanded their site selection. The plan is to phase in the Priority Matrix over the entire UBC within the next 10-15 years with monitoring to continue for the at least 10 years following the installation of equipment.

MacDonald Hydrology Consultants Ltd. (MacHydro) was approached by LLC to complete the geospatial analysis for the UCB to support the identification and prioritization of areas for expanded water monitoring in conjunction with LLC based on the monitoring strategy outlined by Carver and Utzig

(2021a). This report summarizes the implementation plan for the preliminary eight-step approach for each study area and the establishment of a Priority Monitoring Matrix for use by others.

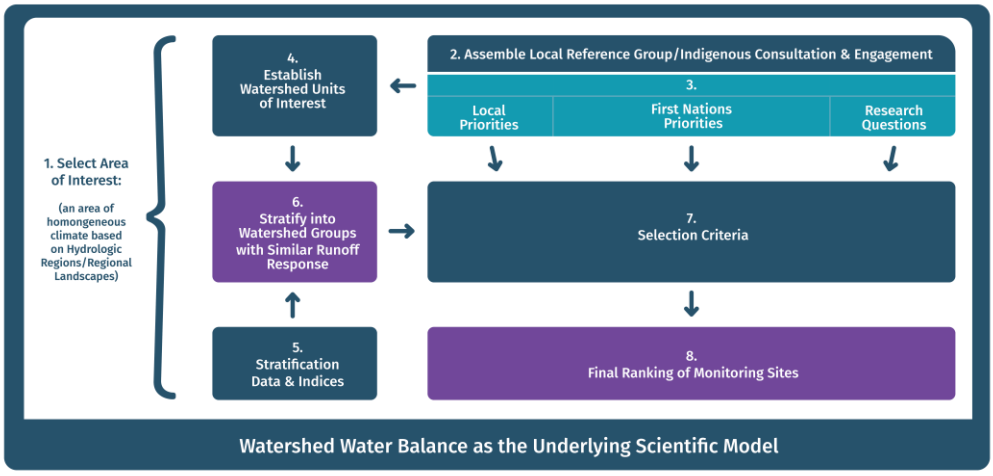

Figure 1. Underlying basis and steps for the implementation of the monitoring strategy (LLC, 2022b).

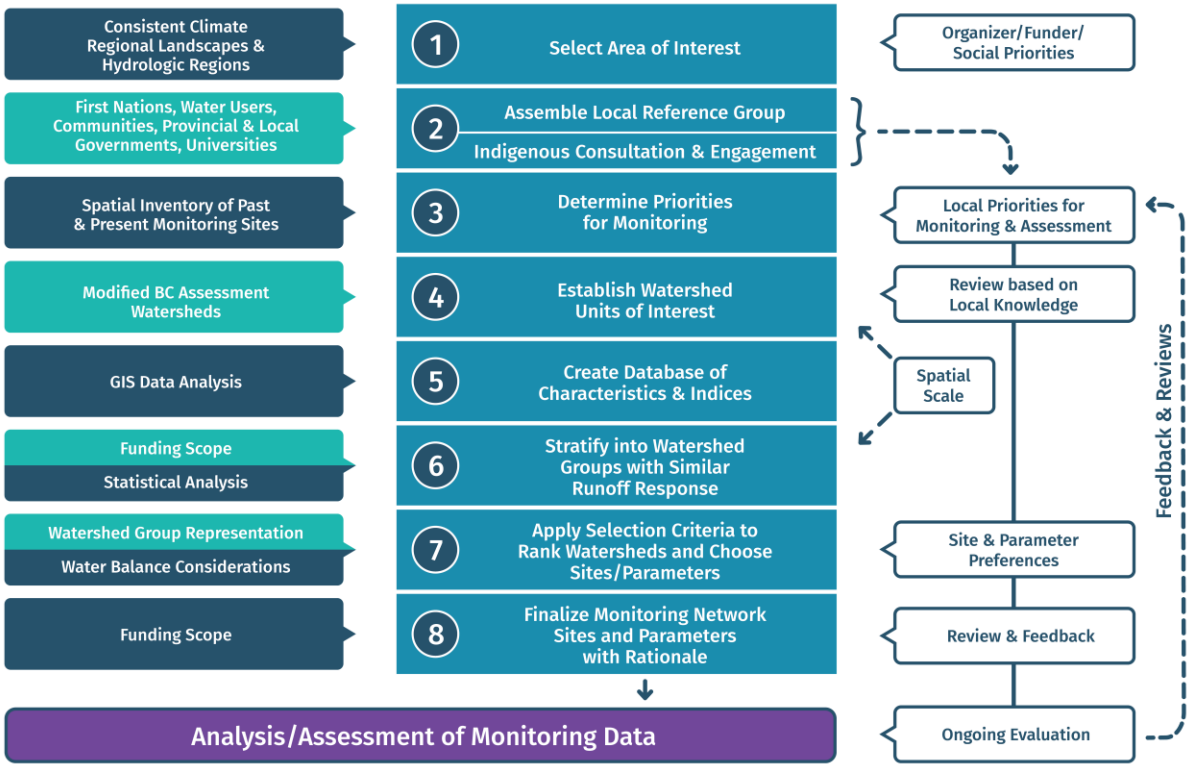

Figure 2. Overview of the framework and the inputs required at each step (LLC, 2022b).

1.2 Project Scope

This report summarizes the geospatial analysis developed for the UCB to support an identification and prioritization of areas for expanded water monitoring in conjunction with LLC. The scope of work presented is for the scientific component that leads the process, and it is assumed that the aspects related to citizen engagement are addressed by LLC staff and/or additional consulting capacity. In terms of water monitoring the scope was limited to:

- Hydrometric: streamflow, water (lake) level, water temperature;
- Weather: air temperature, precipitation at the most basic level, with potential to include relative humidity, wind speed and solar radiation; and
- Snow: snow water equivalent, measured via snow pillows, depth sensors, or periodic snow surveys.
    - Groundwater monitoring and biomonitoring were also identified by Carver 2021b; however, these data types were not evaluated in this initial work.

As stated above, this study focused on three Areas of Interest:

- Columbia-Kootenay Headwaters (CKH): all areas upstream of Donald, BC on the Columbia River),
- Mid-Columbia Kootenay (MCK): local watersheds surrounding Kaslo, New Denver, and Fauquier, BC), and
- Elk River Watershed (Elk): all areas within the Elk River watershed and within Canada.

Following the overall methods and framework outlined by Carver and Utzig (2021a; Figure 1 and Figure 2), we proposed the following sub-tasks to identify and prioritize areas for expanded monitoring within the three pilot Areas of Interest.

1. Confirm boundaries for each Area of Interest, based on Hydrologic Regions (Utzig, 2019), and establish watershed units.
2. Compile geospatial data and characterize runoff response of each Assessment Watershed.
3. Compile available active monitoring locations for relevant parameters in the Area of Interest.
4. Identify areas with limited monitoring.
5. Identify potential monitoring locations.

1.3 Acknowledgements

The Project Team would like to thank the members of the Technical Advisory Group and Local Reference Groups for their input, guidance, and feedback. The members include:

- Kat Hartwig, Executive Director, Living Lakes Canada
- Paige Thurston, Program Manager, Living Lakes Canada
- Maggie Finkle-Aucoin, GIS and database coordinator, Living Lakes Canada
- Emily Mask, Applied Reconciliation Coordinator, Living Lakes Canada
- Nicole Trigg, Communications Director, Living Lakes Canada
- Greg Utzig, Kutenai Nature Investigations Ltd.

- Martin Carver, Aqua Environmental Associates
- Chad Hughes, Executive Director, Elk River Alliance
- Kaileigh McCallum, Junior Ecologist, Elk River Alliance
- Anne-Caroline Kroeger, Project Manager, Elk River Alliance; Local Reference Group Coordinator
- Wendy Booth, Local Reference Group Coordinator, Living Lakes Canada
- Richard Johnson, Local Reference Group Coordinator, Living Lakes Canada

1.4 Acronyms and Abbreviations

BEC	Biogeoclimatic Ecosystem Classification
CBWMF	Columbia Basin Water Monitoring Framework
CKH	Columbia-Kootenay Headwaters
ECCC	Environment and Climate Change Canada
FLNRORD	BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
LLC	Living Lakes Canada
MCK	Mid-Columbia-Kootenay
MoTI	BC Ministry of Transportation and Infrastructure
PCIC	Pacific Climate Impacts Consortium
RL	Regional Landscape
UCB	Upper Columbia Basin

2 Methods

2.1 Confirm watershed boundaries for each Area of Interest

Utzig (2019) proposed Regional Landscapes as a potential landscape classification unit to replace BEC subzone/variants and Ecosections in southeastern BC (Figure 3). By making minor boundary adjustments to the Regional Landscapes and Climatic Subregions to match watershed boundaries, he was able to define ten distinct Hydrologic Regions (Figure 4). The Hydrologic Regions were delineated based on watershed boundaries and averages of climate and streamflow to assess past and future trends in streamflow (Table 1; CBT, 2017). The climate within each of these Hydrologic Regions, although similar, varies with latitude (north to south) and elevation, and form the foundation of the proposed scientific framework (Carver and Utzig, 2021b).

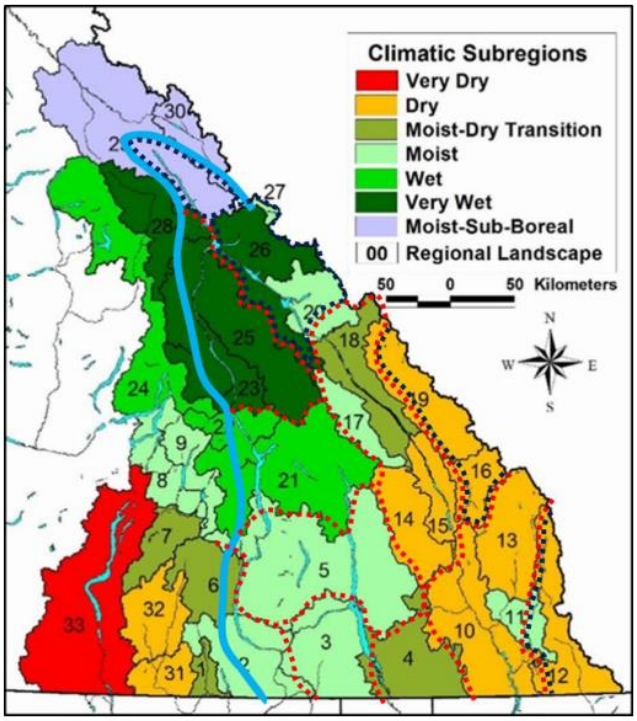

Figure 3. Regional Landscapes and Climate subregions of southeast BC. Also shown in red and blue are potential Areas of Interest based on Regional Landscape groupings (red = front-country; blue = back-country; Carver and Utzig, 2021b).

The three Areas of Interest for this analysis are based primarily on the Regional Landscape boundaries within each of the associated Hydrologic Region (Figure 1). The Columbia-Kootenay Headwaters (CKH) front country Area of Interest consists of Regional Landscapes 14, 15, 17, 18 and part of 20, and the back country consists of Regional Landscapes 16 and 19 – a total of three climatic subregions. The Mid-Columbia-Kootenay (MCK) front country Area of Interest consists of Regional Landscape 5 – one climatic subregion. The Elk River Watershed Area of Interest consists of two Regional Landscapes, part of 11 and 12 – a total of two climatic subregions. These Areas of Interest represent a range of climates and a

diversity of watershed concerns. They also contain existing watershed groups and population centers, which provide an excellent opportunity for engagement through the Local Reference Groups. The three Areas of Interest are outlined in Figure 5.

