Environment and Climate Change Canada

Canada Nature Fund: Community-Nominated Priority Places for Species at Risk

Kootenay Connect: 4CW Columbia Wetlands:

Restoration of habitats and Species at Risk in Columbia Valley

March 31, 2023. Final Report: Year 4

Columbia Wetlands: hydrology, beaver and climate change

KOOTENAY CONNECT

The Columbia Wetlands Stewardship Partners

Columbia Basin trust

Environment and Climate Change Canada / Environnement et Changement climatique Canada

Project authors

Ryan MacDonald, Catriona Leven, Suzanne Bayley, Beth Millions, Rebecca Rooney, Amy Goodbrand and Camille Des Rosiers-Ste.Marie; with contributions from MacHydro and Columbia Wetlands Stewardship Partners

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Executive Summary

This project combines hydrological and ecological assessments to better understand the Columbia Wetland Complex and the individual wetlands within it. It includes a hydrological classification of the different wetland types observed within the Columbia Wetlands and the ecological consequences of their differences. We assessed the vulnerability of the wetlands to climate change and the potential for beaver dam analogues (BDAs) to be used as a low-tech and relatively natural restoration technique. We restored (and repaired) one 54 ha wetland with several beaver dams and gathered the data and support needed to acquire a permit in another 22 ha wetland. We provided The Nature Trust of BC and ECCC, who own and manage a parcel of the Columbia National Wildlife Management Area, with the data and guidance to install and repair beaver dams in site 71 to raise the water levels for spring migrating birds. ECCC (or their contractor) has submitted an application for the restoration and the dams will be built/restored in May 2023, if the permit is approved.

An analysis of the hydrology of the study wetlands was conducted using hydrological and geomorphic variables collected from 35 different wetlands throughout the Columbia Valley, resulting in classification of the wetlands into one of five groups (A, B, C, D, or E). These groups were further characterized based on their connectivity to the channel network using a framework of first-order controls and wetland variables. These classifications include wetlands that are continuous, discontinuous, no connectivity, and fully connected.

Wetlands with continuous connectivity include wetlands in group A which are hydrologically connected with the Columbia River channel network. Wetlands with discontinuous connectivity appear to be

dependent on the elevation of either a gap in the levee or the levee itself being flooded in peak flows to recharge the wetland; wetlands with group B and C hydrographs are in this group. Wetlands with no connectivity are not directly connected to the channel network via gaps in the levee and are likely to respond to unchannelized surface inflow as a result of over-levee flooding as the river stage rises; these wetlands include those in groups D and E. Unconfined wetlands are wetlands where levees are missing in large areas and where the river continuously flows through the wetland; none of the 35 studied wetlands are in this category as these wetlands are more difficult to delineate from the river. Wetlands connected to the main Columbia River make up the greatest percentage of the Columbia Wetlands complex, with 50% or 10,200 ha of the wetlands being highly connected to the main river. 25% of the wetlands are unconfined wetlands with almost no levees, where the river flows through freely. Thus 75% of the 20,000 ha wetlands flood fully with the floodpulse in June. Partially connected wetlands comprise 13% of the wetland complex while isolated wetlands make up 12%; in total, that means that only a quarter of the Columbia Wetland Complex retains water over the winter and in the early spring.

Water balance calculations were completed for each of the wetland types from 2020 to 2022. The 2022 water balances were updated using bathymetric data collected using drone-based RTK survey measurements and wetland depth measurements collected in 2022. The conceptual understanding of wetland water balance was consistent between years. Continuously connected wetlands had the lowest precipitation to evaporation ratios, indicating these wetland types are likely less sensitive to atmospheric conditions. Discontinuously and non connected wetlands had higher precipitation to evaporation ratios, suggesting these wetland types are more influenced by atmospheric conditions (higher relative evaporation).

A physically based, semi-distributed hydrological model was developed for the upper Columbia River Basin to evaluate potential hydrometeorological conditions and wetland water balance responses to climate change. Historical normal annual air temperature reported at the ECCC climate station near Radium is 5.8°C and the annual precipitation is 441 mm. Climate change scenarios project average annual air temperature increases for the study area by 1.4 to 1.7°C by 2050 and 2.4 to 3.6°C by 2080 while precipitation is projected to slightly increase by 27 to 35 mm by 2050 and 53 to 70 mm by 2080 with a shift in the timing (and amount) and phase of precipitation, where the fraction of annual precipitation that falls as snow will be reduced by 4 to 6% by 2050 and 9 to 14% by 2080. Projected climate change would shift the watershed towards more rainfall-dominated runoff and result in earlier snowmelt and spring peak flows, which may change the timing and duration of overbank/overdam/overlevee flooding and the period of inundation. Wetlands that are not continuously connected to the river channel will not receive as much inflow during the maximum annual peak flows and will be more sensitive to the effects of climate change as suggested by the water balances.

The beaver subproject monitored a suite of ecological parameters in 37 of the study wetlands to determine the best type of wetland to restore and to provide the background data for an effectiveness monitoring plan for future wetland restorations. This included monitoring of beaver dams, submersed aquatic vegetation, emergent vegetation, water quality, sediment organic matter content, breeding birds and spring migrating water birds. Not all parameters were measured on all study wetlands. In all study wetlands, the most common type of wetland community is open water habitat (28%) with beak sedge-water sedge marsh second most important in area (14%) with bulrush (12%), swamp horsetail (9%), cattail (8%), and with Sitka willow red osier dogwood-low benchlands (7.5%) less common. There is some data showing that these areas are changing over time; the mapping was based on orthophotographs taken in August when the water levels are normally high. There are differences in the area of vegetative communities in the different hydrologic classes of wetlands (groups A,B,C,D,E). In the entire ~20,000 ha Columbia Wetlands, permanent open water (available over winter and spring) is about 25% of the area, since so many of the open water areas (available in August) drain out over winter. Since open water on the wetland is critical for migrating waterfowl and SAR, much of our most intense monitoring was in potential restoration wetlands and reference wetlands. We measured the number of gaps (in the levees to the river) and the number of beaver dams blocking those gaps. We found that group A wetlands have more gaps than dams, resulting in the continuous connectivity that defines them. Group B wetlands have more beaver dams than gaps, while group C and D/E wetlands have no unblocked levee gaps. This suggests that most of the aquatic and semi-aquatic organisms, including migratory birds, will use group B and C/D wetlands in the spring, except for the deeper pools in group A wetlands. It also suggests that we will be modifying/restoring beaver dams to group A wetlands to provide habitat for spring migrating birds. We found that migrating birds and sediment organic content are among the best parameters to measure in potential restoration wetlands. The sediment organic content builds up in wetlands that do not flush out over winter with organic matter being >15% in wetlands that keep water over winter while it is often less than 12% in wetlands that drain out over winter. The number of species of spring migrating birds was higher in wetlands that retain water over winter. For example, Site 24 (a potential future restoration site) had only 9 species of waterbirds, while nearby Site 21 had 23 species of waterbirds and raptors. There were also fewer individual birds observed in Site 24, with 100 individuals observed in Site 24 and 372 observed in Site 21; the most numerous species in Site 24 was American Wigeon (34 individuals observed), while in Site 21 it was Ring-necked Duck (115 individuals observed). We are putting together a monitoring plan to determine how effective our restoration will be. We identified 3 potential wetlands for restoration with restoration with artificial beaver dams or the repair of degraded beaver dams and collected some ecological data on those sites. Additional ecological data will be collected in 2023 to refine the selection of restoration sites.

1.0 Introduction

The Columbia Wetlands, stretching from Columbia Lake in the south to just north of Golden in the northern reach of the study area, are floodplain wetlands along the only undammed portion of the Columbia River. The Columbia Wetland system is one of the longest contiguous wetlands in North America (Zimmerman, 2004) at approximately 180 km long and spreading over 26,000 ha in area (Environment and Climate Change Canada, 2018). These wetlands provide important wildlife habitat and ecosystem services such as recharging groundwater, supplying water for agriculture and residential use, mitigating flood impacts, storing carbon and providing recreational opportunities. The wetlands are important culturally to both First Nations and settlers in the Columbia Valley and are located on the traditional territories of the Ktunaxa Nation, Secwepemc First Nation, Shuswap First Nations Band, and Metis Nation Columbia River.

The Columbia River between Columbia Lake and Golden meanders substantially through the valley bottom with multiple side channels and many wetlands created by erosion and deposition across the floodplain due to the low elevation gradient of approximately 19 cm/km, (Environmental Stewardship Division Kootenay Region, 2004). While much of the Columbia River is highly regulated by large-scale hydro-electric dams, the headwaters of the Columbia River are not, and as such these floodplain wetlands are maintained by the natural flood pulse of water flowing over natural river levees while flood waters advance and retreat across the valley, a process that has major effects on all aspects of the wetlands (MacDonald Hydrology Consultants Ltd., 2021; Makaske *et al.,* 2009). The Columbia Wetlands show anastomosing morphology, with multiple interconnected channels enclosing flood basins, and with stable channels and frequent crevassing of the natural levees to form gaps (Makaske *et al.,* 2009).

Among the many ecosystem services they provide, the Columbia Wetlands provide habitat for a diverse number of organisms, including providing particularly vital habitat for migrating birds. The Columbia Wetlands comprise an important part of the Pacific Flyway; one of North America's four major migratory routes (Environment and Climate Change Canada, 2018). Migratory birds use the wetlands as a stopover site, including provincially listed species such as tundra swan (*Cygnus columbianus* (Ord, 1815)) which is on the BC Blue List 'of special concern' with a Provincial Conservation Status of S3N (special concern, non-breeding population). The Columbia Wetlands Waterbird Survey, which covered approximately 39% of the total Columbia Wetlands area, documented 41,095 birds of 90 different species in 2019 present in the wetlands; over the five years of the survey, 163 bird species were documented, with a maximum single day count of 20,822 individuals on 15th October 2016 (Darvill, 2020).

The Columbia Wetlands face several threats, one of the most concerning being climate change (Hopkinson *et al.,* 2020; Utzig, 2021). The Columbia Wetlands are particularly sensitive to climate change as mountainous regions experience accelerated temperature increases and changes to precipitation due to climate change compared to the global land average (Peppin et al. 2022). While results globally are inconclusive (Rangwala and Miller, 2013), glaciers are shrinking in western North America due to increasing temperatures, with some having retreated up to 2 km since 1900. Corresponding decreases in streamflow have been recorded, including in the Canadian Rocky Mountains (Moore *et al.,* 2009). Across the Rocky Mountains, particularly in the Northern Rockies and Upper Columbia River, the observed late 20th century snowpack declines resulting from springtime warming are almost unprecedented in magnitude, with corresponding impacts on streamflow and water supply (Pederson *et al.,* 2011).

Annual temperatures in the Columbia Wetlands have already increased by 1˚C and further increases of 2 ˚C to 4 ˚C are projected (Utzig, 2021). Changes to precipitation amounts, timing, and form are also predicted by climate models, with less snow and more rain falling in the Columbia Valley (Utzig, 2021). As the Columbia Wetlands are dependent on natural flood pulses, which are primarily driven by snowmelt and rainfall (Makaske *et al.,* 2009), the decreasing snowpack of the Canadian Rockies and changes in precipitation are a direct and urgent threat to the hydrology of the Columbia River and its floodplain wetlands. There is less water in the Columbia Wetlands today than historically (Brahney, *et al.*, 2017) and current projections indicate that there will be increasingly less water in the future (Utzig, 2021).

Reductions in peak and annual flows in the Columbia Valley may have detrimental effects on the Columbia Wetlands. Many of the individual wetlands within the Columbia Wetland Complex have levees that are responsible for containing the water within the wetlands; these wetlands require that the Columbia River achieve a flow that overtops the levees in order to recharge them. Some of these wetlands have one or more gaps in the natural levees that enclose them, allowing for greater connectivity to the Columbia River as water is able to flow through these gaps before the river floods enough to overtop the levees. The Columbia River does not flood to overtop the levees every year, only doing so in approximately half of the time (Suzanne Bayley, pers. comm.) meaning that these levee gaps are the only way that water is able to enter the wetlands in years when the river does not flood over the levees.

An area of research that is currently not well understood is how the presence of beaver dams in wetland levee gaps may either hinder water entry during the flood or assist in water retention after the flood. With climate change reducing the amount of water entering the Columbia River, whether or not water can enter wetlands without overtopping the levees is a question of concern. Beavers may provide some natural mitigation of the effects of climate change on the Columbia Wetlands by increasing wetland resilience and complexity, and specifically by increasing open water area (Hood and Bayley, 2008). Beavers are a crucial part of many wetland systems and have long been recognized as both ecosystem engineers and as animals that provide many ecosystem services. They increase the complexity of wetland habitats, and have profound ecological, hydrological, and geomorphological effects (Larsen *et al.,* 2021; Thompson *et al.,* 2021; Westbrook *et al.,* 2006) such as decreasing temperature extremes, providing carbon storage, increasing the diversity and abundance of other organisms across many taxonomic groups, and moderating extreme flow changes (Bouwes *et al.,* 2016; Nummi *et al.,* 2019; Nummi and Holopainen, 2020; Thompson e*t al.,* 2021; Wohl, 2013). They provide a foundational structure to wetlands and are increasingly important parts of wetland and watercourse re-naturalization and management plans (Colleen and Gibson, 2000; Nummi and Holopainen, 2020).

This project aims to combine hydrological and ecological research to better understand the Columbia Wetland Complex and the individual wetlands within it, including a hydrological classification of different wetland types we see within the Columbia Wetlands and the ecological consequences of their differences. We are also assessing the vulnerability to climate change of the wetlands complex as a whole and within those hydrological wetland classes, and the potential for beaver dam analogues (BDAs) as a low-tech and relatively natural restoration technique.

2.0 Wetland Hydrology Analysis

The study area for this project includes the Upper Columbia Watershed between Columbia Lake and Golden, with field investigation focused on the north-central portion of this area (Figure 1). The area encompasses high elevation mountain ranges including the Rocky Mountains to the east and the Columbia and Purcell Mountains in the west, separated by a deep post-glacial valley known as the Rocky Mountain Trench. The region extends from under 800 m above sea level (a.s.l.) in the Rocky Mountain Trench, to over 3,500 m a.s.l. at the highest mountain peaks in the Rocky Mountains. Total mean annual precipitation is around 450 mm. The region predominantly consists of coniferous forests below 2,200 m a.s.l. and alpine grasslands and talus above. Within the Rocky Mountain Trench, the Columbia River flows slowly, creating a braided system of wetlands within the wide valley.

The Columbia Wetlands complex is approximately 180 km long and over 26,000 ha in area (Environment and Climate Change Canada, 2018), stretching from Columbia Lake in the south to Golden in the north. Within this larger area, 40 wetlands sites have been studied in detail (Figure 1; Appendix 1). Unfortunately, some sites have been lost, either due to environmental factors, malfunctions, or unknown issues, and some sites have been added over the three years of data collection. For the purposes of the hydrologic analysis, only the 35 sites with two or more consecutive years of data between 2020 and 2022 were included.

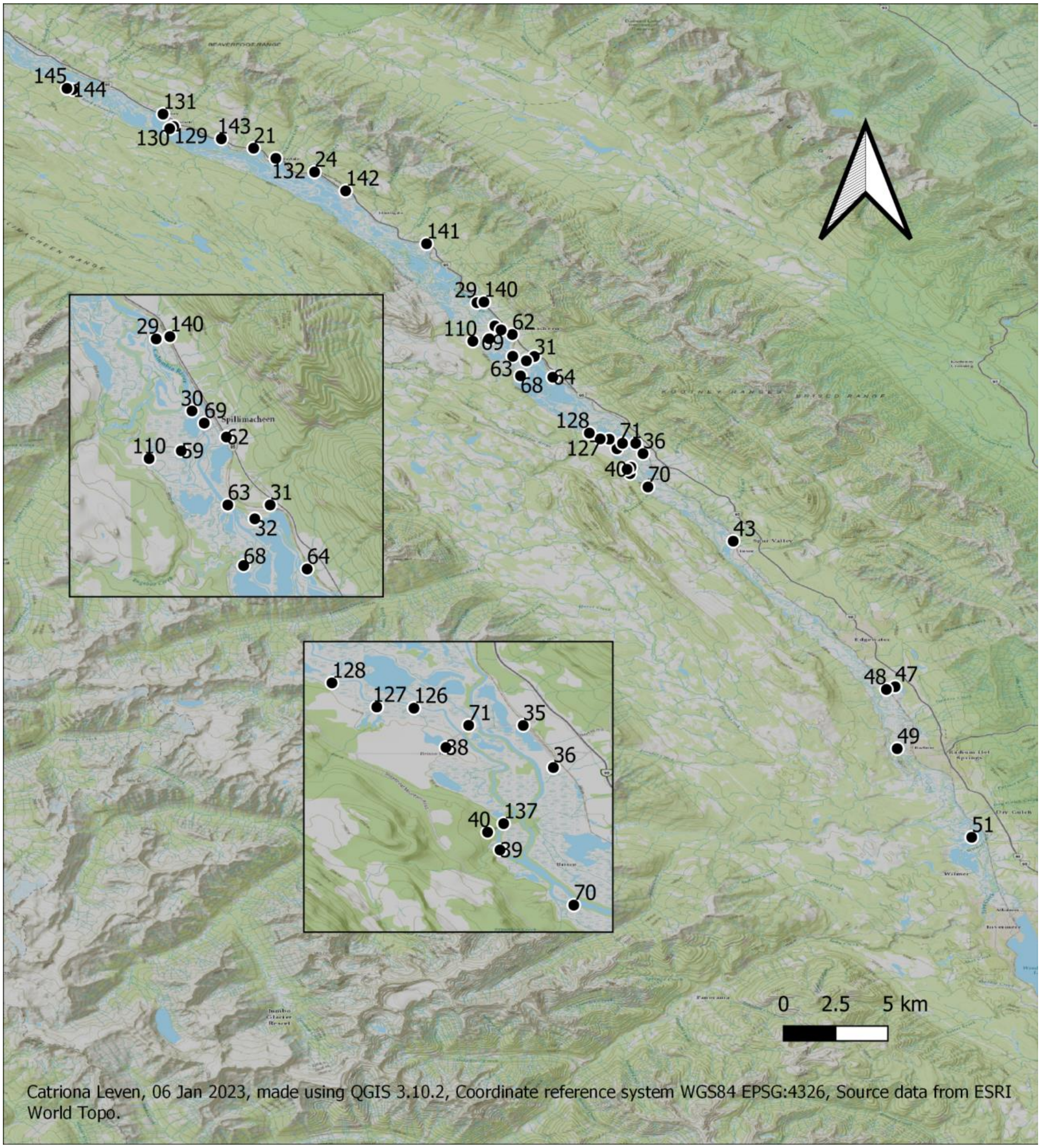

Figure 1. Map of the individual wetland sites studied in this project.

2.1 Wetland Hydrology and Classifications

Several hydrological and geomorphic variables were collected from 2020 to 2022 at 35 different wetlands throughout the Columbia Valley. Hobo U-20 water level loggers were used to measure water levels (m) at individual wetlands, as well as on the Columbia River at Bott's Channel near Brisco and on the Columbia River at the Spillamacheen Bridge. Water level loggers were installed each year in May and removed in

October. Water levels(and temperature) were collected at 4-hour intervals and corrected with a barometric pressure sensor located at Brisco.

Information on geomorphic characteristics of each wetland were collected, including: the count of beaver dams located within 10 m of the wetland (DamNo10), the total width of wetland gaps that allow river, creek, or between wetland water inflow or outflow (TFGapW), and the area of the wetland (Area). Water levels, geomorphic characteristics, and conductivity were then used to develop a conceptual understanding of wetland water balances to infer the predominant water sources and fluxes to assist in identifying vulnerable wetlands. The range of continuous initial variables was standardized by subtracting the mean and dividing by the standard deviation for each value of each variable. Further, a Principal Component Analysis (PCA) was conducted using hydrograph variables, geomorphic characteristics, and wetland water conductivity to explore the different wetland groups, where wetlands were grouped into one of five groups (A, B, C, D, or E) depending on their hydrograph and geomorphic characteristics. Wetland hydrographs over the past three years can be seen in Figure 3 to Figure 10, grouped by their wetland type.

A framework of first-order controls and wetland variables were then used to further group the wetlands into three types based on the wetland's connectivity to the channel network. The first-order controls include topography, topology, and typology (Buttle, 2006). Topography refers to the geomorphic setting of the wetland. Topology reflects the relative role of the wetlands in modulating water inputs from contributing slopes and a measure of the degree of hydrologic connectivity with the steam network. Topology also deals with whether a wetland shows continuous or discontinuous (both in time and space) hydrologic connectivity. Lastly, typology refers to the predominant hydrologic fluxes (vertical versus lateral) and characterizes the relative residence time of water held within wetlands before making its way to the stream channel. The three types of wetland connectivity in the 35 wetlands studied are continuous connectivity, discontinuous connectivity, and no connectivity (

Table 1).

Wetlands with continuous connectivity include wetlands with a group A hydrograph. These wetlands have a relatively high degree of hydrologic connectivity with the channel network. Geomorphic data indicates all wetlands are connected to the main river channel via a gap in the levee (Appendix 2). Water levels in these wetlands have a similar hydrograph response to water levels measured in the Columbia River at Spillimacheen Bridge and Bott’s Channel (Figure 2). Therefore, these wetlands experience water level fluctuations as river levels rise and fall (i.e., exhibit a flashier hydrograph). The Columbia River was unfortunately not monitored at the same location for all three years as the logger at the Spillimacheen Bridge was lost in 2022, and the 2021 site in Bott’s Channel was washed away in 2021. However, river levels for the different years show the relative hydrograph trends each year. Years 2020 and 2021 saw sharper and more sudden increases during freshet. Due to the cool, late spring in 2022, the Columbia River did not spike in the same manner with a sharp peak flow in late June/early July as it did in 2020 and 2021. Instead, the hydrograph shows a more rounded out response with high water occurring in June and remaining high throughout July. Group A wetlands show a similar trend with sharper water level peaks in 2020 and 2021 and a more rounded out peak in 2022 (Figure 3 to Figure 5).

Table 1 Description of topology (i.e., refers to degree of hydrologic connectivity with the main channel network and degree of connectivity over space and time), typology (i.e., refers to the hydrograph response, which infers the predominant hydrologic fluxes and relative residence time of water held in wetland), and topography (i.e., refers to geomorphic setting of the wetland).

<table>
<tr><th>Topology</th><th>Typology</th><th>Topography</th><th>Wetland Group</th></tr>
<tr><td>Continuous connectivity</td><td>Response fluctuates with rise & fall of river stage</td><td>River gap</td><td>Group A</td></tr>
<tr><td rowspan="2">Discontinuous connectivity</td><td rowspan="2">Responds post-overbank or overdam flooding, easily drains overflow</td><td rowspan="2">River gap, creek gap or between wetland gap; gap and/or dam elevation</td><td>Group B</td></tr>
<tr><td>Group C</td></tr>
<tr><td rowspan="2">No connectivity</td><td rowspan="2">Responds post-overlevee (overdam) flooding, slow drainage</td><td rowspan="2">No gap; levee (or dam) elevation</td><td>Group D</td></tr>
<tr><td>Group E</td></tr>
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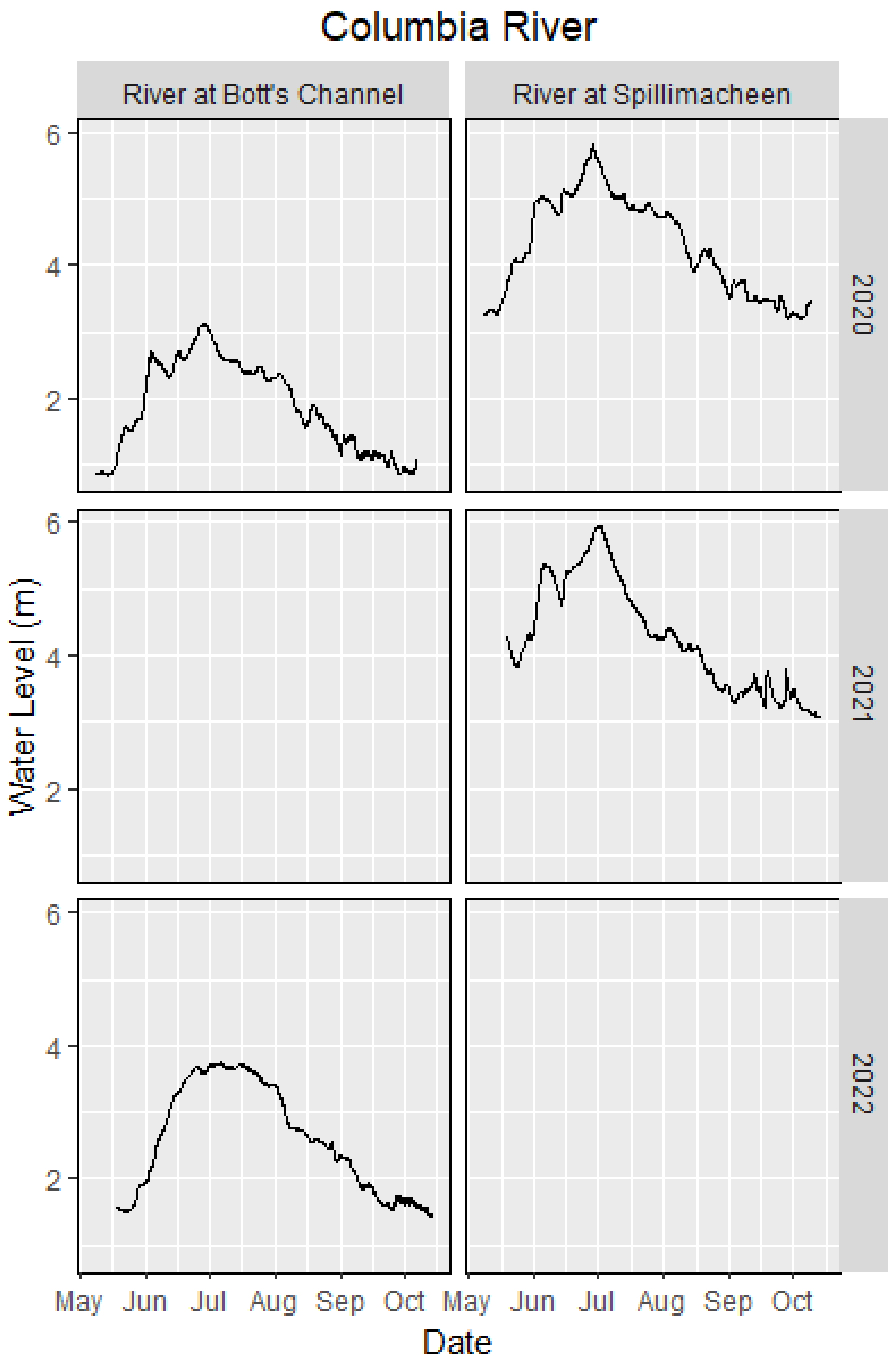

Figure 2. Water levels on the Columbia River at the Spillimacheen Bridge for 2020 and 2021 and in the Botts Channel of the Columbia River for 2020 and 2022. The Spillimacheen River gauge was lost in 2022. The Bott's Channel site was lost in 2021 and was reinstalled at a nearby, more secure location within the river channel in 2022; water levels between years are therefore not comparable, but the hydrograph trends are. The base level of the hydrographs differ due to the location of the logger. The hydrograph trends are similar, however.