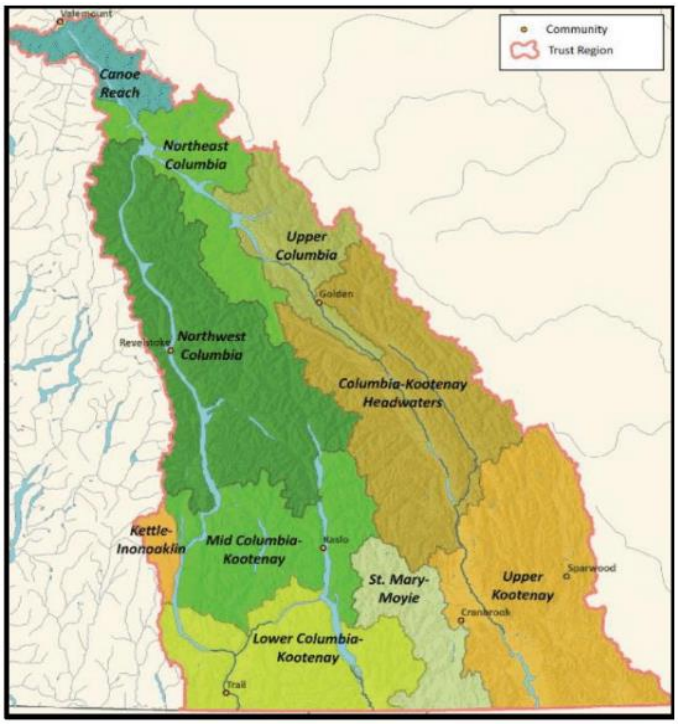

Figure 4. The ten UCB Hydrologic Regions indicated by patterns of climate and surface runoff (Carver and Utzig, 2021a).

Table 1. Relative climate across the UCB's hydrologic regions (Carver and Utzig, 2021a).

Hydrologic Region	Climate Overview
Canoe Reach	Moderate moist summers, cold moist winters with moderate snowpacks
Columbia-Kootenay Headwaters	Warm moist summers, cold dry winters with moderate snowpacks at higher elevations
Kettle-Inonoaklin	Very hot dry summers, mild winters with moderate-to-low snowpacks. Transitional to regions west of the Basin.
Lower Columbia Kootenay	Hot dry summers, moderately cool winters with moderate snowpacks at higher elevations
Mid-Columbia-Kootenay	Transitional between Northwest Columbia and Lower Columbia-Kootenay
Northeast Columbia	Warm wet summers, cold wet winters with deep snowpacks
Northwest Columbia	Moderate wet summers, wet cool winters with deep snowpacks
St. Mary-Moyie	Transitional between Lower-Columbia Kootenay and Upper Kootenay
Upper Columbia	Warm moist summers, cold wet winters with moderate snowpacks at higher elevations
Upper Kootenay	Very dry to moist hot summers, cold dry winters with low-to-moderate snowpacks

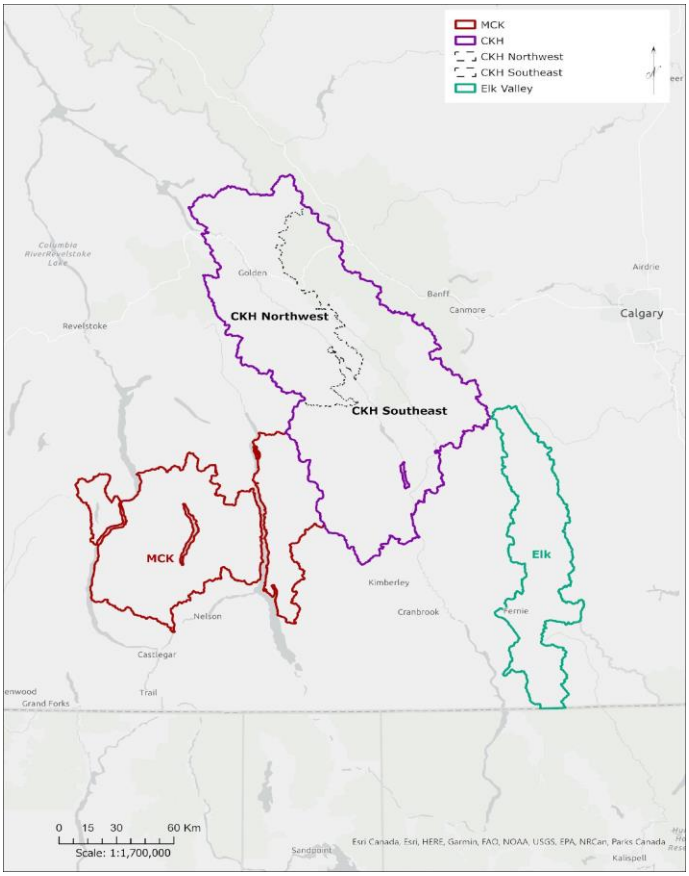

Figure 5. Pilot Areas of Interest: Columbia-Kootenay Headwaters, Mid-Columbia Kootenay and the Elk River Watershed

2.2 Compilation of Geospatial Data and Characterization of Runoff Response

To better isolate the diversity in hydrologic response, the Regional Landscapes within each Area of Interest were divided into smaller watershed units, using the BC Freshwater Atlas Assessment Watersheds (BC FWA; BC Data Catalogue, 2022a). Although each Assessment Watershed has a unique hydrologic signature based on its specific climate, land cover, and elevation, within each region some watersheds are likely to have similar characteristics; therefore, similar streamflow/runoff patterns. This overlap in hydroclimatic conditions suggests that watersheds can be coarsely stratified into groupings that reflect generalized hydrologic conditions. To identify watershed "types" within each Area of Interest and to assess which "types" have limited active hydroclimatic monitoring, a range of climate, land cover and morphometric statistics were compiled. These statistics were heavily informed by a pilot clustering study completed in the upper Columbia River (East Kootenay Area of Interest, MacDonald Hydrology Consultants, 2020).

2.2.1 Geospatial Data Sources

To characterize the hydrologic conditions of each watershed, several spatial morphometric, climatological, and physiographic datasets were compiled from several sources and are summarized in Table 2.

Table 2. Data sources used in watershed clustering.

Clustering Indicator	Units	Data Source	Citation
Infiltration Rating	none	Personal Communications	Carver and Utzig (2021)
Basin Shape Index	none	BC FWA	Spence et al. (2007)
Mean Elevation	m	CDEM	NRCan (2022), Hollister et al. (2021)
Maximum Elevation	m	CDEM	NRCan (2022), Hollister et al. (2021)
Slope-Aspect	rad	CDEM	NRCan (2022), Hollister et al. (2021)
Temperature	C	ClimateBC	Wang et al. (2016)
Precipitation	mm/year	ClimateBC	Wang et al. (2016)
Snow Fraction	%	ClimateBC	Wang et al. (2016)
Relative Humidity	%	ClimateBC	Wang et al. (2016)
Wetland Fraction	%	BTM - Present Land Use	BC Data Catalogue (2022b)
Forest Fraction	%	BTM - Present Land Use	BC Data Catalogue (2022b)
Glacier Fraction	%	BTM - Present Land Use	BC Data Catalogue (2022b)

Infiltration Rating was provided by Carver and Utzig (2021, *pers. comms.*) and assigned a value to each Assessment Watershed based on the watershed's soil texture and geology. The Basin Shape Index (BSI) was derived for each watershed where BSI = (0.28*Perimeter) / Area, following Spence et al. (2007). Elevation data were derived from the Canadian Digital Elevation Model (CDEM; NRCan, 2022) which was accessed using the `elevatr` package in R (Hollister et al., 2021) at a 100 m spatial resolution. The mean and maximum elevation were obtained from the raster for each Assessment Watershed, while the Slope-Aspect was calculated using the average hillshade value for the watershed. Air Temperature, Precipitation, Snow Fraction, and Relative Humidity were obtained from ClimateBC v7.10 (Wang et al., 2016) over the 1981-2010 normal period and were averaged over each Assessment Watershed.

Land cover information was obtained from the Baseline Thematic Mapping (BTM) – Present Land Use obtained from the BC Data Catalogue (2022b) using the `bcdata` R package (Teucher et al. 2021). Wetland Fraction was derived by the fractional coverage within each watershed that was classified as "Wetland" or "Fresh Water", Forest Fraction as the fractional coverage containing a classification including the words "Forest" or "Logged", and Glacier Fraction as the fractional coverage classified as "Glacier".

2.3 Cluster Analysis

A cluster analysis was used to group Assessment Watersheds based on their hydrologic characteristics. Clustering was completed by first scaling (normalizing) all clustering indicators used in the study (Table 2). Scaled clustering indicators were then classified using hierarchical cluster analysis on a set of

dissimilarities, using the `hclust` function in the R (R Core Team, 2021) using Euclidean distances and the 'ward.D' method.

Multiple iterations were considered with differing numbers of prescribed groups, but 4-5 groups provided the best spread while maintaining spatial structure. This iterative process was informed by several qualitative aspects, such as the study goals (i.e., how many groups of watersheds could be monitored) and local knowledge (how "different" are these watersheds within the Area of Interest), as well as more quantitative measures, such as the spread/distribution of clustering indicators between groups, significant differences between groups, and weighted sum of squares on the scaled dataset.

The Columbia-Kootenay Headwaters Area of Interest was divided into two regions to align with the Regional Landscape groupings and associated climatic subregions. The northwest region included Regional Landscapes 17, 18 and 20 (two climatic subregions – moist and moist-dry transition) and the southeast region included Regional Landscapes 14, 15 and a portion of 20 (moist-dry transition climatic subregion). See Appendices C for the Columbia-Kootenay Headwaters cluster analysis details for the two regions. The cluster analysis was performed on each region and then combined to create six watershed groupings for the entire Columbia-Kootenay Headwaters Area of Interest (Figure 6). Watershed Groups are as follows: A – Middle elevation; B – High elevation (Rocky Mountains); C – Low elevation; D – High elevation; E – High elevation (Purcell Mountains); F – Glaciers. This Area of Interest is primarily comprised of Watershed Groups A and C (Table 3).

The Mid-Columbia Kootenay Area of Interest consisted of only one Regional Landscape (5 - moist subregion) so one iteration of cluster analysis was conducted on this entire area. A total of five watershed groupings were defined for the Mid-Columbia Kootenay Area of Interest (Figure 7). Watershed Groups are as follows: A – Glaciers; B – High elevation, cooler, wetter; C – Middle elevation, warmer, drier; D – High elevation, warmer, drier; E – Lower elevation, warmer, drier. This Area of Interest is primarily comprised of Watershed Group B (Table 3).

The Elk River Watershed consists of two Regional Landscape – part of 11 and 12 (moist and dry climatic subregions) and only one iteration of the cluster analysis was performed to define four watershed groups (Figure 8). Watershed Groups are as follows: A – Low elevation, warmer drier; B – High elevation, cooler, wetter; C – Middle elevation, drier; D – Middle elevation, wetter. This Area of Interest is primarily comprised of Watershed Groups A and B (Table 3).

Table 3. Percent of the total Area of Interest comprised by each Watershed Group.

Watershed Group	CKH	MCK	Elk
A	33%	9%	40%
B	15%	37%	30%
C	24%	21%	8%
D	11%	18%	21%
E	8%	15%	
F	9%		

The results of the cluster analysis are provided in Appendix A for the three Areas of Interest.

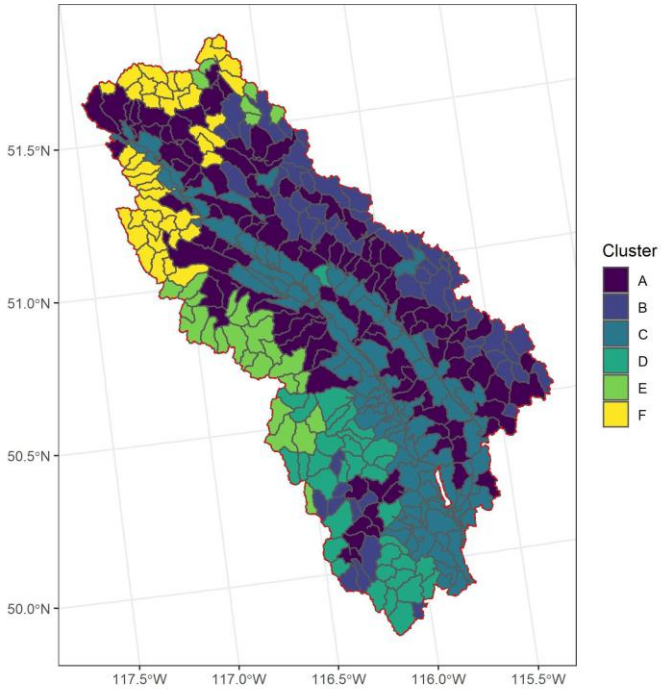

Figure 6. Columbia-Kootenay Headwaters cluster analysis as watershed groups. A – Middle elevation; B – High elevation (Rocky Mountains); C – Low elevation; D – High elevation; E – High elevation (Purcell Mountains); F – Glaciers.