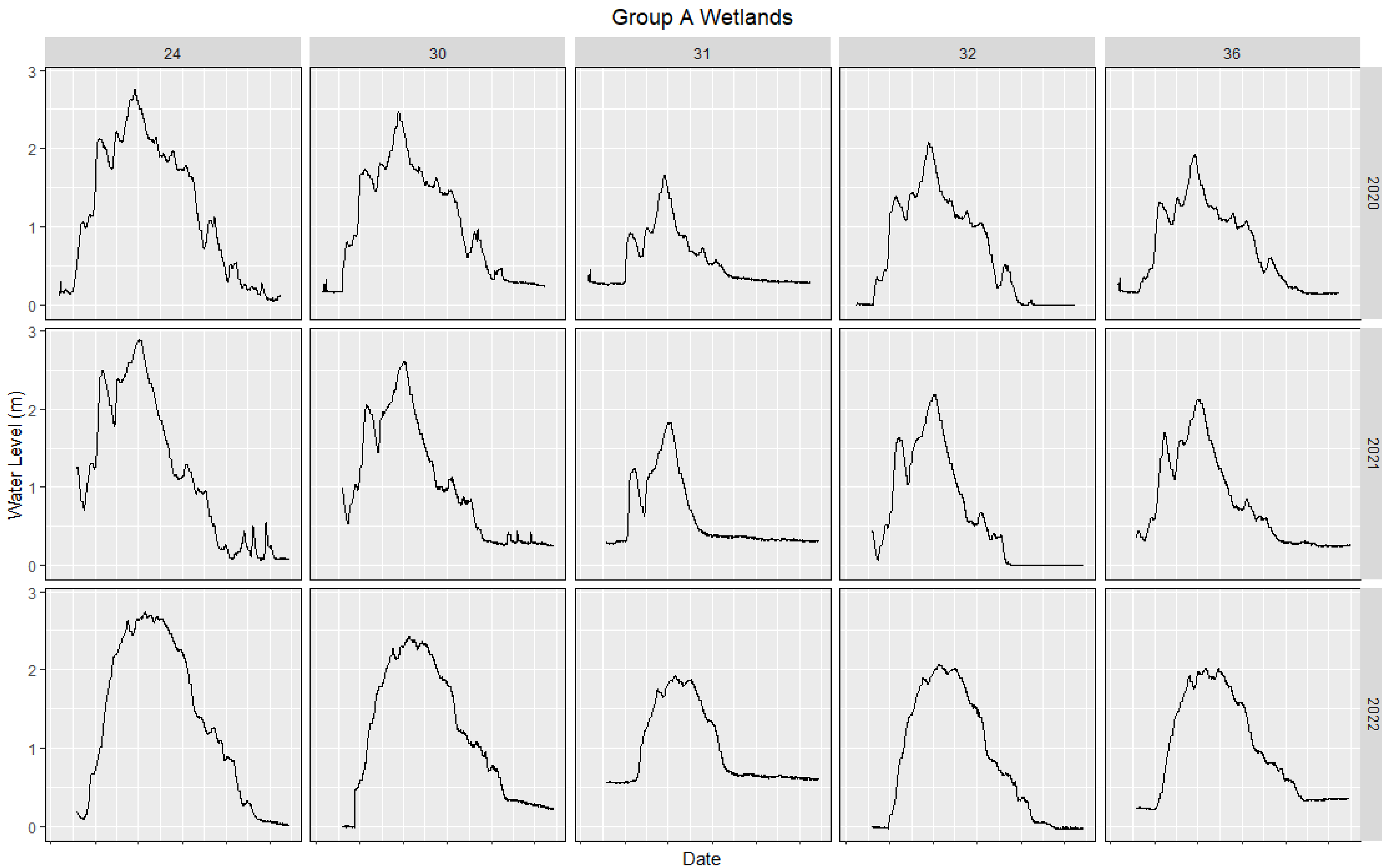

Figure 3. Water levels at five of the fifteen group A wetlands.

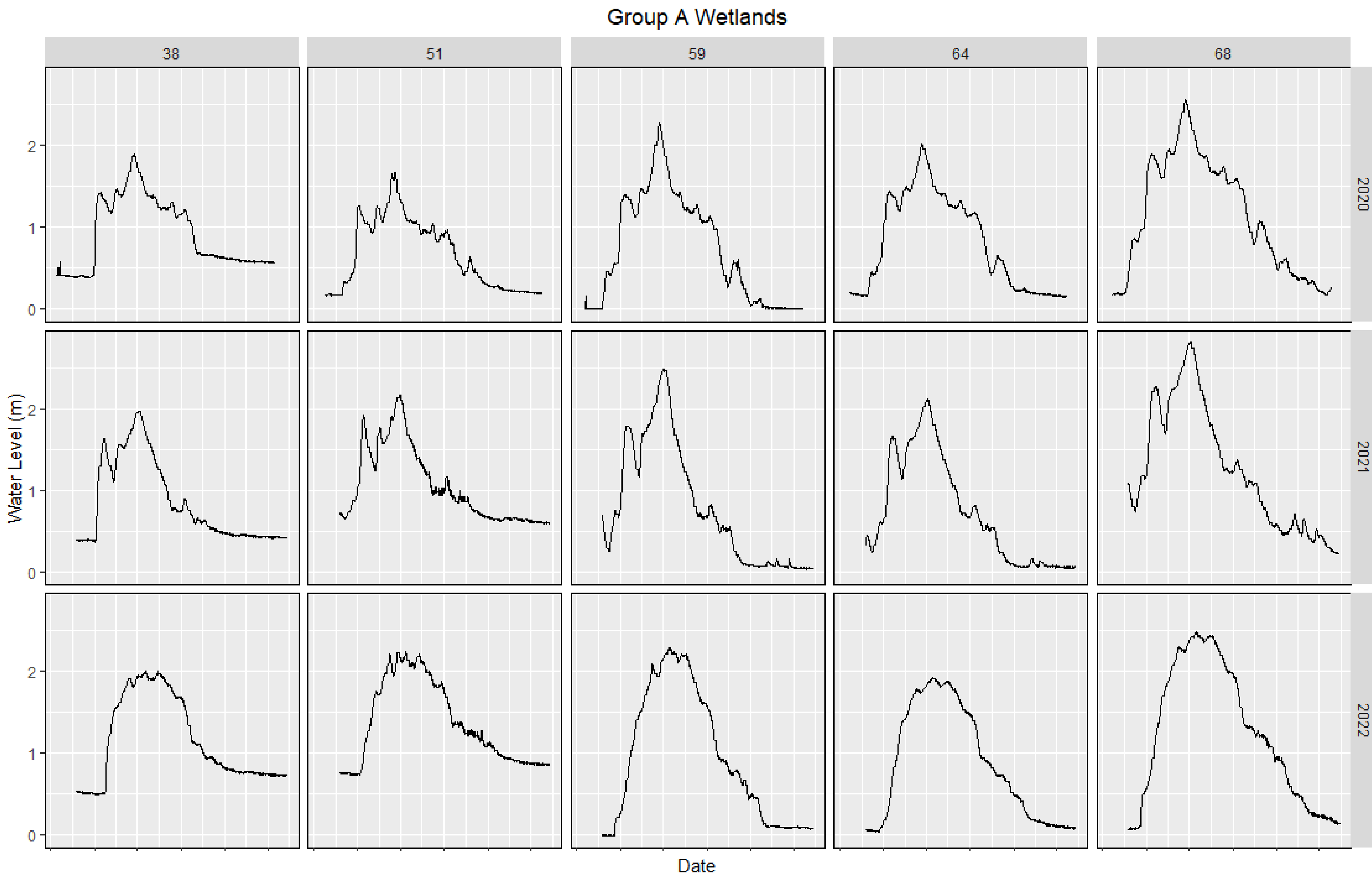

Figure 4. Water levels at five of the fifteen group A wetlands.

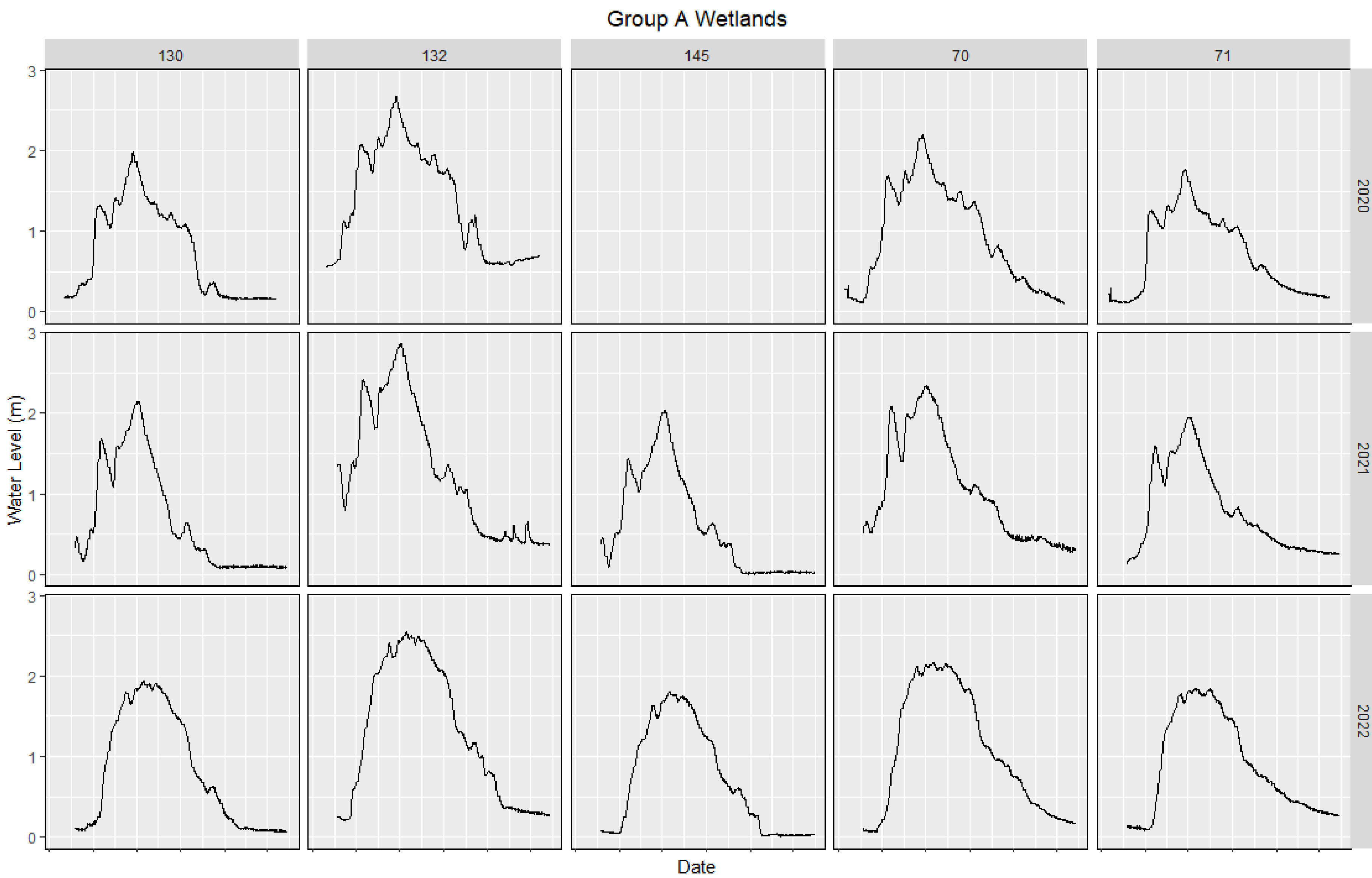

Figure 5. Water levels at five of the fifteen group A wetlands.

Wetlands with discontinuous connectivity appear to have an inlet/outlet with inflow and outflow dependent on the elevation of a beaver dam (overdam flooding) or the bank elevation of the gap in the levee (overbank flooding) or the bank elevation of the adjacent wetland (overbank flooding), where the adjacent wetland is connected via gaps to the channel network. Geomorphic data indicate most wetlands have gaps that allow inflow of river, creek, or adjacent wetland surface water, but the rate and magnitude of inflow is dependent on exceeding the elevation threshold. Wetlands with group B and C hydrographs are in this group (Figure 6 to Figure 8).

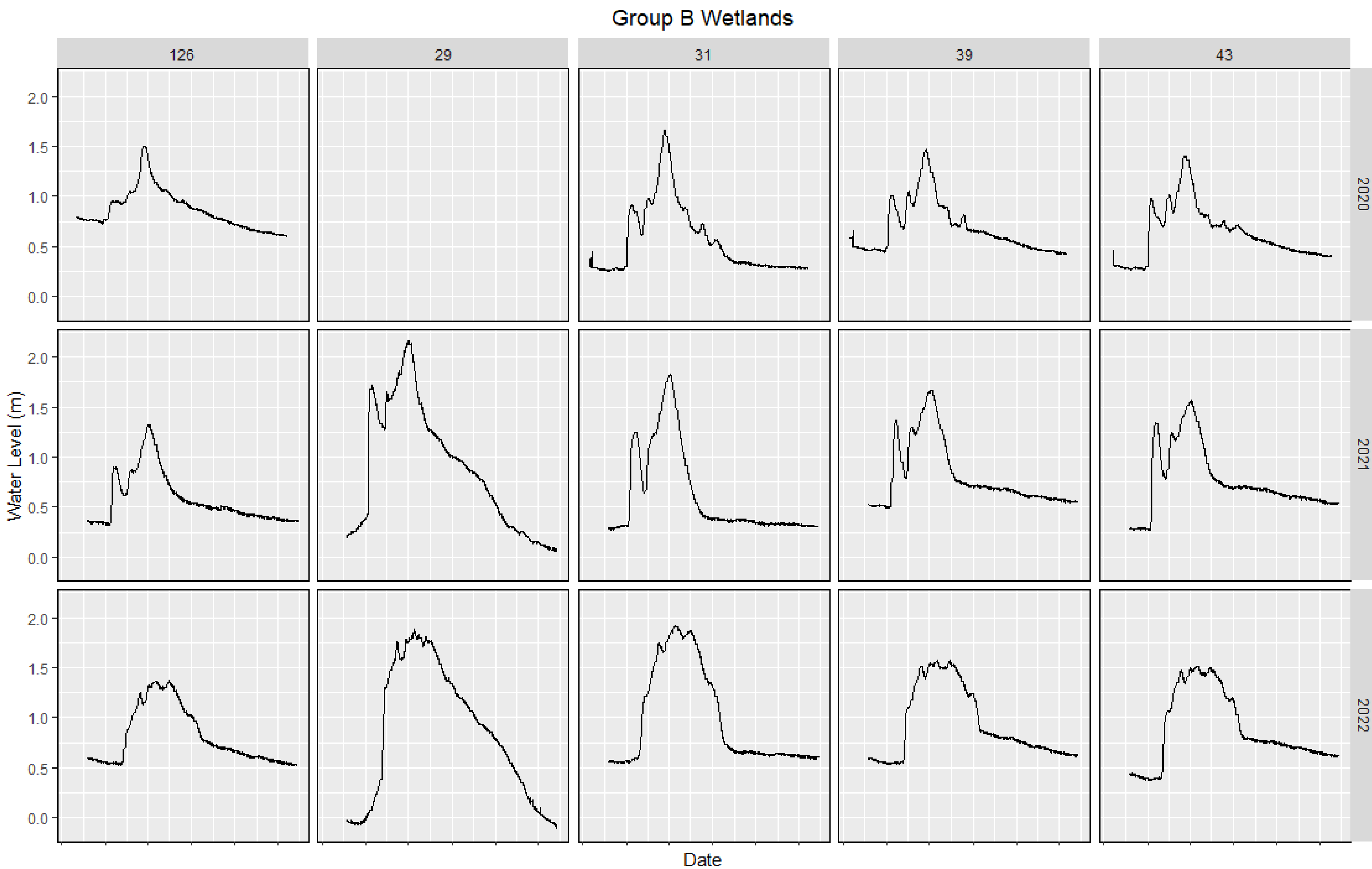

Figure 6. Water levels at five of the ten group B wetlands.

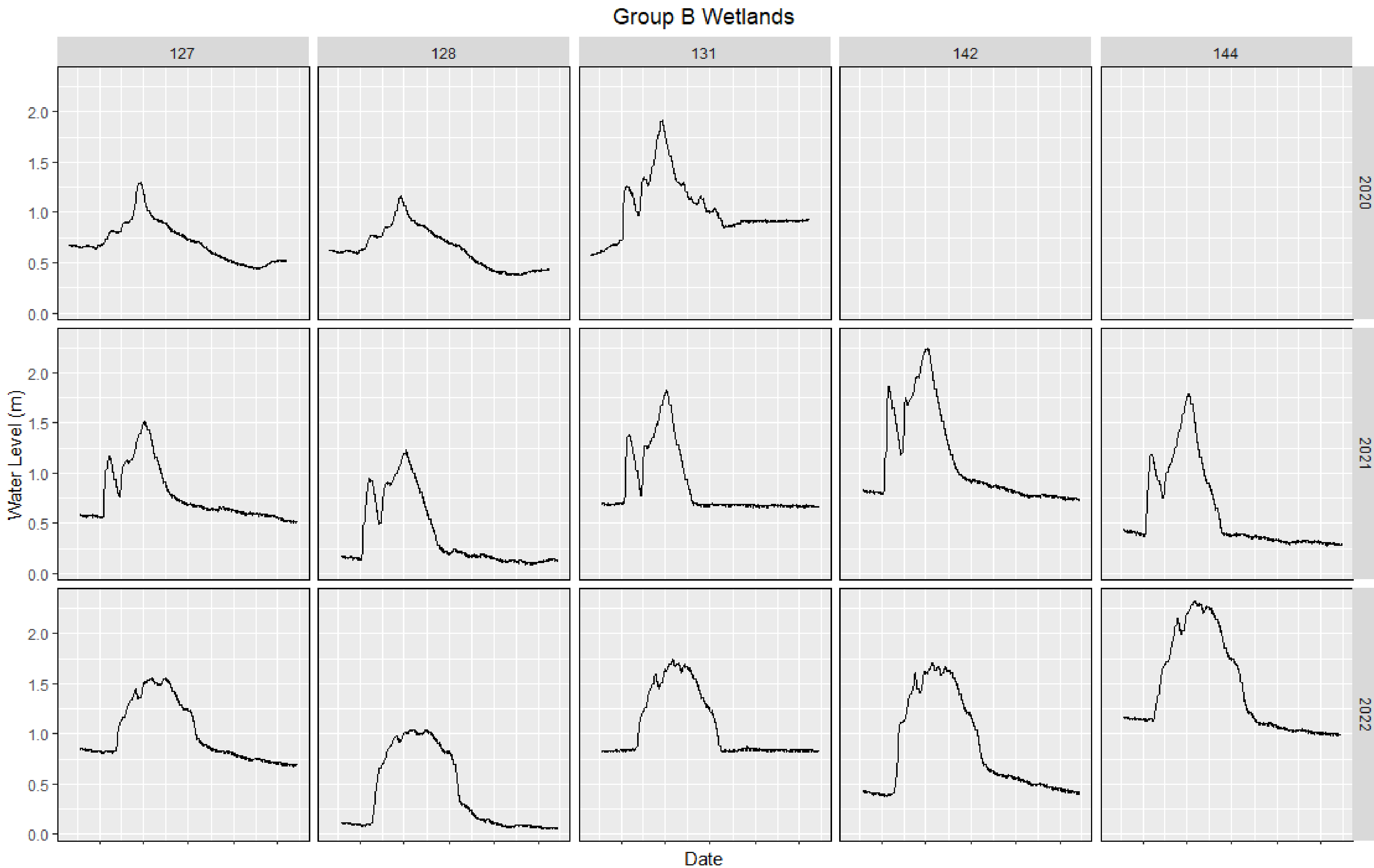

Figure 7. Water levels at five of the ten group B wetlands.

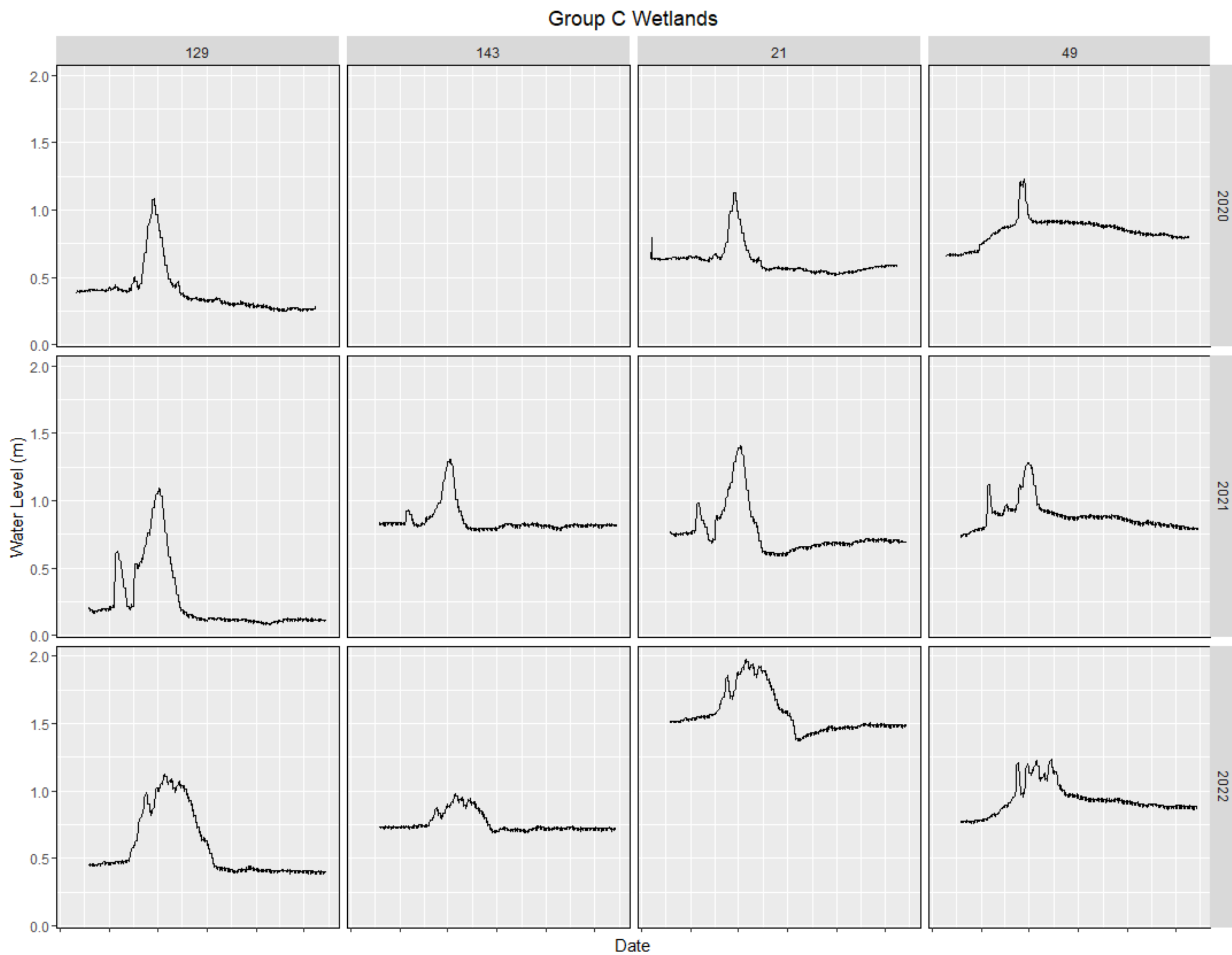

Figure 8. Water levels at the group C wetlands.

The wetland water levels in group B typically did not show a response until the early June peak and had a faster maximum annual peak recession rate, while wetland water levels in group C had a more subdued response during the early June peak and maximum annual peak events. The differences in response between group B and C are likely due to the elevation threshold and the water level needed to exceed the threshold for flooding. These wetlands also had a faster recession rate compared to hydrographs of groups D and E (Figure 9 and Figure 10), which may be due to an apparent outlet that allows water to more easily drain. This wetland type is less connected to the channel network via surface pathways and the water level changes would be a result of overbank (overdam) flooding, groundwater inflow, drainage and loss to evapotranspiration.

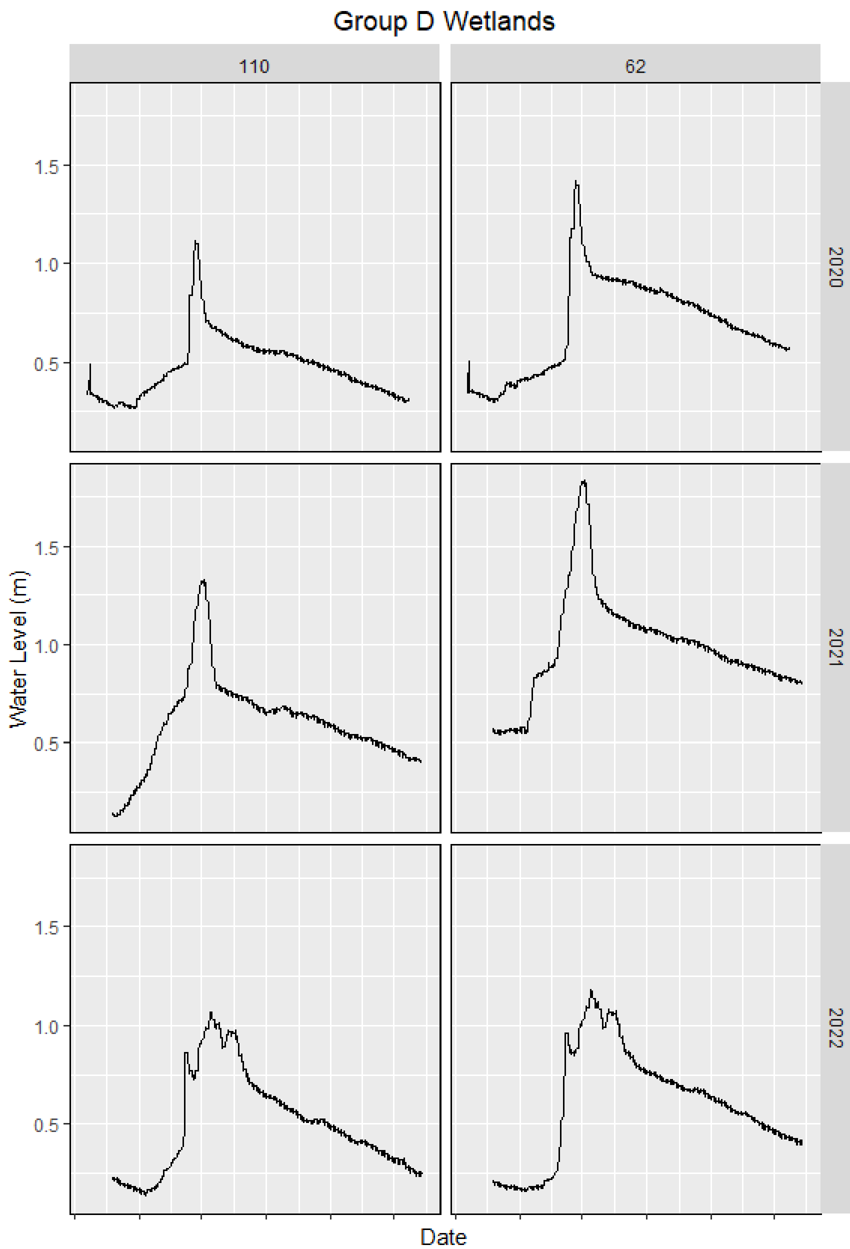

Figure 9. Water levels in the group D wetlands.