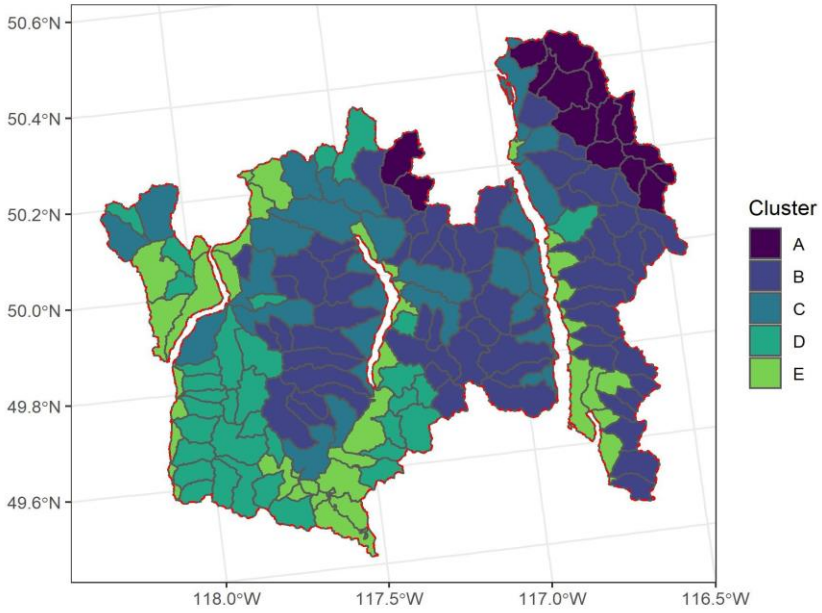

Figure 7. Mid-Columbia-Kootenay Watershed Groups. A – Glaciers; B – High elevation, cooler, wetter; C – Middle elevation, warmer, drier; D – High elevation, warmer, drier; E – Lower elevation, warmer, drier

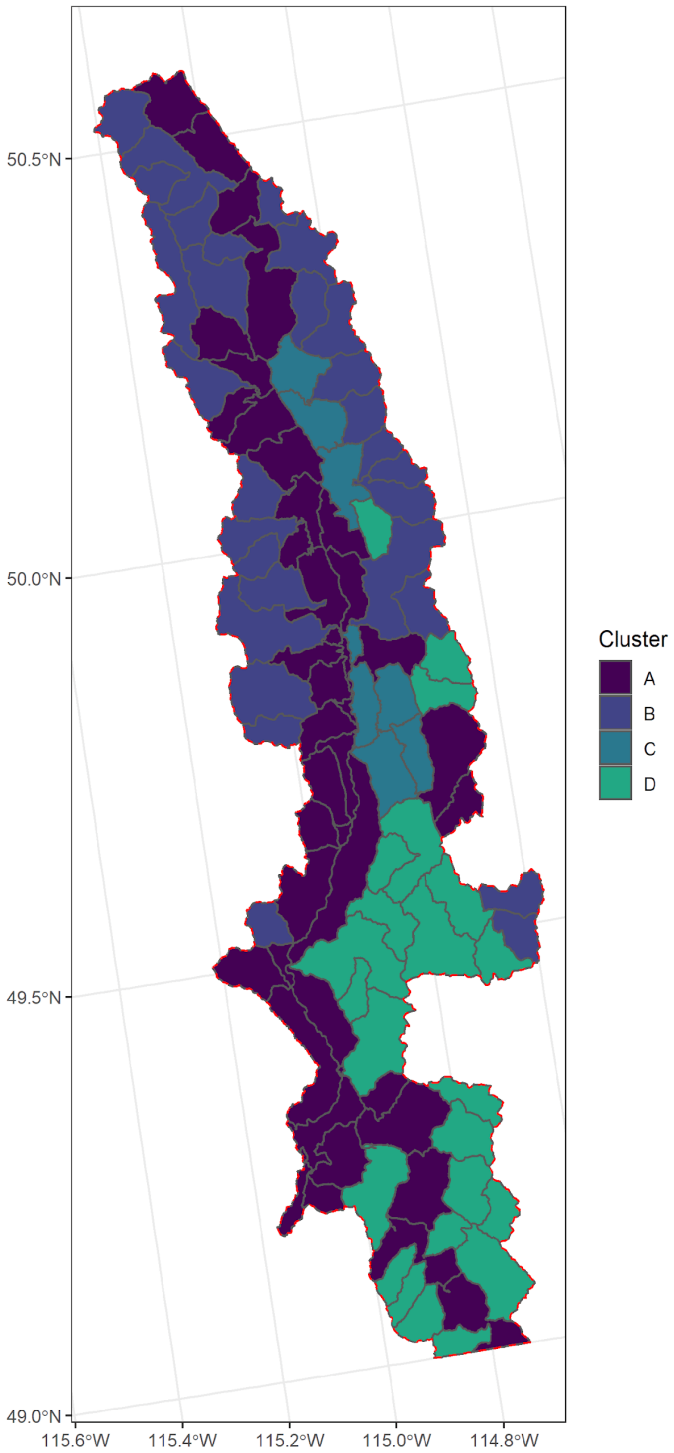

Figure 8. Elk River Watershed Groups. A – Low elevation, warmer drier; B – High elevation, cooler, wetter; C – Middle elevation, drier; D – Middle elevation, wetter.

3 Compile Available Monitoring Locations

The first step in the monitoring data acquisition was to compile known and public data sources. This included Environment Canada, as well as provincial networks, including FLNRORD, MoTI, and BC Hydro. The metadata on these stations was obtained in a variety of ways, depending on which networks were selected, either directly from the data source, or through a third-party service, such as the Pacific Climate Impacts Consortium's *BC Station Data*. The monitoring stations were filtered to select sites that were collecting identified parameters, available data, and active and inactive data collection.

3.1 Datasets

Several types of hydrometric and climate datasets were compiled during this phase of work. A summary of the network name and associated parameters used for this step is summarized in Table 4. Summary of the network name and attributes for all three Areas of Interest. Data sources and licensing are provided in Appendices B and C.

Table 4. Summary of the network name and attributes for all three Areas of Interest.

Network Name	Station Count			Status	Parameters	Period		
	CKH	*MCK*	*Elk*			*CKH*	*MCK*	*Elk*
Climate								
Agricultural and Rural Development Act Network - *from PCIC*	90	60	92	Historical / Inactive	Precipitation Amount Surface Snow Depth Air Temperature	1965-1984	1969-1984	1965-1991
BC ENV - Automated Snow Pillow Network		2	2	Active/ Inactive	Precipitation (Cumulative) Surface Snow Depth Air Temperature Snow Water Equivalent		2020-current	1979-2020
BC ENV - Manual Snow Survey	17	9	0/8	Active/ Inactive	Snow Depth Snow Water Equivalent	1940-current	1938-current	1938-2020
BC FLNRORD - Wild Fire Management Branch *retrieved from PCIC*	25	10	1	Current	Precipitation Amount Air Temperature Wind Direction Relative Humidity Wind Speed Dewpoint	1970-current	1990-current	2001-current
BC HYDRO *retrieved from PCIC*	3	3	3	Current	Precipitation Amount Air Temperature Snowfall Amount	1993-current	2018-current	1982-current
BC MoTI - *from PCIC*	14	14	6	Current	Precipitation Amount Rainfall Amount Snowfall Amount Surface Snow Depth Air Temperature Wind Speed Relative Humidity	1975-current	1975-current	1970-current
Environment Canada	34	13	17	Current	Precipitation Amount Rainfall Amount Snowfall Amount Surface Snow Depth Air Temperature	1909-current	1907-current	1913-current
Hydrometric								
Water Survey of Canada	3/53	4/82	6/18	Active/ Discontinued	Flow Water Levels	1911-current	1914-current	1914-current

4 Identify Areas with Limited Monitoring

The objective of this study was to ensure that at least one representative Assessment Watershed from each Watershed Group was being monitored to understand the runoff regime. To address the gap in data monitoring, a list of potential monitoring locations within Watershed Groups with limited monitoring data were identified.

4.1 Spatial Overlay of Clustering and Monitoring Sites

To identify areas which have limited monitoring, the Watershed Groups were overlain with all known monitoring locations for each Area of Interest (Figures 9-11). This allowed the Project Team to quantify the number or density of monitoring sites within hydrologically similar areas.

A summary of the active and inactive full and partial climate stations within each Watershed Group and for each Area of Interest is shown in Figure 12. A full climate station included all parameters of interest (i.e., air temperature, snow depth, precipitation, etc.) and a partial climate station was missing at least one of the parameters. Within the Columbia-Kootenay Headwaters Area of Interest, climate station information was limited in Watershed Groups E and F. Within the Mid-Columbia Kootenay Area of Interest climate station information was limited for Watershed Group A, with no active stations and one inactive station, and limited in group E with only two active stations. Within the Elk River Valley Area of Interest, climate station information was limited for Watershed Group B, with no active stations and 7 inactive stations.

A summary of the active and inactive Water Survey of Canada (WSC) hydrometric stations (i.e., collecting discharge data and/or water level) is show in Figure 12. These also included the BC Hydro stations. Within the Columbia-Kootenay Headwaters active hydrometric stations are missing for Watershed Groups B, D and E. Within the Mid-Columbia Kootenay no active hydrometric stations are in Watershed Group A. Within the Elk River Watershed, there is no hydrometric station within Watershed Group D. Historically there were more active Water Survey of Canada hydrometric stations in operation than currently across British Columbia and Canada. Hydrometric stations being operated by a third-party (e.g., industry, community groups, etc.) were not included in this data gap initial analysis. It was expected that through the Local Reference Groups third party hydrometric stations would be used to inform the final station location.

The results from this final step provided a quantitative and qualitative analysis of major monitoring data gaps in the Areas of Interest.

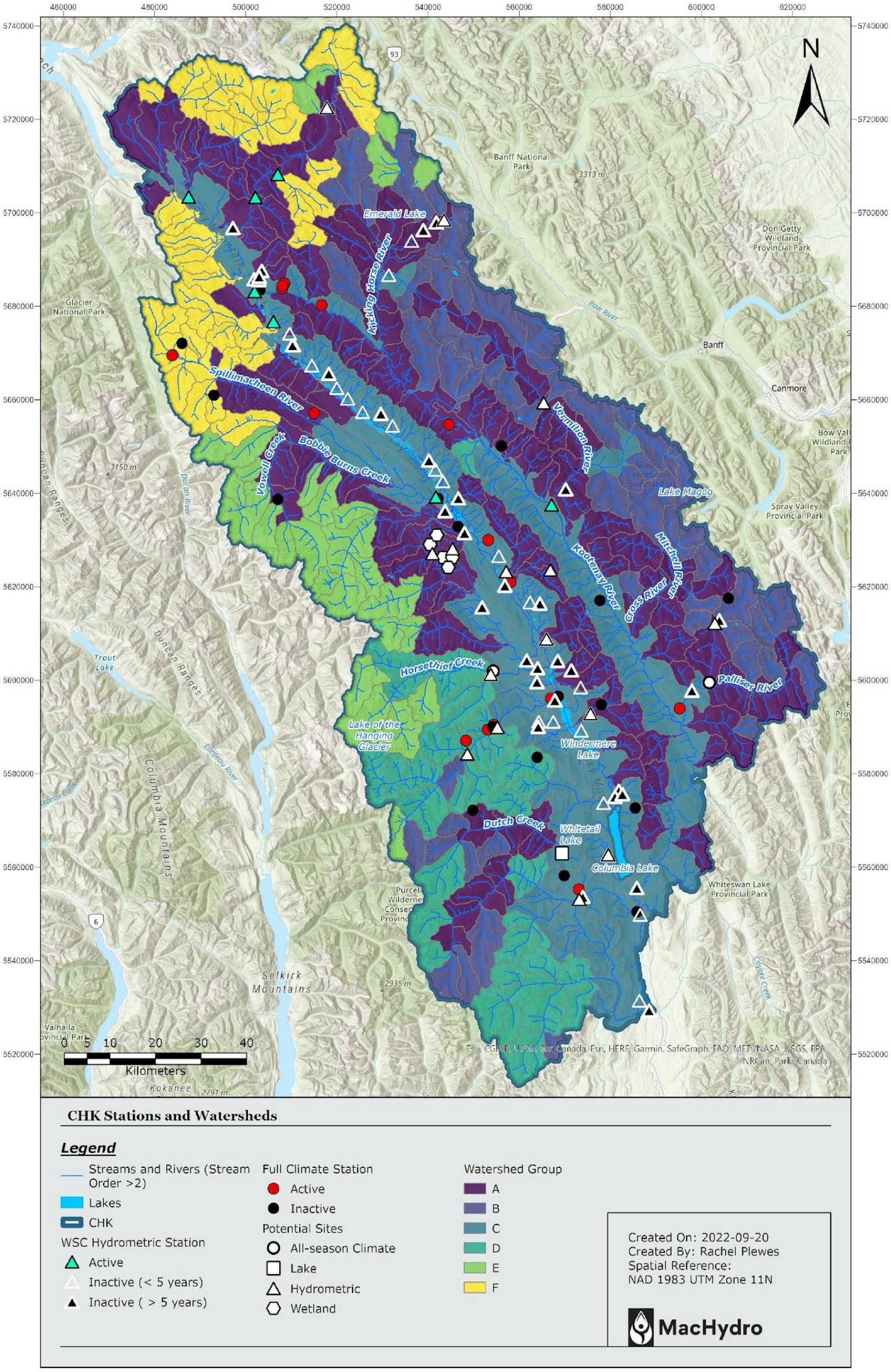

Figure 9. Watershed Groups overlaid with monitoring locations for the Columbia Kootenay Headwaters.