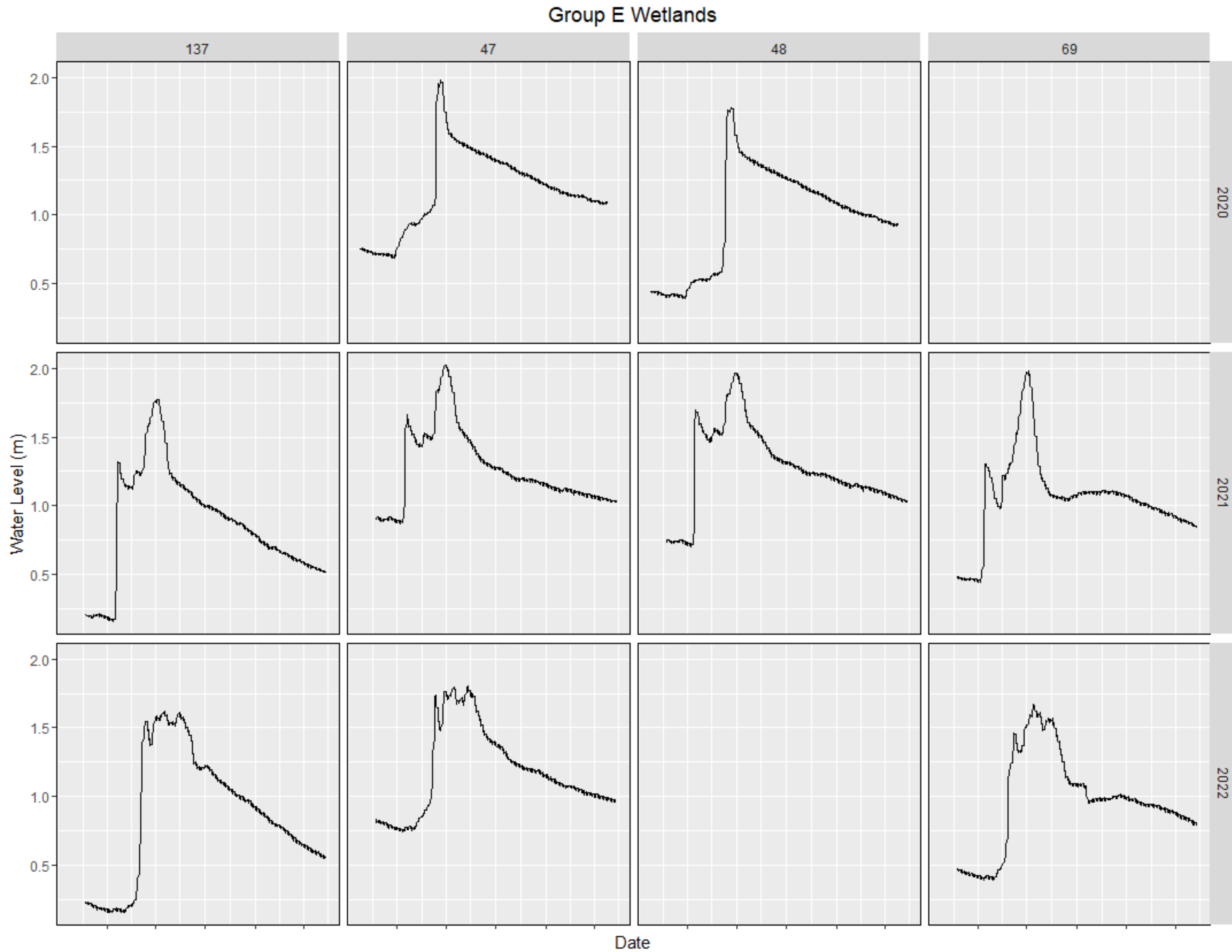

Figure 10. Water levels in the group E wetlands.

Wetlands with no connectivity are not directly connected to the channel network via gaps in the levee. Geomorphic data indicates there were no gaps that moved water into these wetlands. Rather, wetlands likely respond to unchanneled surface inflow because of over-levee flooding as the river stage rises. The wetland water levels in group E (Figure 10) did show a response to the early June peak event and had a slower maximum annual peak recession rate that resulted in a higher water level at the end of the season compared to the spring. In contrast, group D had no distinct early June peak response (Figure 9) likely due to the influence of dams but had a slow maximum annual peak recession rate like group E. The slow drainage and higher storage in this wetland type is likely a result of no apparent surface outlet. These wetlands would experience high rates of evapotranspiration in the summer period.

To determine the distribution of broad wetland types across the entire Columbia Valley study area, remotely sensed imagery was combined with the study wetland classifications to delineate distinct wetlands throughout the study area from Invermere to Parson (Figure 11). Wetland boundaries were distinguished and areas were calculated using ArcGIS in conjunction with various imagery sources and vegetation mapping. In doing so, a fourth classification of wetland was discovered, those being unconfined wetlands.

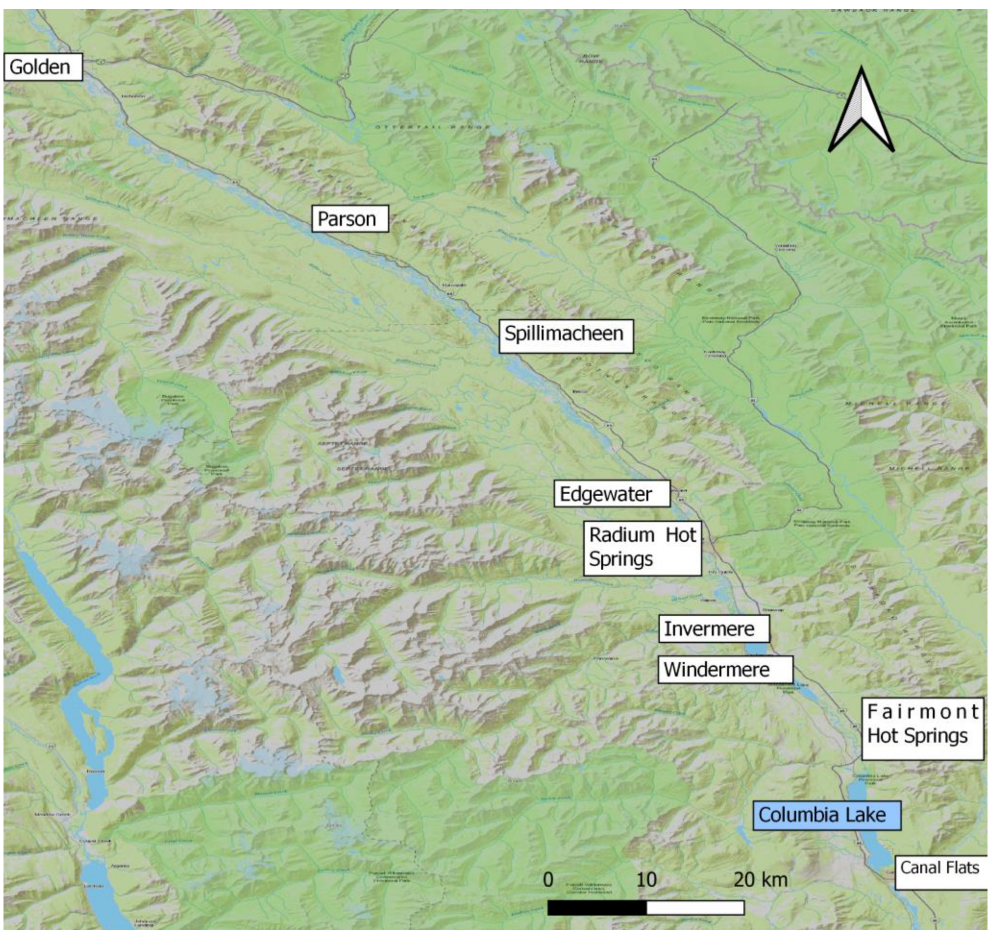

Figure 11. Map of the Columbia Valley from Canal Flats to Golden, with settlements marked.

Unconfined wetlands are wetlands where levees are missing in large areas and where the river continuously flows through the wetland. It is difficult to distinguish floodbasins in unconfined wetlands within the Columbia Valley floodplain, as they have no natural levees delineating the individual wetlands. Only one of the study wetlands (and none of the 35 wetlands with two or more years of hydrometric data) belong to this category as the unconfined nature makes these wetlands difficult to distinguish from each other and the river.

In a GIS analysis of the entire wetlands from Fairmont to Donald, we estimate that most of the wetlands are fully connected with the main Columbia River. Figure 12 shows that most of the Columbia Wetlands complex comprises wetlands highly connected to the main river (50%, or 10,200 ha). 25% of the wetlands are unconfined wetlands with almost no levees, where the river flows through freely. Hence about 75% of the entire Columbia Wetlands complex are of this type, flooding completely with the flood pulse in the late spring and early summer and draining out in late fall and winter, retaining very little open water by the early spring.

Partially connected and isolated wetlands collectively comprise approximately 25%, or 5375 ha, with 13% being partially connected wetlands and 12% isolated wetlands (Figure 12). These are the wetland types that retain water over the winter and in the early spring, thus providing essential habitat for migratory waterbirds (discussed in more detail in below section 4.2). Knowing that only about 25% of the Columbia Wetlands complex retains water until spring is important for management decisions, such as the potential installation of artificial beaver dams to enhance the area for migrating birds in spring.

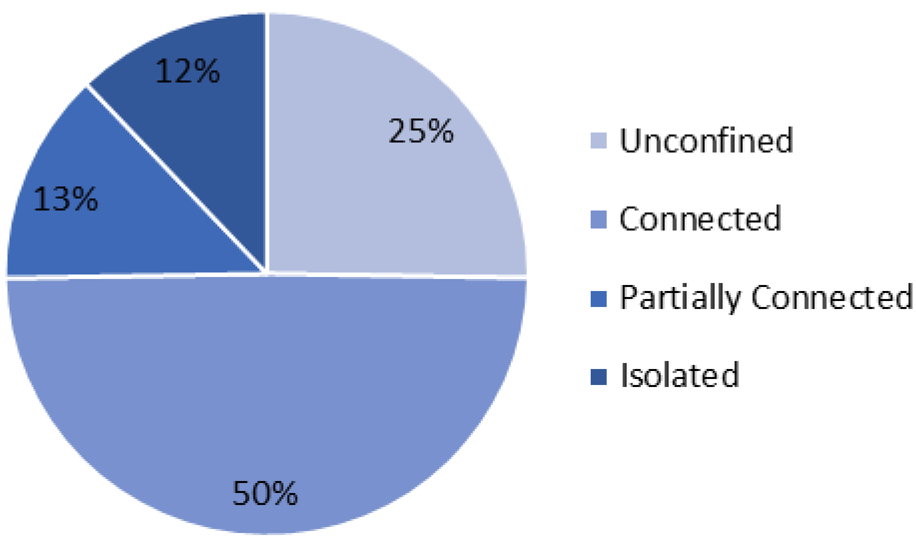

Figure 12. Proportion of the 20,000 ha Columbia Wetlands connected to the main Columbia River. The unconfined and connected wetlands are fully connected to the Columbia River. Partially connected and isolated wetlands have restrictions which reduce the flood pulse and reduce the drainage out of the wetland.

2.2 Wetland Water Balances

A daily volumetric water balance was calculated from May 15 - September 30, 2020, 2021, and 2022 for all monitored wetlands using the following equation:

$$\Delta S = P - E + Q_i - Q_o + G_i - G_o \quad (4)$$

where, ΔS was the change in wetland storage volume (m^3), P was precipitation as rainfall, E was actual evaporation (m^3), Q_i was the inflow and Q_o was the outflow of surface water (includes both channelized and unchanneled flow), and G_i was the inflow and G_o was the outflow of groundwater. The difference between water balance inputs and outputs was used to estimate the net volume of surface and groundwater flow (Net) for the wetland as these water balance terms were difficult to measure or estimate in the field. Therefore, the water balance was estimated as:

$$Net = \Delta S - P + ET \quad (5)$$

The Net term would also include any cumulative error in the measurement and calculation of the water balance components. A combination of daily wetland water level records, various weather data including rainfall data, daily average minimum and maximum air temperature (°C), relative humidity (%), and wind speed (m s^{-1}), wetland survey data of the lowest estimated point in each wetland, and maximum surface area of the wetland delineated from LiDAR imagery and orthophotos were used to calculate wetland water balances.

The total monthly (June, July, and August) and growing season (May 15 – September 30) volumetric water balances were calculated for each wetland, averaged over all three years of study. The total growing season water balance by type indicated continuously connected wetlands (group A) had the greatest Net value compared to the other groups**Error! Reference source not found.**. Conceptual wetland water balances for wetlands continuously connected (group A), discontinuously connected (group B and C), and not connected (group D and E) to the channel network. Values represent the total growing season and are presented in m^3 with mm in brackets (Figure 13). Continuously connected wetlands had the lowest P:E ratio (1:3) compared to wetlands that are not connected and discontinuously connected (1:4).

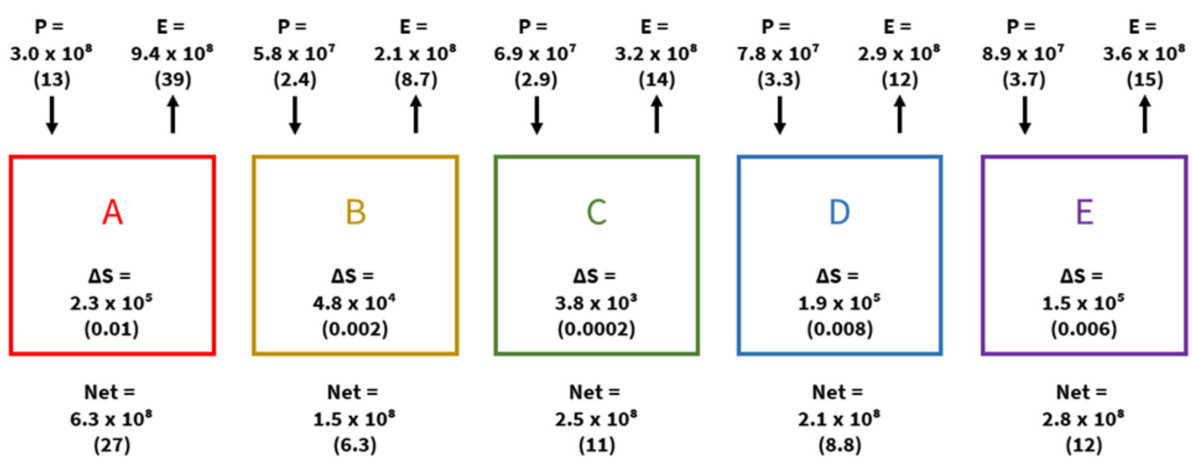

Figure 13. Conceptual wetland water balances for wetlands continuously connected (group A), discontinuously connected (group B and C) and not connected (group D and E) to the channel network. Values represent the total growing season and are presented in m^3 with mm in brackets.

2.3 Wetland Bathymetry

Three wetlands were surveyed in 2022 to improve our understanding of wetland bathymetry within the Columbia Valley and refine water balance estimates. Wetlands 59, 71, and 127 were selected representing groups A and B as these are the two most common wetlands in our study. Surveys included both aerial and manual elevation measurements for an elevation profile of each wetland (Figure 14 to Figure 16). Size and access were major constraints of this preliminary work and future bathymetry investigations will ideally examine wetland groups C, D, and E. The cost of bathymetry prevented us from further measurements this year.

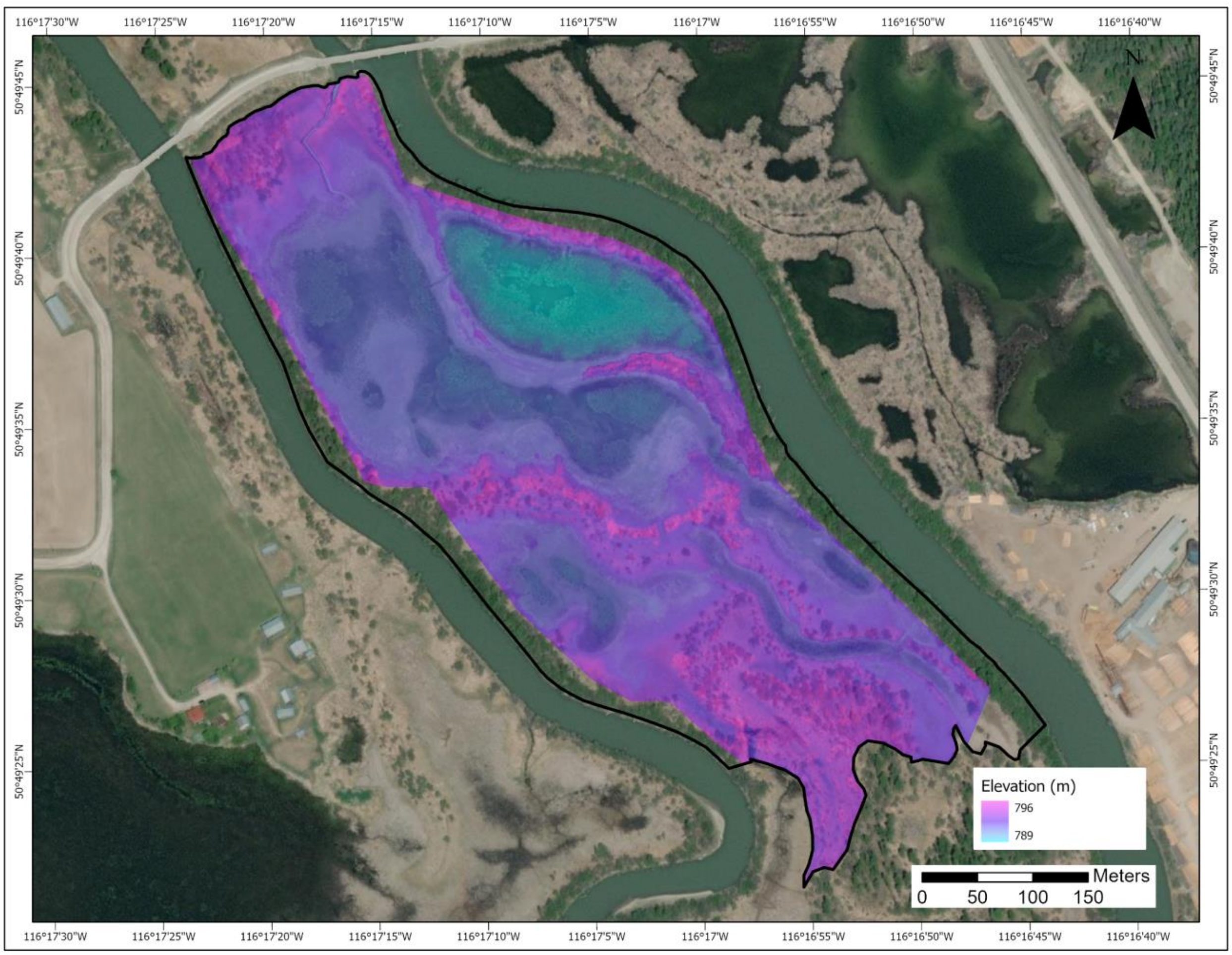

Figure 14. Bathymetry of site 71 showing areas of higher elevation in pink and lowest elevation in blue; the elevations range from 789 m to 796 m. This wetland will receive an artificial beaver dam and repair existing dams on the outflow.

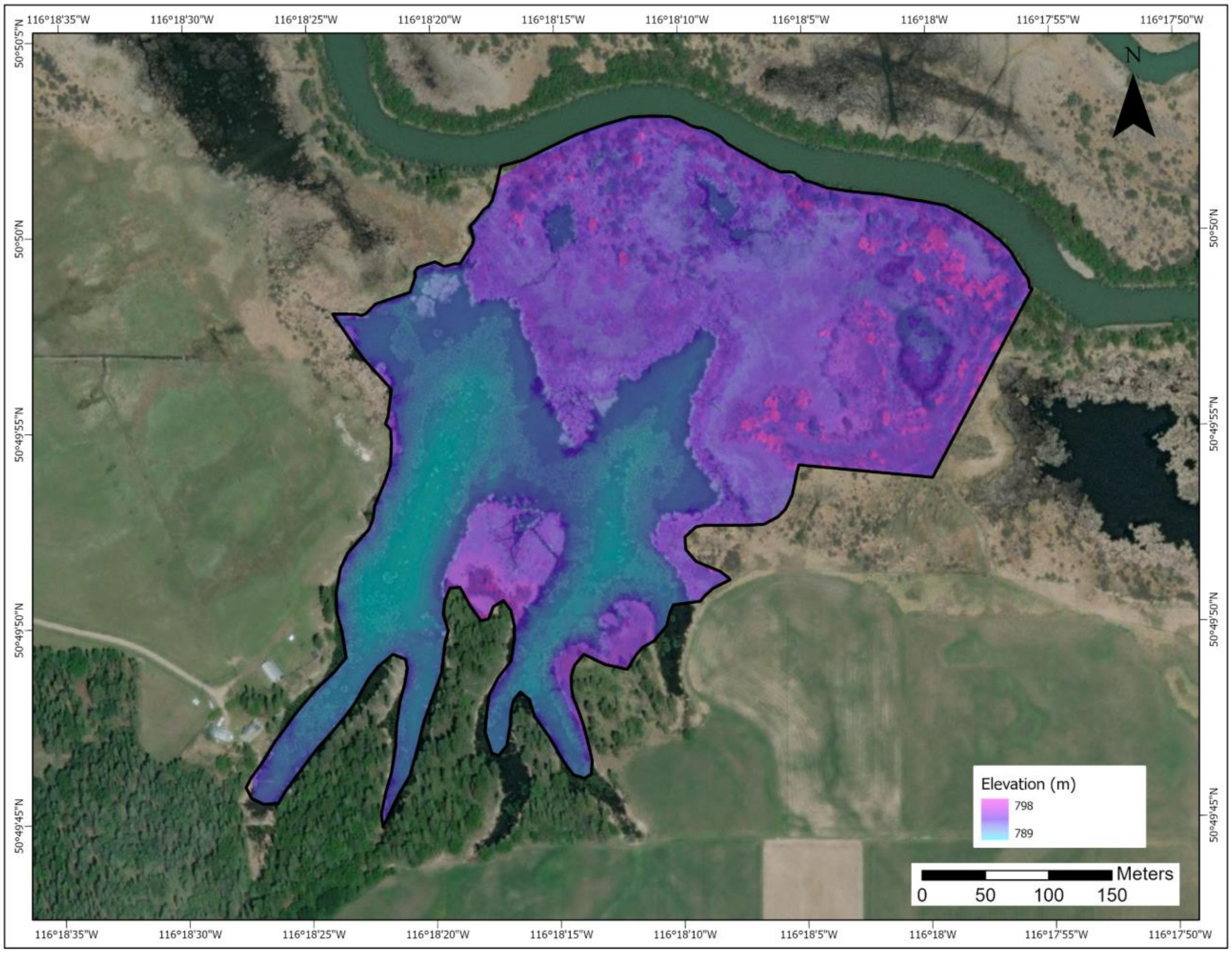

Figure 15. Bathymetry of site 127 showing areas of higher elevation in pink and lowest elevation in blue; the elevations range from 789 m to 798 m.

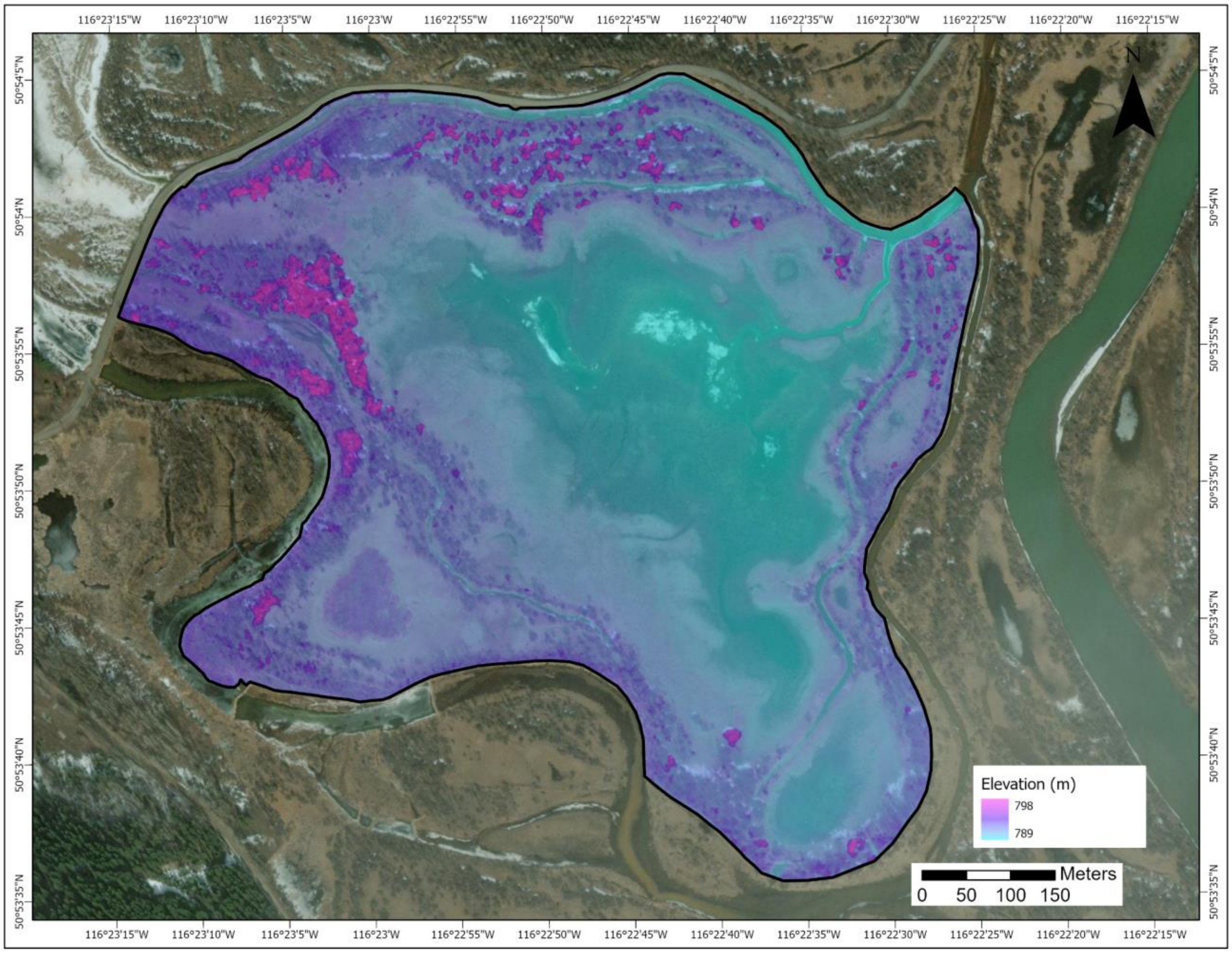

Figure 16. Bathymetry of site 59 showing areas of higher elevation in pink and lowest elevation in blue; the elevations range from 789 m to 798 m.