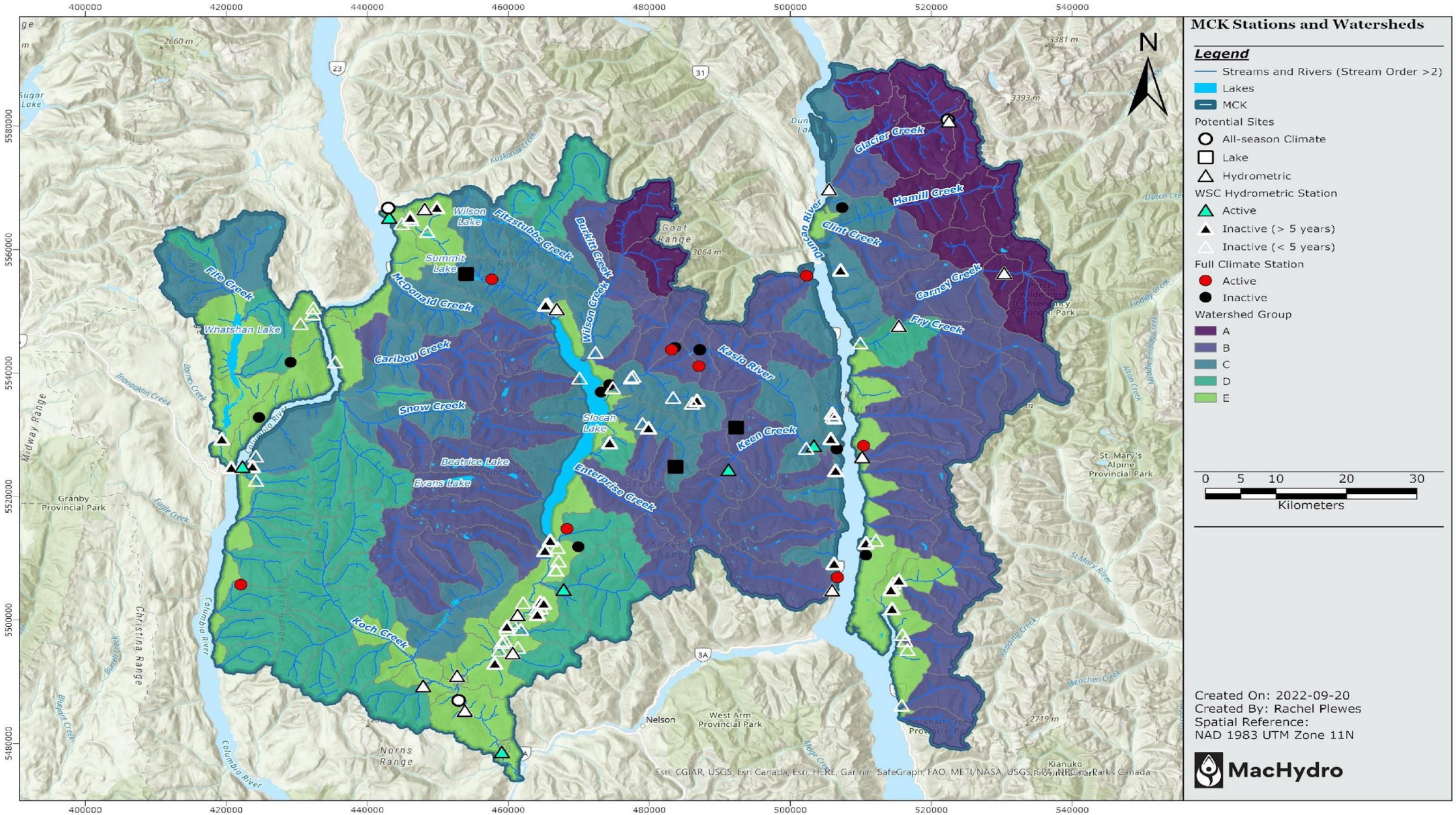

Figure 10. Watershed Groups overlaid with monitoring locations for the Mid-Columbia Kootenay.

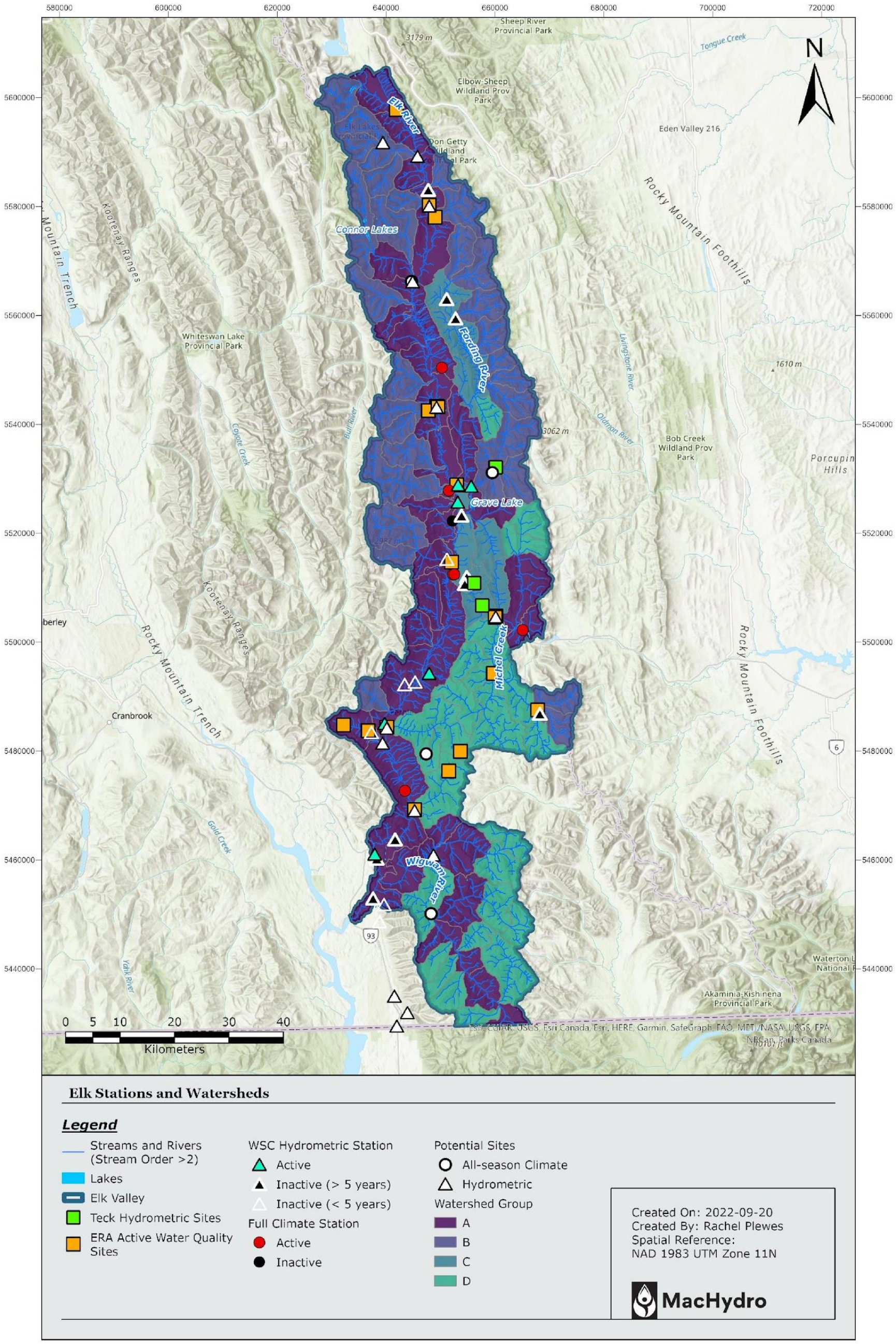

Figure 11. Watershed Groups overlaid with monitoring locations for the Elk River Watershed.

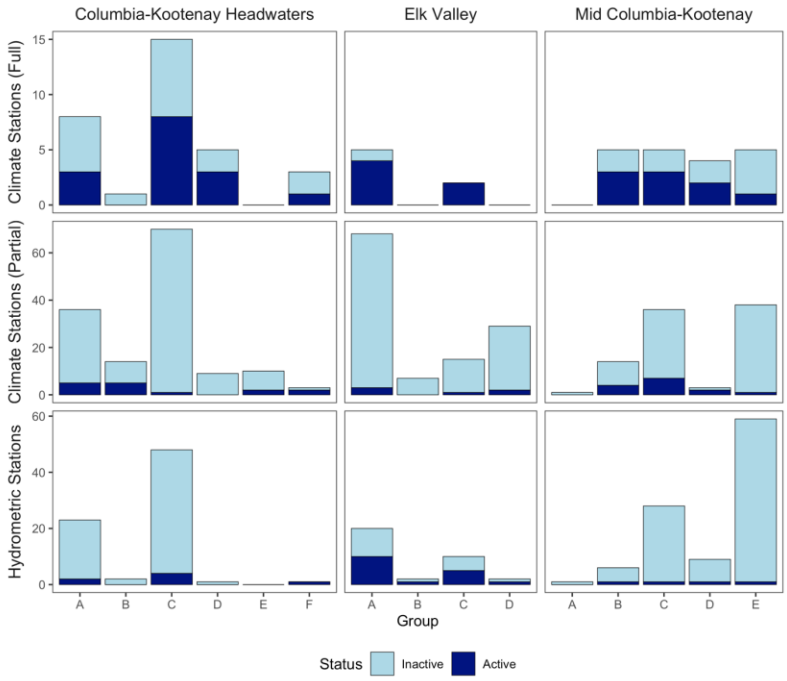

Figure 12. A count of the number of active and inactive monitoring stations within each watershed group and Area of Interest.

4.2 Gap Analysis

The following outlines all criteria used to prioritize site selection for climate and hydrometric monitoring stations:

4.2.1 Hydrometric (Stream Discharge)

- Was there an active climate station near the watershed that would be representative of precipitation, snow depth and air temperature?
- Does the recommended hydrometric network cover a range of watershed scales and elevations? Does it capture smaller watersheds (i.e., less than 100 km^2)?
- Does the recommended site within the representative watershed of each Watershed Group drain a large lake or wetland complex (store runoff) that would not represent discharge in another ungauged watershed?
- Was there a discontinued hydrometric station that could be re-activated?
- Does the proposed site location have road or easy access?

4.2.2 Hydrometric (Lake Level)

- Was there a discontinued water level monitoring station within the lake?
- Was there an active hydrometric station downstream of the lake?
- Are there known concerns with the lake or watershed?

4.2.3 Climate

- Was there a climate station within a representative watershed of each Watershed Group?

- Was there an active climate station near the hydrometric gauges that would be representative of precipitation and air temperature?
- Was there a discontinued climate station with a long-term data record that could be re-activated?
- Does the proposed site location have road access and relatively easy site preparation (i.e., within a forest clearing, relatively flat terrain)?

4.3 Site Selection

Based on the gap analysis, the initial suite of potential monitoring sites is listed in Appendix D for the three Areas of Interest. The Elk River Watershed potential hydrometric station locations align with the Elk River Alliance water quality monitoring site locations. This initial suite of potential monitoring sites for the three Areas of Interest are to be further refined through community feedback.