3.0 The role of climate change in the Columbia Wetlands

3.1 Columbia Wetlands Vulnerability to Climate Change

In order to evaluate potential hydrometeorological conditions and wetland water balance responses to climate change, a physically-based, semi-distributed hydrological model was developed for the upper Columbia River Basin. The basin-scale model was developed as an adapted version of the HBV-EC model, emulated within the Raven Hydrological Modelling Framework version 3.0 (Craig et al., 2020). The model simulates streamflow and other hydro-climatic variables (i.e., snowmelt, evaporation, etc.) at a daily timestep from 1980-2019. The model spatially distributes daily minimum and maximum air temperature and precipitation from all weather stations across the study region. The model simulates major hydrological processes including canopy interception, snow accumulation and melt, glacier melt, evaporation, soil infiltration, percolation, and baseflow, as well as surface runoff. Methods used for model parameterization and calibration can be found in Chernos and MacDonald, 2022.

Changes to wetland water balance components due to climate change were evaluated with two future scenarios generated from statistically downscaled climate scenarios obtained from Environment and Climate Change Canada (ECCC, 2021) under two representative concentration pathways (RCPs; Figure 17). RCP 4.5 corresponds to a scenario where carbon emissions stabilize by 2040, while RCP 8.5 represents a scenario with minimal greenhouse gas emission mitigation. Full methods describing how these scenarios were applied to the model can be found in Chernos and MacDonald, 2022.

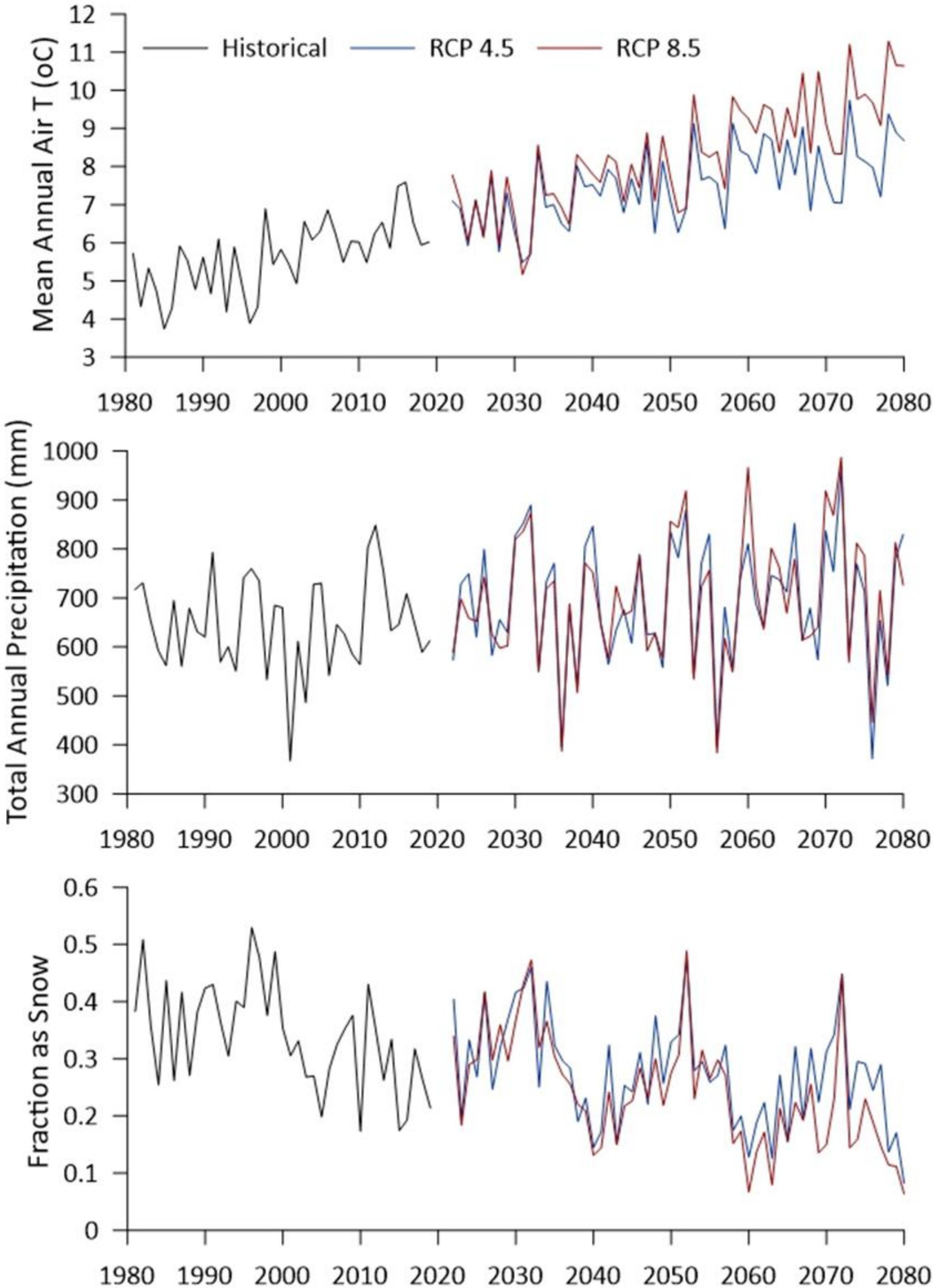

Figure 17. Annual climate parameters under historical and future scenarios for the study area.

For the northern hemisphere, warmer air temperatures associated with climate change are expected to alter precipitation and evapotranspiration patterns (Feulner et al., 2013). For areas within the Upper Columbia Basin that are characterized by high elevations, cold air temperatures, high precipitation and glaciers will be particularly vulnerable since these future climate conditions will further accelerate glacier retreat (MacDonald Hydrology Consultants, 2020). Changes in climate will affect streamflow in both the high-elevation and low-elevation areas of the watershed, which will affect the hydrologic inputs to the wetlands.

Historical normal annual air temperature reported at the ECCC climate station near Radium is 5.8°C and the annual precipitation is 441 mm. Climate change scenarios project average annual air temperature increases for the study area (1.4 – 1.7°C by 2050, 2.4 – 3.6°C by 2080; Figure 17). Precipitation is projected to slightly increase (27 – 35 mm by 2050, 53 – 70 mm by 2080; Figure 17), but the change in the timing (and amount) and phase of precipitation will have a greater impact on wetland hydrology. There is an expected reduction in the fraction of annual precipitation that falls as snow (4 – 6% by 2050, 9 – 14% by 2080; Figure 4). Reduction of snowfall at high-elevation would be critical for late-season streamflow. Already, Columbia River flows at Nicholson have declined 13% in recent decades (Brahney et al., 2017), with much of the decline in August (Moore et al., 2020).

Wetlands in the lowlands of mountain landscapes receive their water primarily from groundwater discharge and the stream network (Winter, 2000). Given that the wetlands are in the Upper Columbia River floodplain, near the headwaters of both streams and groundwater flow systems, the upgradient watersheds of either water source are relatively small, which makes the region more vulnerable to changes in climate. All wetlands in the upper Columbia River floodplain will likely be vulnerable to climate change, but at different time scales given that both streams and groundwater flow systems are snowmelt (glacier)-dominated.

Projected climate change would shift the watershed towards more rainfall-dominated runoff and result in earlier snowmelt and spring peak flows, which may change the timing and duration of overbank/overdam/overlevee flooding and the period of inundation. Some wetlands not continuously connected to the river channel do not receive as much inflow during the maximum annual peak flows (flood <0.5) compared to those that are continuously connected (flood 2-3 m during maximum annual peak flow). Therefore, with projected climate change, the more isolated wetlands would flood less and there would be concerns that a wetland under an extended growing season with greater evapotranspiration rates would not retain as much standing water over the winter and be particularly vulnerable to climate change.

At the wetland-scale, wetlands continuously connected via surface pathways (group A) would be less vulnerable to climate change compared to more isolated wetlands (groups D and E). Although the fraction of snowfall will likely decrease, an increase in precipitation (as rain) will likely be able to maintain this wetland type despite a likely increase in E from warmer air temperatures. Wetlands that have discontinuous connectivity with the channel network (group B, C) would be more vulnerable to warmer air temperatures (increased E) and a shift in precipitation phase from snowfall to rainfall, which could shift the timing and magnitude of the peak flows. Water levels that do not exceed the elevation of the gap bank or dam would increase the vulnerability of the discontinuously connected wetlands by reducing the volume of water within the wetland. Groundwater inflow would then be needed to maintain the wetland water level with an increase in E. However, groundwater inflow rates would depend on the wetland's hydrogeologic setting and groundwater flow system. This would be a similar situation for wetlands not connected to the channel network (group E), which depend on the river stage to exceed the levee elevation to flood the wetland. Therefore, how well (e.g., duration, timing) a wetland is connected to the channel network and how connectivity varies with changes in streamflow will determine the vulnerability to climate change. Wetlands that have discontinuous connectivity or no connectivity would be the most vulnerable and most important to mitigate to maintain habitat quality and bioecological functioning of the wetland.

3.2 Benchland wetlands in the Columbia Valley

CWSP has been contracted to restore a wetland in the headwaters of the Columbia River between Canal Flats and Spillimacheen in 2023-2027. An initial assessment was done to determine where the most appropriate wetlands in the benchlands on the west side of Columbia Valley are located.

Desktop reconnaissance was used to locate the most appropriate locations for further field and arial assessment of bench wetlands in 2023. Five main areas of concentrated wetlands were found north of Invermere and 1 area of concentrated wetlands just west of Columbia Lake (Figure 18 and Figure 19). There has been abundant alteration and destruction of wetlands on the west benches of Columbia Wetlands; the GIS assessment will be supplemented by a field assessment in 2023 to determine which of the wetlands would most benefit from restoration and which would have the highest local and landscape ecological value.

The desktop reconnaissance exercise was necessary to scope potential wetland clusters which could be further investigated via a helicopter survey. Wetland selection was narrowed based on criteria for greatest long term restoration success. Criteria included:

1. Located in the west benchlands between Canal Flat and Spillimacheen;

2. Small wetland between 3-5 hectares;

3. Not on private or municipal land, and;

4. Not a DIFFUSE wetland, meaning it has its own basin and is not a riparian zone on the edge of a creek or lake. (*Open water was not always qualified as a lake; Lake (larger than 0.05 - 1 km^2) of the wetland needed to be larger than that of open water).

The latest provincial spatial databases of wetlands polygons, lake polygons, stream linework, landownership polygons and vegetation classification polygons were used for this exercise (Appendix 3).

A step-by-step walk through the process is outlined in Appendix 4 including the narrowing of available wetland polygons per each step.

To summarize, the number of available wetland polygons dropped significantly (from 13,185 polygons to 77 polygons) once selected by location (west benchlands), size (less than 5 hectares), and excluding polygons which intersect or are completely within private or municipal lands. The remaining 77 polygons were intersected with lakes and stream polygons and linework to identify potential diffuse wetlands. These polygons were individually QA/QC'd to confirm if they were considered diffuse or not. Of the 77 polygons, 44 were considered not diffuse/possessed their own basin. This approach will be further explored to highlight appropriate sites for field analysis. A second more refined analysis completed on March 29 2023 is in Appendix 3-5.

Table 2. Number of wetlands within each zone.

Zone	Number of wetlands
1	6
2	12
3	3
4	3
5	5

These zones are a broad scale method to narrow down the search for the appropriate wetland for restoration (Table 2). The area of the zones varies therefore further investigation of the individual wetlands are required to further narrow down the zones by helicopter and field reconnaissance. The second GIS assessment (in Appendix 3-5) included small lakes (<35ha) in the analysis, since they appear to be drying out and may be likely candidates to restoration.