4.4 Future Site Selection

Carver and Utzig (2021b) provided total costs of network installation and operation based on the following number of recommended station types installed within each Regional Landscape:

- 5 hydrometric stations
- 1 year-round climate station
- 2 snow course stations
- 2 seasonal climate stations
- 4 lake/wetland level stations

Based on the number of Regional Landscapes or partial Regional Landscapes that each Area of Interest incorporates, Table 5 summarizes the number of stations Carver and Utzig (2021b) estimated should be installed, along with the current active stations within each Area of Interest. The Columbia Kootenay Headwaters incorporates four Regional Landscapes. The Mid-Columbia Kootenay Area of Interest consists of one Regional Landscape. The Elk River Watershed Area of Interest consists of three partial Regional Landscapes. Table 5 only shows the active WSC hydrometric stations located within small watersheds (<100 km^2) in each Area of Interest. They recommended that the hydrometric stations be installed on smaller streams (e.g., watersheds less than 100 km^2) because existing WSC stations tend to focus on the larger systems (Figure 13).

Table 5. Recommended number of stations per Area of Interest based on Carver and Utzig (2021b), and current active stations within the Area of Interest shown in brackets.

Station Type	Columbia Kootenay Headwaters	Mid-Columbia Kootenay	Elk
Hydrometric*	20 (1 WSC active)	5 (1 WSC active)	9 (1 WSC active)
Year-Round Climate	4 (15 active)	1 (8 active)	3 (6 active)
Snow Course	8 (13 active)	2 (13 active)	4 (3 active)
Seasonal Climate	8 (2 active)	2 (1 active)	4 (3 active)
Lake/Wetland Level	16 (0 active)	4 (0 active)	6 (0 active)

**WSC hydrometric stations within small watersheds (< 100 km^2).*

Based on the results of this data gap analysis, we recommend that additional hydrometric stations should be installed within small watersheds to develop an understanding of smaller scale hydrologic response. There is one active WSC hydrometric station located within a small watershed in each Area of Interest: Split Creek at the Mouth (08NB016) in CKH Watershed Group F, Keen Creek Below Kyawats Creek (08NH132) in the MCK Watershed Group B, and Hosmer Creek Above Diversions (08NK026) in the Elk River Watershed Group A. We note that there are a couple of hydrometric stations installed in smaller watersheds but above the 100 km^2 threshold: Line Creek (08NK022, 138km^2) in the Elk River Watershed in Watershed Group B and Lemon Creek (08NK160, 181 km^2) in the Mid-Columbia Kootenay Watershed Group D Areas of Interest.

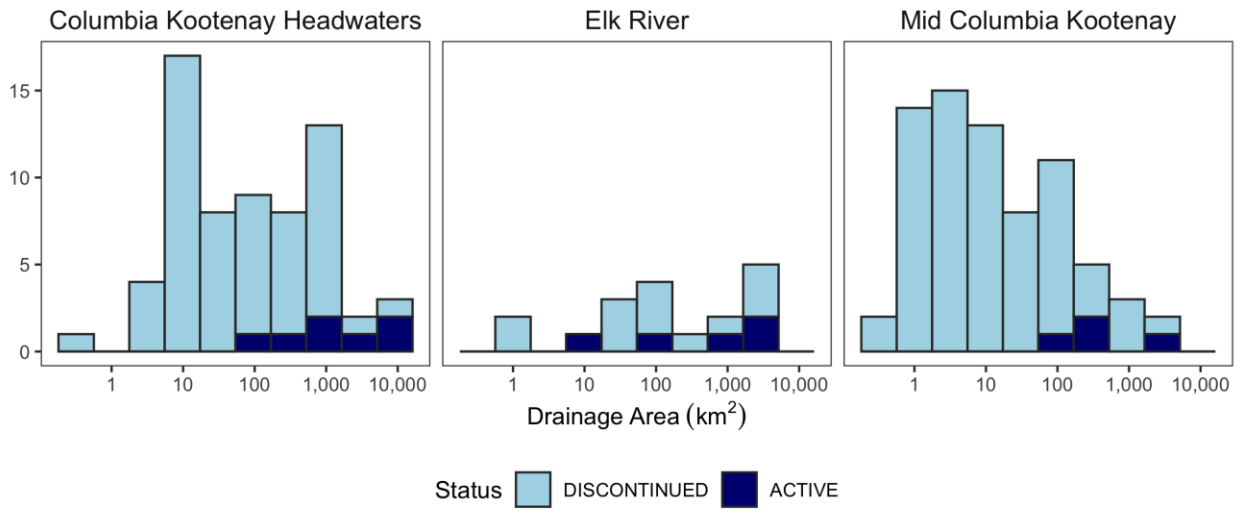

Figure 13. Counts of Water Survey of Canada hydrometric stations in each Area of Interest. Most monitoring on smaller watersheds has been discontinued in this region.

When we compare the active climate stations within each Area of Interest to what Carver and Utzig (2021b) recommended, there is an adequate number of year-round climate stations in all three Areas of Interest, and an adequate number of snow course stations in the Columbia-Kootenay Headwaters and Mid-Columbia Kootenay; the Elk River Watershed would require one additional station. Additional seasonal climate stations could be installed in all three Areas of Interest. All three Areas of Interest have very limited lake and wetland monitoring stations.

The cluster analysis allowed us to further refine the freshwater atlas watersheds, within each Area of Interest and Regional Landscape, into smaller areas (Watershed Groups) that represented unique hydroclimatic characteristics. We were then able to identify specific Watershed Groups with limited hydrometric or climate monitoring station sites. As shown in Figure 12, and Table 5, additional hydrometric stations should be installed in small watersheds. We recommend that each Watershed Group contain at least one hydrometric station, with additional stations being installed in the larger Watershed Groups within each Area of Interest as shown in Table 3. We recommend that each Watershed Group, within each Area of Interest, also have at least one active full climate station at mid to high elevation. One full climate station should be installed within Watershed Groups B and E of the Columbia Kootenay Headwaters, Watershed Group A of the Mid-Columbia Kootenay, and Watershed Groups B and E of the Elk River Watershed.

Finally, we note that the choice of Assessment Watersheds affects the size and distribution of clusters in this study. By design, Assessment Watersheds are approximately the same size, and focus on representing individual tributaries, rather than encompassing mainstems and larger watersheds. As a watershed drainage area increases, it increases in diversity since it is the amalgamation of several watershed "types". For example, the Elk River at Fernie includes glacierized headwaters, high elevation reaches, lowlands, and mid-elevation forests (a combination of all clusters identified in this study). As such, these "hybrid" watersheds are not identified for monitoring within this study, instead the focus is on smaller tributaries to these mainstems that included two Watershed Groups at most.

5 Summary

Given that it is not feasible to monitor all watersheds within the vast Upper Columbia Basin, the intent of this Priority Monitoring Matrix approach was to ensure that the watershed selection process for monitoring is efficient and covers the range of watershed types within the basin. We were able to identify monitoring locations that efficiently capture the range of conditions within each Area of Interest without duplicating efforts of monitoring adjacent or locations with similar hydroclimatic conditions using a cluster analysis that differentiates watersheds based on hydroclimatic characteristics. The recommended potential station locations for each Area of Interest did not consider third-party data sources and should be further refined through the Local Reference Groups and field assessments.

5.1 Recommendations for Potential Site Selection

The following questions may be used to help refine the final station location.

Hydrometric station site:

- What is the watershed size (less than 100 km^2)?
- Is there year-round access (road or trail) to the site?
- Is the equipment suitable to capture high and low flows?
- Can equipment be left in year-round or seasonal station only?
- Are sites able to be enroute to other sites to decrease field access costs?
- Confirm that the potential site links to other monitoring networks.
- Ensure all hydrometric monitoring sites are captured (e.g., local community groups, third party, industry, etc., and not just on WSC stations).
- Confirm how many sites are active in each watershed group.
- If considering a historic site, confirm why the site was abandoned or decommissioned.
- Is the watershed natural or heavily disturbed (try to select a combination of both)?
- Are sensitive aquatic species a concern?
- Are there active water licenses and if so, what type are they? Are there known future water licenses or water needs in the future proposed?
- Is there an opportunity to partner with others to help with the monitoring?
- Private vs crown land and are permits or agreements required?
- Are there future development plans for the area either upstream or downstream of the potential site?
- What are the questions will this data be used to answer?

Climate station site:

- Is there an opportunity to pair climate stations with hydrometric stations?
- Is there year-round access (road or trail) to the site?
- Is the equipment suitable to capture the parameters of interest (e.g., in high snow accumulation areas, etc.)?
- Are there opportunities to partner with others to help with the monitoring?
- What are the questions will this data be used to answer?

6 Closing

MacHydro (hereafter Project Team) prepared this document for the account of Living Lakes Canada. The material in it reflects the judgment of the Project Team considering the information available to the Project Team at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. The Project Team accepts no responsibility for damages, if any, suffered by any third party because of decisions made or actions based on this document.

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We trust the above satisfies your requirements. Please contact us should you have any questions or comments.

Sincerely,

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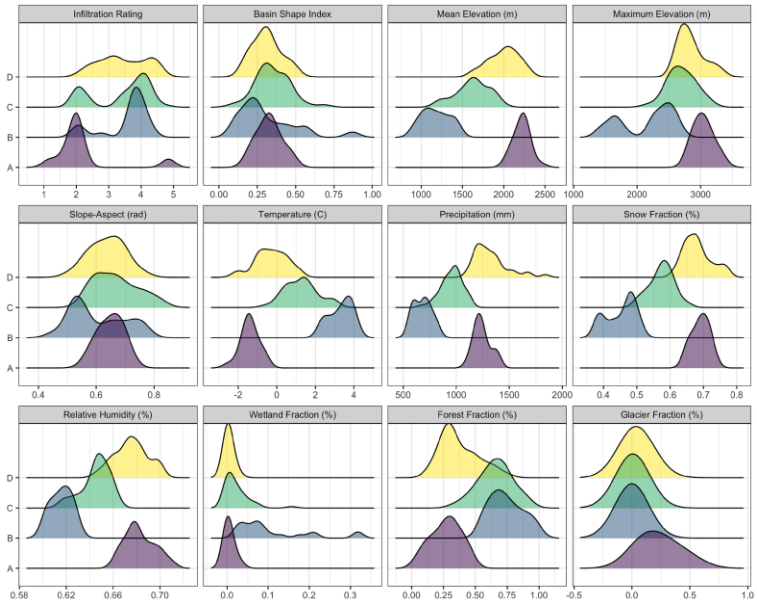
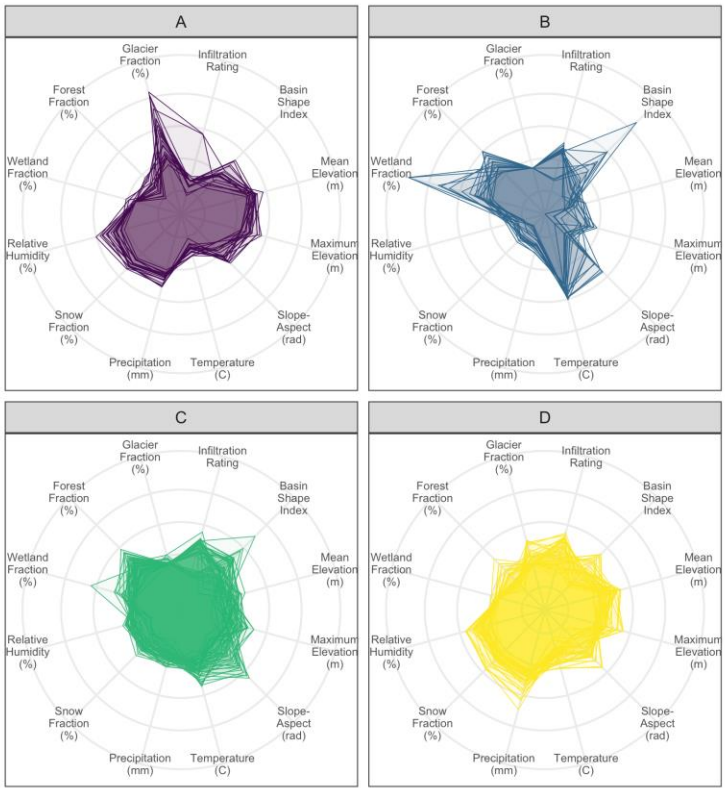
8 Appendices

8.1 Appendix A: Cluster Analysis Outputs for each Area of Interest



a. *Density Analysis*



b. Radar Analysis

Figure A1. Columbia-Kootenay Headwaters northwest cluster analysis outputs. C. Cluster map. A – High elevation, cool, wet. B. Low elevation, warm, dry. C. middle elevation, warmer, drier. D. High elevation, cooler, wetter.

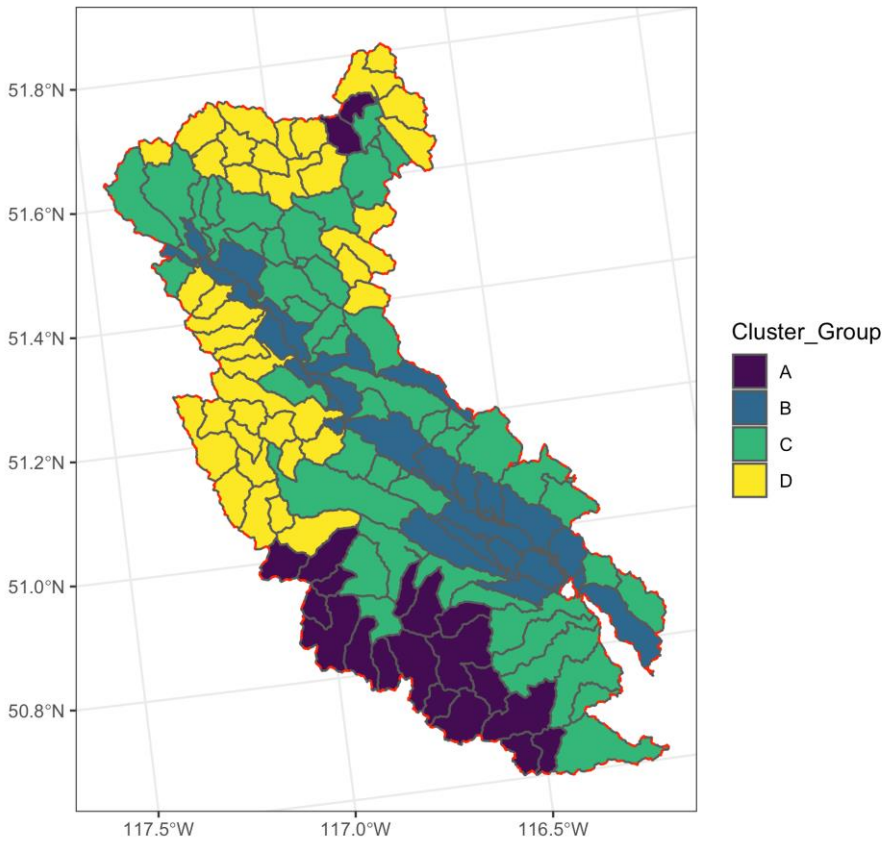
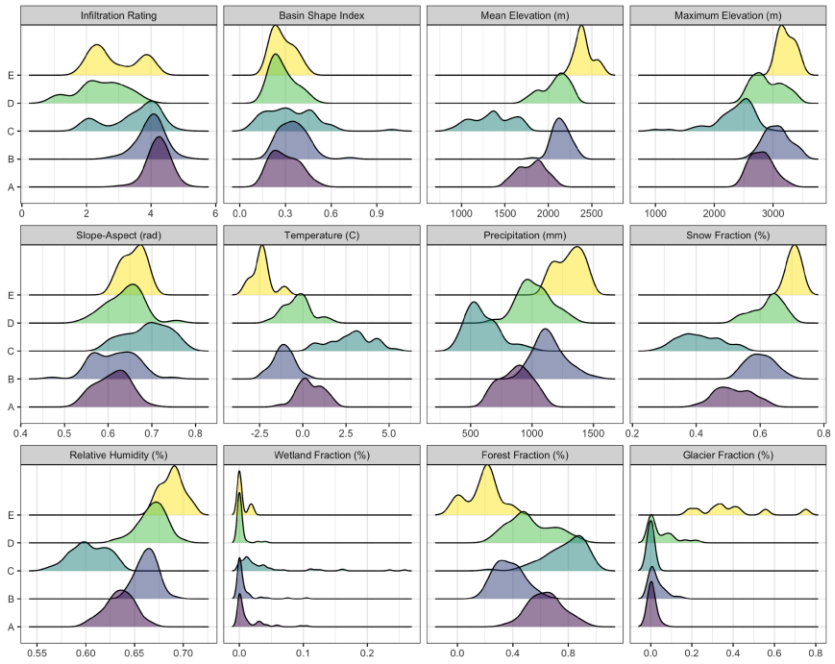
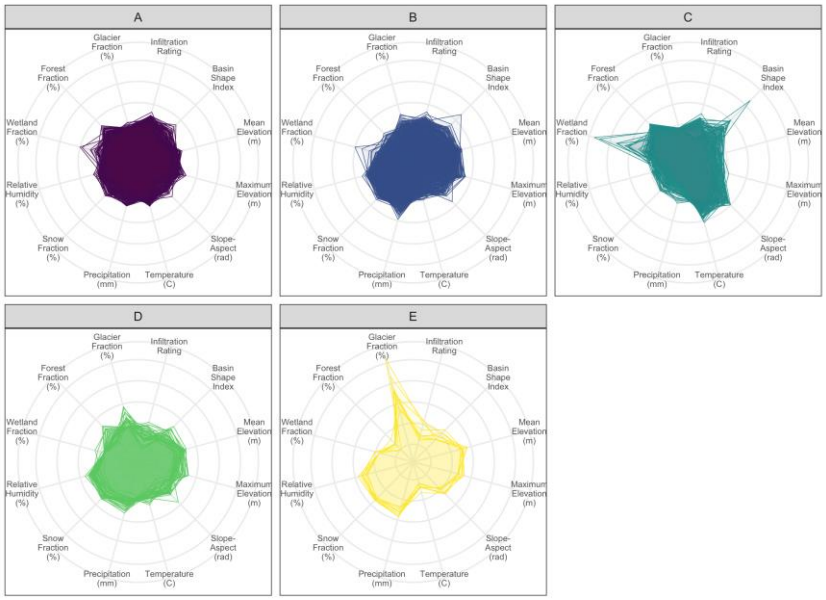


Figure A2. Columbia-Kootenay Headwaters northwest region cluster analysis output.



a. Density Analysis



b. Radar Analysis

Figure A3. Columbia-Kootenay Headwaters southeast cluster analysis outputs. Watershed groups defined as: A – Middle elevation. B – mid to high elevation, cooler, wetter. C – lower elevation, warmer, drier. D – mid to high elevation, drier. E – high elevation, wet.

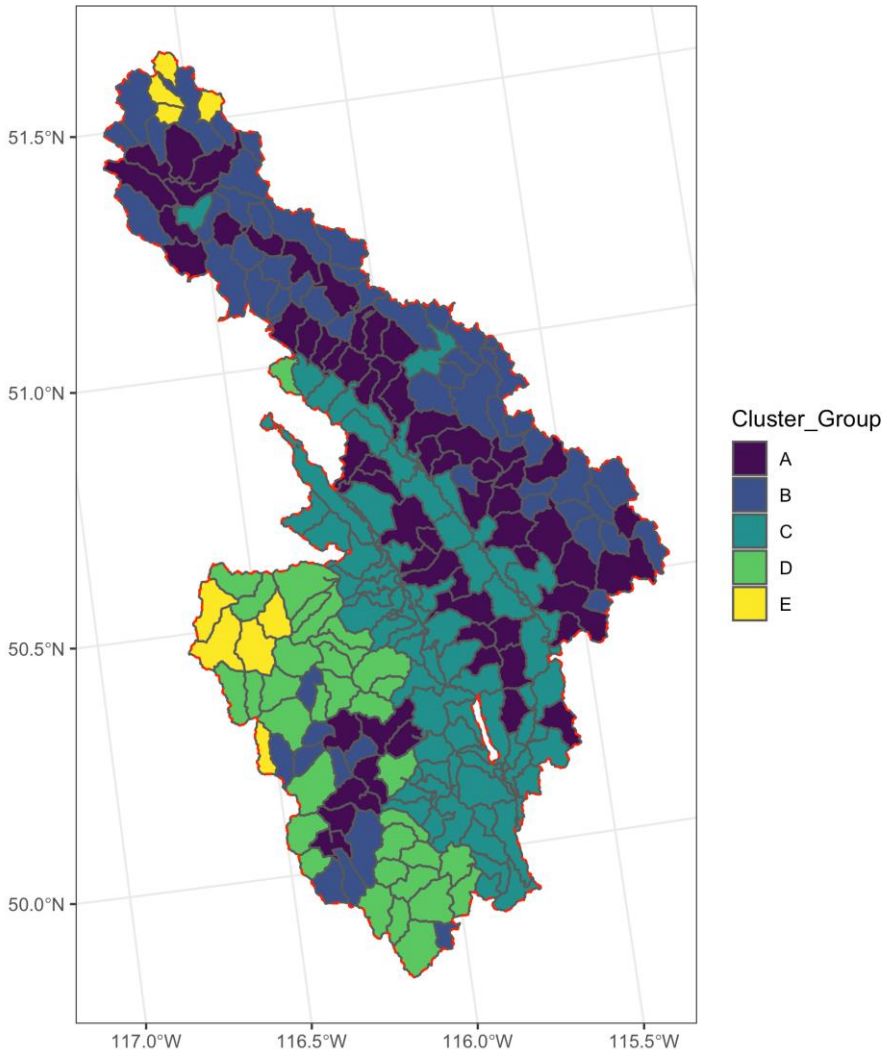
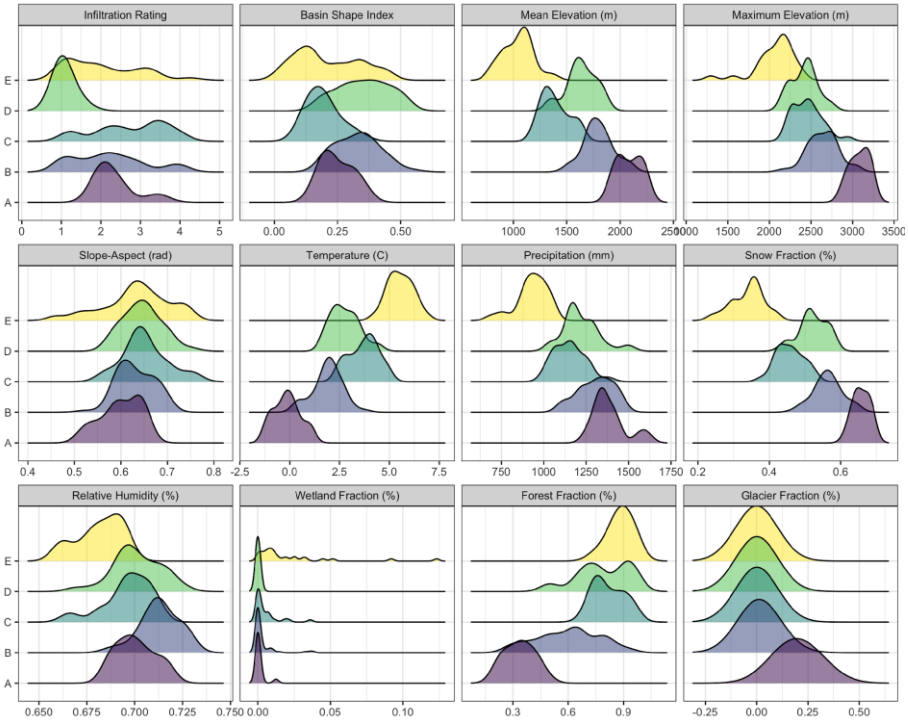
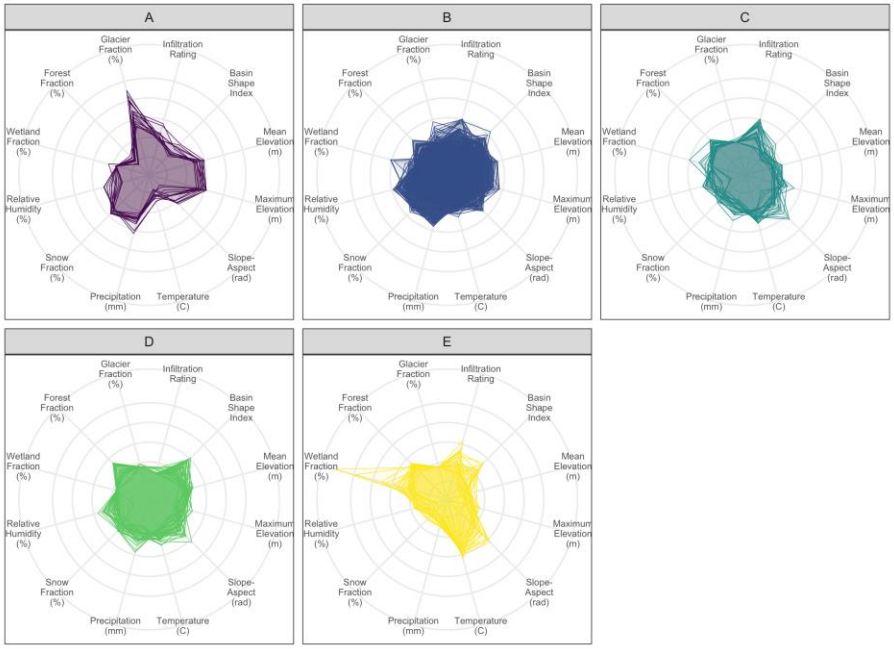


Figure A4. Columbia-Kootenay Headwaters southeast region cluster analysis output.

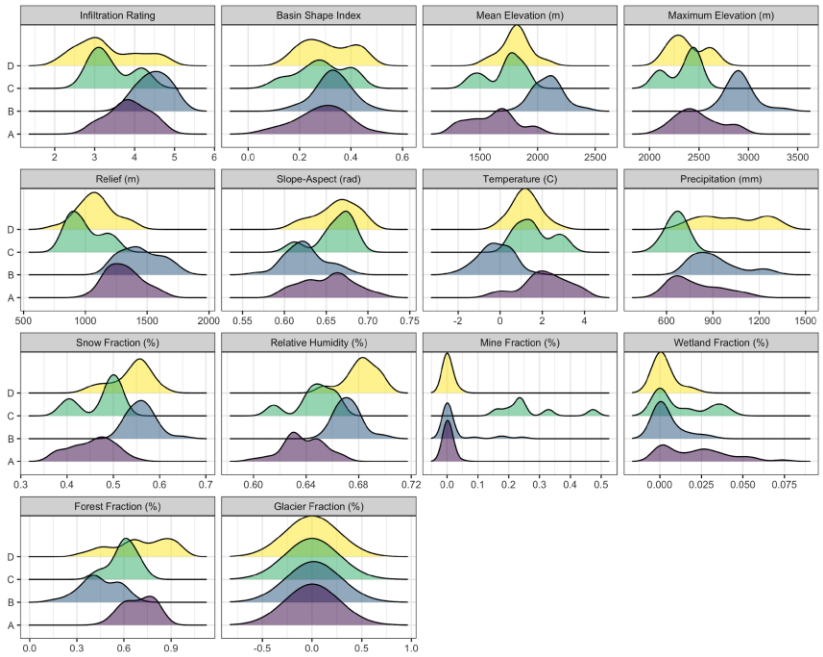


a. *Density Analysis*

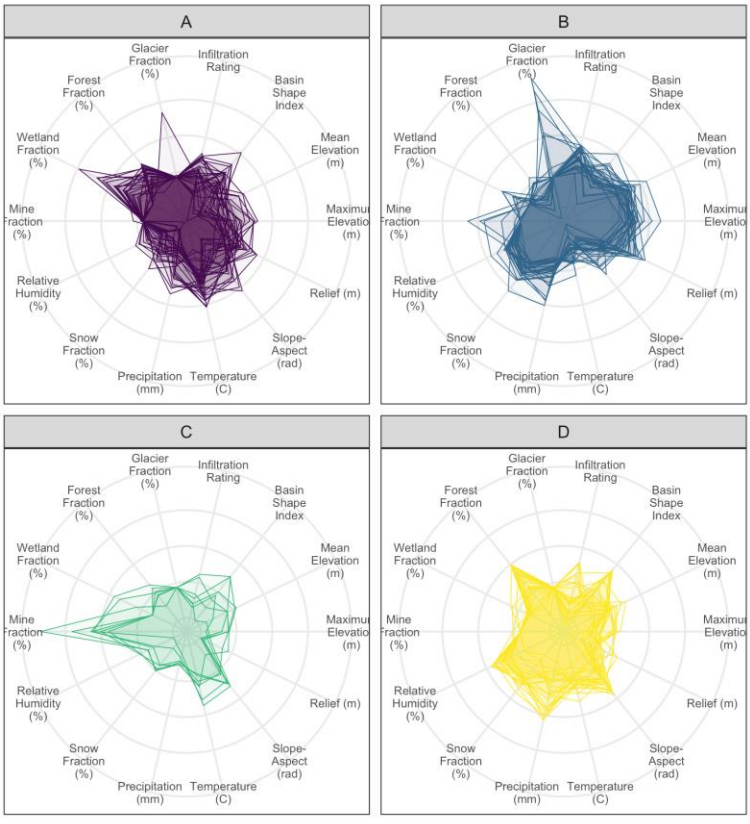


b. *Radar Analysis*

Figure A5. Mid-Columbia-Kootenay cluster analysis outputs. Watershed Groups: A – Glaciers; B – High elevation, cooler, wetter; C – Middle elevation, warmer, drier; D – High elevation, warmer, drier; E – Lower elevation, warmer, drier.



a. *Density Analysis*



b. *Radar Analysis*

Figure A6. Elk River Watershed Cluster Outputs. Watershed Groups: A – Low elevation, warmer drier; B – High elevation, cooler, wetter; C – Middle elevation, drier; D – Middle elevation, wetter.

8.2 Appendix B: Spatial Data Compiled and Created

Table B1. List of compiled spatial data in database.

Layer Name	Category	Credits	Report	Access	Coverage
BEC_Map	Climate	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Forest Analysis and Inventory		Public	Full
Temperature Sites	Climate	MacDonald Hydrology Consultants Ltd.		Public	Full
Precipitation Sites	Climate	MacDonald Hydrology Consultants Ltd.		Public	Full
Snow Sites	Climate	MacDonald Hydrology Consultants Ltd.		Public	Full
Hydrometric_Stations_Summary	Other			Public	Full
Freshwater_Atlas_Watershed_Groups	Other			Public	Full
BC_Parks_Ecological_Reserves_and_Protected_Areas	Other	Ministry of Environment and Climate Change Strategy, BC Parks - Provincial Services		Public	Full
BC_Major_Cities_Points_1_2000000__Digital_Baseline_Mapping	Other	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Digital_Road_Atlas_DRA___Master_Partially_Attributed_Roads	Other	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Lakes	Surface	DataBC. Published by the Ministry of Forests, Lands and Natural Resource Operations - GeoBC.	Watersheds Risk Analysis (2019)	Internal CVRD	Partial
Wetlands	Surface	DataBC. Published by the Ministry of Forests, Lands and Natural Resource Operations - GeoBC.	Watersheds Risk Analysis (2019)	Internal CVRD	Partial
Streams	Surface	DataBC. Published by the Ministry of Forests, Lands and Natural Resource Operations - GeoBC.	Watersheds Risk Analysis (2019)	Internal CVRD	Partial
Freshwater_Atlas_Assessment_Watersheds	Surface	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Freshwater_Atlas_Watershed_Groups	Surface	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Freshwater_Atlas_Wetlands	Surface	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Freshwater_Atlas_Stream_Network	Surface	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Freshwater_Atlas_Rivers	Surface	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full
Freshwater_Atlas_Lakes	Surface	Ministry of Forests, Lands, Natural Resource Operations and Rural Development, GeoBC		Public	Full

8.3 Appendix C: Data Source Licensing Information

Table C1. Sources, description, and licensing information for networks used in hydrometric and climate data compilation.

Network	Description	Link
Agricultural and Rural Development Act Network	Data from Agricultural and Rural Development Act Network has been acquired from Pacific Climate Impacts Consortium (http://www.pacificclimate.org/data/bc-station-data). PCIC's terms of use are: https://pacificclimate.org/terms-of-use. This data is a copy of an official work that is published by the Government of Canada and the reproduction has not been produced in affiliation with or with the endorsement of the Government of Canada. For more information on the terms and conditions of the data please see: http://www.ec.gc.ca/default.asp?lang=En&n=12345678-1&xsl=mainhomeitem&xml=5830C36B-1773-4E3E-AF8C-B21F54633E0A.	http://www.ec.gc.ca/default.asp?lang=En&n=12345678-1&xsl=mainhomeitem&xml=5830C36B-1773-4E3E-AF8C-B21F54633E0A
BC Hydro	Data from BC Hydro has been acquired from Pacific Climate Impacts Consortium (http://www.pacificclimate.org/data/bc-station-data).	https://www2.gov.bc.ca/gov/content/data/open-data/open-government-licence-bc
British Columbia Ministry of Environment - Automated Snow Pillow Network	Data from Automated Snow Pillow Network has been acquired from Ministry of Environment and Climate Change Strategy and DataBC.	https://www2.gov.bc.ca/gov/content/data/open-data/open-government-licence-bc
British Columbia Ministry of Environment - Manual Snow Survey	Data from BC Ministry of Environment Manual Snow Survey has been acquired from Ministry of Environment and Climate Change Strategy and DataBC.	https://www2.gov.bc.ca/gov/content/data/open-data/open-government-licence-bc
British Columbia Ministry of Environment - Real-time Water Data Reporting	Data from BC ENV - Real-time Water Data Reporting has been acquired from Ministry of Environment and Climate Change Strategy and DataBC (https://www.env.gov.bc.ca/wsd/data_searches/water/).	https://www2.gov.bc.ca/gov/content/data/open-data/open-government-licence-bc

Network	Description	Link
British Columbia Ministry of Environment – Water Rights Databases	Warranty Disclaimer This information is provided as a public service by the Government of British Columbia, Box 9411, Victoria, British Columbia, Canada V8W 9V1. This website and all of the information it contains are provided "as is" without warranty of any kind, whether express or implied. All implied warranties, including, without limitation, implied warranties of merchantability, fitness for a particular purpose, and non-infringement, are hereby expressly disclaimed. Links and references to any other websites are provided for information only and listing shall not be taken as endorsement of any kind. The Government of British Columbia is not responsible for the content or reliability of the linked websites and does not endorse the content, products, services or views expressed within them. Limitation of Liabilities Under no circumstances will the Government of British Columbia be liable to any person or business entity for any direct, indirect, special, incidental, consequential, or other damages based on any use of this website or any other website to which this site is linked, including, without limitation, any lost profits, business interruption, or loss of programs or information, even if the Government of British Columbia has been specifically advised of the possibility of such damages.	https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-licences-approvals/water-rights-databases
BC FLNRORD - Wild Fire Management Branch	Data from BC Ministry of Forests, Lands and Natural Resource Operations - Wild Fire Managment Branch has been acquired from Pacific Climate Impacts Consortium (http://www.pacificclimate.org/data/bc-station-data). PCIC's terms of use are: https://pacificclimate.org/terms-of-use.	https://www2.gov.bc.ca/gov/content/home/copyright
BC MoTI	Data from BC Ministry of Transportation has been acquired from Ministry of Transportation and Infrastructure and Pacific Climate Impacts Consortium (http://www.pacificclimate.org/data/bc-station-data). PCIC's terms of use are: https://pacificclimate.org/terms-of-use.	https://www2.gov.bc.ca/gov/content/home/copyright
Environment Canada	Data from Environment Canada has been acquired from The Meteorological Service of Canada and Pacific Climate Impacts Consortium (http://www.pacificclimate.org/data/bc-station-data). PCIC's terms of use are: https://pacificclimate.org/terms-of-use. This data is a copy of an official work that is published by the Government of Canada and the reproduction has not been produced in affiliation with or with the endorsement of the Government of Canada. For more information on the terms and conditions of the data please see: http://www.ec.gc.ca/default.asp?lang=En&n=12345678-1&xsl=mainhomeitem&xml=5830C36B-1773-4E3E-AF8C-B21F54633E0A and http://weather.gc.ca/mainmenu/disclaimer_e.html.	http://www.ec.gc.ca/default.asp?lang=En&n=12345678-1&xsl=mainhomeitem&xml=5830C36B-1773-4E3E-AF8C-B21F54633E0A
Water Survey of Canada	Data from Water Survey of Canada has been acquired from Environment Canada (https://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=9018B5EC-1). This data is a copy of an official work that is published by the Government of Canada and the reproduction has not been produced in affiliation with or with the endorsement of the Government of Canada. For more information on the terms and conditions of the data please see: http://www.ec.gc.ca/default.asp?lang=En&n=12345678-1&xsl=mainhomeitem&xml=5830C36B-1773-4E3E-AF8C-B21F54633E0A.	http://wateroffice.ec.gc.ca/disclaimer_info_e.html

8.4 Appendix D: Suite of Potential Monitoring Locations

8.4.1 Columbia Kootenay-Headwaters Area of Interest (East Kootenay)

Table D1. Suite of potential lake, mid-elevation wetland and hydrometric monitoring station options defined by the gap analysis for Columbia-Kootenay Headwaters.

Historical Station ID	Type	Location	Watershed Group	Status	Record Length	Nearby active climate station	Drainage Area (km^2)	Rationale
	Lake	Whitetail Lake	C	New	NA	FLNRO-WMB Emily Creek	NA	Water quality measured by East Kootenay Invasive Species Society, potential Watershed Type C, flows into Deer Creek
E242738	Mid-elevation Wetland	Cartright Lake	A	Inactive	NA	ECCC Brisco (8 km away)	NA	Two water quality samples in 2000, flows into Dunbar Creek
	Mid-elevation Wetland	Topaz Lake	A	New	NA	ECCC Brisco (8 km away)	NA	Flows into Dunbar Creek
	Mid-elevation Wetland	Big Fish (Dunbar) Lake	A	New	NA	ECCC Brisco (8 km away)	NA	Flows into Dunbar Creek
	Mid-elevation Wetland	Twin (Fish) Lakes	A	New	NA	ECCC Brisco (8 km away)	NA	Flows into Dunbar Creek
	Mid-elevation Wetland	Halfway Lake	A	New	NA	ECCC Brisco (8 km away)	NA	Flows into Dunbar Creek
08NA021	Hydrometric	Luxor Creek near Brisco	A	Inactive	4 (pre-1970)	MoTIe Vermillion Pit	87	Beside Kindersley
08NA022	Hydrometric	Kindersley Creek near Brisco	A	Inactive	4 (pre-1970)	MoTIe Vermillion Pit at bottom of watershed	42	Heavy pest infestation, newer harvest, proposed harvest, odder basin shape - long SE to NW orientation
	Hydrometric	Dunbar Creek near Brisco	A (like a C, but on bench)	New	NA	ECCC Brisco (8 km away, bottom valley)	61	Measure at elevation break, below mid-elevation wetlands, flows into Templeton River (old WSC gauge, limited data), lots of harvest (most 20 years old)

Historical Station ID	Type	Location	Watershed Group	Status	Record Length	Nearby active climate station	Drainage Area (km^2)	Rationale
	Hydrometric	Dunbar Creek at Leadqueen Francis Rd	Like E (grouped as A)	New	NA	ECCC Brisco (15 km away)	26	Glaciers in headwaters, above mid-elevation wetlands, understand contribution of wetlands and small tributaries
08NA024	Hydrometric	Windermere Creek near Windermere	A	Inactive	41	FLNRO-WMB Toby Creek (low elevation, 9 km away); FLNRO-WMB Palliser (8 km away)	84	Some harvest, lots of MPB
08NA018	Hydrometric	Sinclair Creek at Radium Hot Springs	A	Inactive	31	EC Kootenay NP West Gate in watershed (low elevation)	94	Lots of MPB, no newer harvest (>20 years old)
08NF005	Hydrometric	Albert River at 1310 Contour	B	Inactive	28	None	70	Little MPB, some harvest (>20 years old)
	Hydrometric	Floe Lake	B	New	NA	BC Hydro Flow Lake in watershed	25	Drains flow lake, glacier, access off the 93, no mapped MPB or harvest, National Park
	Hydrometric	Deer Creek	C	New	NA	FLNRO-WMB Emily Creek	68	Drains into Findlay Creek, and drains a larger mid-elevation lake (1110 masl) Whitetail Lake, near Canal Flats, newer harvest blocks (>20 years old), some heavy MPB
08NA062	Hydrometric	Marion Creek near Canal Flats	C	Inactive	4 (pre-1970)	FLNRO-WMB Emily Creek (10 km away)	93	Some harvest, some MPB, drains into Columbia Lake
	Hydrometric	Delphine Creek	D	New	NA	MoTI Little Dragon, others nearby	66	Drains into Toby Creek, upstream of panorama
	Hydrometric	Taynton Creek	D	New	NA	MoTI Panorama, other nearby	80	Drains into Toby Creek, At Panorama. Little MPB relative to others, no new harvest. Lots of water use,
08NA060	Hydrometric	Bruce Creek near Wilmer	D	Inactive	11	None	81	Old ECCC Wilmur climate station from early 1900s, MPB only in lower, some harvest
08NB015	Hydrometric	Blaeberry River below Ensign Creek	Like E (grouped as A)	Inactive	23	BC Hydro Wildcat	230	Look at multiple scales of flow, drains headwaters of Blaeberry, old hydrometric in an A, but drains E and F

Table 5. Suite of potential all season climate monitoring station options defined by the gap analysis for Columbia-Kootenay Headwaters.

Historical Station ID	Location	Watershed Group	Status	Record Length	Rationale
	Albert River up Forest Service Road	B	New	NA	Old FLNRO-WMB ZZCross in watershed, but only collected 1 year of data and lat/long shows up in windswept region Representative climate station for Albert River if installed
1148957	ECCC Wilmur	D	Inactive	2 (early 1900s)	Representative climate station for Bruce Creek if installed

8.4.2 Mid-Columbia-Kootenay Area of Interest (West Kootenay)

Table D2. Suite of potential lake and hydrometric monitoring station options defined by the gap analysis for Mid-Columbia Kootenay.

Historical Station ID	Type	Location	Watershed Group	Status	Record Length (years)	Nearby active climate station	Drainage Area (km^2)	Rationale
	Lake	Summit Lake	C	New	NA	ECCC Nakusp 20 km away		Upstream of Slocan Lake via Bonanza Creek, MoTIe Summit Lake climate station, central Kootenay invasive species monitoring water quality, is there lake level?
	Lake	Fishermaiden Lake	C	New	NA	None		Drains into Silverton Creek, Creek monitored by Slocan Streamkeepers?
	Lake	Flint Lakes	B	New	NA	None		Headwaters of Carlyle Creek, monitored by KWS, high-elevation lake
08NH131	Hydrometric	Carney Creek below Pambrun Creek	A	Inactive	32	None	119	Watershed Group A, not sure if road access, site decommissioned 2004
08NH130	Hydrometric	Fry Creek below Carney Creek	D (drains B, A)	Inactive	47	KWS Kootenay Joe	585	Scale Watershed Group, but drains an old fire
	Hydrometric	Glacier Creek	A	New		None	70	Watershed Group A, some fire, on FSR Glacier Creek Road at bridge
08NH003	Hydrometric	Glacier Creek near Howser	B (drains A)	Inactive	31	None	282	Scale Watershed Group

Historical Station ID	Type	Location	Watershed Group	Status	Record Length (years)	Nearby active climate station	Drainage Area (km^2)	Rationale
08NH101	Hydrometric	Coffee Creek near Ainsworth	B	Inactive	45	Redfish Snow Pillow (top), MoTIe Coffee Creek (bottom)	87.3	Only creek not monitored off Kokanee Glacier (currently monitored for mass balance via LiDAR with UNBC)
	Hydrometric	Gray Creek near Crawford Bay	B	New	NA	Two Gray Creek Snow Pillows, Reactive ECCC Kootenay Bay (26 years) 7 km away, Reactivate ECCC Crawford bay (62 years) 7 km away	42	Two snow pillows in headwaters, no glacier, some newer harvest 2005/2006, some MPB
	Hydrometric	Powder Creek across Kaslo	C	New	NA	FLNRO-WMB Powder Creek (20 years)	50	Some 2008 harvest, some MPB, small lake in headwater, not developed
08NJ120	Hydrometric	Winlaw Creek near Winlaw	D	Inactive	36	None, FLNRO-WMB Slocan (30 years) 21 km away. Could reactivate MoTIm Winlaw (15 years)	41	Watershed Group D, long survey record, but heavily affected by MPB (doesn't look salvage harvested)
08NJ042	Hydrometric	Airy Creek near Passmore	D	Inactive	2	None, Reactivat ECCC Passmore (17 years)	58	Watershed Group D, old Slocan Streamkeepers site, some harvest
	Hydrometric	Springer Creek near Slocan	D	New	NA	FLNRO-WMB Slocan	50	Watershed Group D, climate station in lower watershed, MPB, some new harvest, some fire from 2007
08NJ126	Hydrometric	McFayden Creek near Vallican	E	Inactive	50	None, Reactivate ECCC Passmore (17 years)	6	Watershed Group E, old Slocan Streamkeepers site, 2020 wildfire ~50%,
08NJ152	Hydrometric	Wolverton Creek at Slocan Park	E	Inactive	6	None, Reactivate ECCC Passmore (17 years)	15	Watershed Group E, measured by Wolverton Creek Monitoring 2006-2020, moderate MPB
08NJ016	Hydrometric	Jerome Creek near Appledale	E	Inactive	56	None. Could use FLNRO-WMB Slocan (30 years), 16 km away	3	Watershed Group E, forests disturbed by harvest or moderate heavy MPB, measure upstream of old cutblocks
08NE021	Hydrometric	Brouse Creek above Diversions	E	Inactive	63	None, Reactivate ECCC Nakusp (88 years), MoTIe Summit Lake is 16 km away, but higher elevation (in C)	1	Watershed Group E, very small drainage area 1 km2, moderate -heavy MPB headwaters, strip cutting
08NJ117	Hydrometric	Arthur Creek near Rosebery	E	Inactive	11	ECCC New Denver (97 years) is 14 km away	3	Watershed Group E, light to moderate MPB, ~4 km2

Table D3. Suite of potential all season climate monitoring station options defined by the gap analysis for Mid-Columbia Kootenay.

Historical Station ID	Location	Watershed Group	Status	Record Length (years)	Rationale
	Glacier Creek	A	New	NA	If install hydrometric for Watershed Group A
EC1145300	Nakusp	D	Inactive	88	Warmer relative to other areas, representative climate station for proposed hydrometric sites
EC114Q3C9	Passmore	D	Inactive	17	Warmer relative to other areas, representative climate station for proposed hydrometric sites

8.4.3 Elk River Valley Area of Interest

Table D4. Suite of potential hydrometric monitoring stations. Stations are based on the current (2022) Elk River Alliance water quality monitoring locations, gap analysis, and discussions with the Elk River Valley alliance. Lizard Creek and Forsyth Creek were already chosen as sites to be installed in 2022.

Historical Station ID	Location	Watershed Group	Status	Drainage Area (km^2)	Nearby active climate station
	Boivin Creek mouth	B	New	38	FLNRO WMB Round Prairie 9 km away, Reactivate ECCC Elkford
08NK004	Lizard Creek mouth	A	Inactive	45	ECCC Sparwood 2 km away
	Cadorna Creek mouth	B	New	68	None
	Cadorna Creek upstream of Abruzzi Creek	B	New	26	None
	Bleasdell Creek mouth	B	New	22	None
	Morrissey Creek mouth	D	New	83	MoTIe Morrisey 3 km away

Historical Station ID	Location	Watershed Group	Status	Drainage Area (km^2)	Nearby active climate station
	Coal Creek mouth	D	New	96	ECCC Sparwood 1 km away
	Forsyth Creek Mouth	A	New	113	None
	Alexander Creek mouth	A+D	New	152	MoTIe Crowsnest 2 km away

Table D5. Suite of potential all season climate monitoring station options defined by the gap analysis for Elk River Valley.

Historical Station ID	Location	Watershed Group	Status	Record Length (years)	Rationale
2C09Q (ECCC)	Coal Creek watershed - Morrissey Ridge	C	Inactive	41	Aligns with a hydrometric station in either Coal Creek or Morrissey Creek. Confirm the Morrissey Ridge station is no longer active.
115547 (ARDA)	Line Creek	B	Inactive	3	Line Creek has an active WSC hydrometric station
	Forsyth Creek watershed	A + B	New	0	ERA installed a hydrometric station in 2022 at the mouth of Forsyth Creek. Either install in Forsyth Creek or Quarrie Creek watersheds.