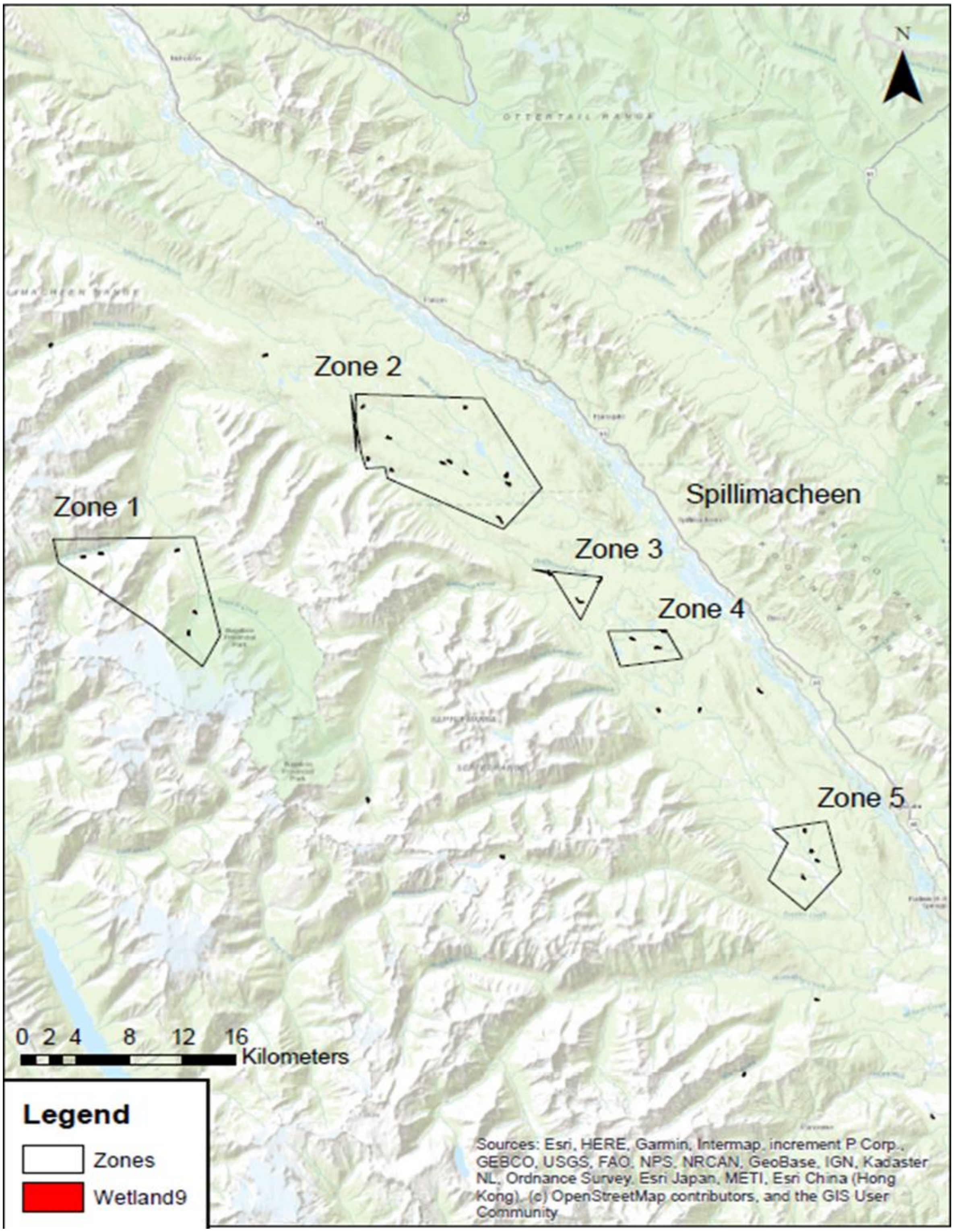

Figure 18. Map of high-density wetlands on west benches from Invermere to Spillimacheen BC.

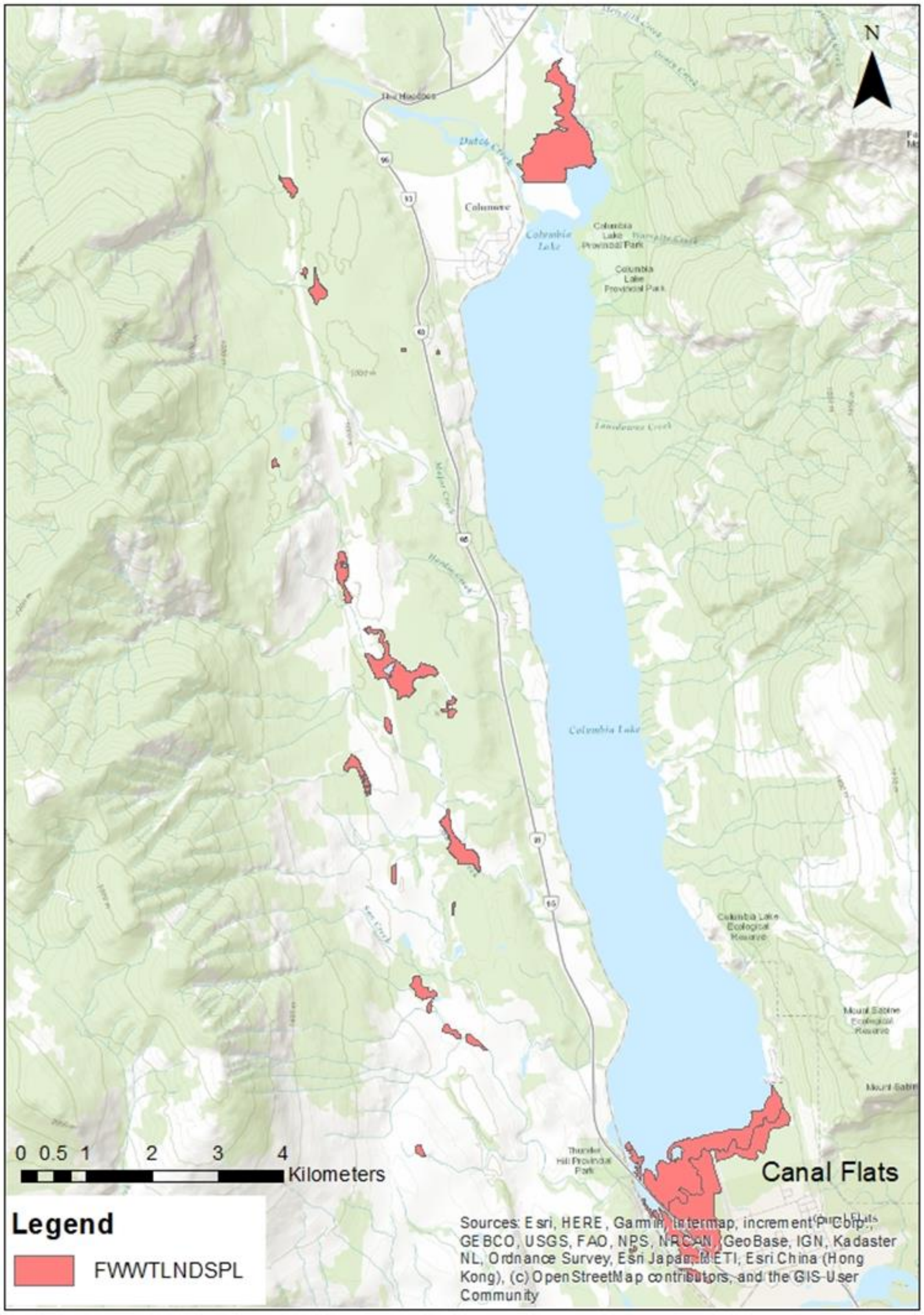

Figure 19. Map of the densest wetlands west of Columbia Lake

4. Ecological characteristics of the different wetland Groups

4.1 Ecological characteristics of different wetland groups, and links to beaver activity

As part of this project, we also analyzed various components of the ecology of the 38 study wetlands to examine whether the different hydrological groups also showed different ecological characteristics. We studied beaver dams, submersed aquatic vegetation, emergent vegetation, water quality, sediment organic matter content, breeding birds, and spring migratory water birds.

4.1.1 Vegetation

Remote sensed imagery was used to map the vegetation communities of the Columbia Wetlands complex, using previous work from MacKenzie and Moran (2004) to define the ecosystem types (ecotypes). GIS and in-person assessments were then used to determine the study wetland perimeters in order to identify the ecotypes found within each study wetland.

Across 38 of the study wetlands, comprising a total area of 2416 ha, the most common ecotype found is open water with 672 ha or 27.83% of the area, with modified shrub swamp being the least commonly found ecotype at 0.44ha or 0.02% of the area (Table 3). This value for open water is deceptive, as this is the open water present in August, when water levels are reasonably high after the flood pulse (approximately 2.5 m in the Columbia River at Brisco in 2022). Much of the time there is less open water than this, particularly in the early spring when migratory waterbirds are using this habitat type, before the flood pulse begins, when there would have been less than 1.5m of water in the Columbia River at Brisco in 2022. Cattail marsh, identified as an important and at-risk ecological community, is the fifth most common ecotype, comprising 200 ha or 8% of the study wetland area.

Table 3. The area (in hectares and percent of the total area of all the study wetlands) of different vegetation communities within the 2416 ha that is the combined area of all the study wetlands.

Rank	Ecosystem Type	Type Area (ha)	Type %	Description
1	OW	672.46	27.83%	Shallow Open Water
2	Wm01	343.14	14.20%	Beaked Sedge – Water Sedge Marsh
3	Wm06	279.96	11.59%	Bulrush Marsh
4	Wm02	214.88	8.89%	Swamp Horsetail Marsh
5	Wm05	199.90	8.27%	Cattail Marsh
6	Fl04	188.21	7.79%	Sitka willow – Red-osier dogwood – Horsetail low-bench floodplain

7	Ws	181.03	7.49%	Shrub swamp (site association not known)
8	Wm15	146.33	6.06%	Bluejoint Reedgrass Marsh
9	Fm02	102.89	4.26%	Cottonwood – Spruce – Dogwood mid-bench floodplain
10	Ws04	17.82	0.74%	Drummond's willow – Beaked sedge swamp
11	PD	16.07	0.67%	Pond
12	RI	12.71	0.53%	River
13	Fa	12.13	0.50%	Active channel flood class
14	Fl06	10.08	0.42%	Sandbar willow low-bench floodplain
15	Wm.mo	5.99	0.25%	Modified marsh
16	Fm07	4.75	0.20%	Aspen – Dogwood – Water birch mid-bench floodplain
17	MU	2.74	0.11%	Mud Flat
18	111	1.76	0.07%	Wet forest class in BGC units
19	Wm14	1.40	0.06%	American Common Reed Marsh
20	Ff01a	1.30	0.05%	Water birch – Red-osier dogwood – Rose flood fringe phase
21	GB	0.45	0.02%	Gravel Bar
22	Ws.mo	0.44	0.02%	Modified shrub swamp

Within each wetland group, the percent of each ecotype varies greatly; we chose to analyse the top five ecotypes: Shallow Open Water, Beaked Sedge-Water Sedge Marsh, Bulrush Marsh, Swamp Horsetail Marsh, and Cattail Marsh. Shallow Open Water is important for many waterbirds and is also an indication of the amount of water in a wetland. Beaked Sedge-Water Sedge Marsh is an ecotype that does not require constant water presence and so is an indication of areas of wetland that experience water drawdown during the year (MacKenzie and Moran, 2004). Bulrush Marsh and Cattail Marsh have overlapping site associations, including high water levels, though Cattail Marsh is often associated with high nutrient (particularly phosphorus and nitrogen) levels and Bulrush Marsh is more tolerant of vigorous water movement (MacKenzie and Moran, 2004).

Open Water, Bulrush Marsh, and Cattail Marsh are often found in habitat mosaics with each other, and this mosaic has been identified as an important habitat for wetland birds; in the Columbia Wetlands complex, Cattail Marsh has been identified both as a habitat at risk and as being particularly important for wetland birds (Darvill and Westphal, 2020).

Beaked Sedge-Water Sedge is most common in group A wetlands (Figure XXX), as would be predicted given that this ecotype is tolerant of drying out for much of the year, conditions found in group A wetlands due to their constant connectivity to the Columbia River (as seen in the hydrographs in Section 2). Conversely, Cattail Marsh presence is lowest in group A wetlands (Figure XXX), where the lack of water retention due to the constant connectivity to the Columbia River reduces the amount of suitable conditions for cattails to grow. Groups B, C, D, and E all have similar percentages of Cattail Marsh, though there is a difference in the range of Cattail Marsh found in the wetlands in each group. For example, within group B, the wetland with the highest percentage of Cattail Marsh present is Site 35 with 28.7% Cattail Marsh, and the wetland with the lowest percent Cattail Marsh is Site 126 with 15.9% Cattail Marsh. In contrast, within the group D/E wetlands, Site 110 is 56.9% Cattail Marsh (the highest of all our study sites), while Site 69 is only 6.9% Cattail Marsh. As Cattail Marsh is a habitat of conservation interest, knowing in which types of wetlands it is located is important to better understand how to manage wetlands for the benefit of this habitat type.

The Open Water ecotype is hard to analyse as it varies greatly throughout the year, with the smallest amount of Open Water found in later winter/early spring. It is consistently the most common ecotype across all the studied wetland types (Figure 20) but is not the most common ecotype within each wetland. Vegetation mapping was done using data from August 2020, which is not during the peak of the flood pulse although it is still when the river is relatively high and the wetlands retain water even if they are group A wetlands. Thus, while Site 30 is 26.73% Open Water in August, by April a lot of that Open Water area is exposed wet soil.

It is evident from the ecotype survey (Figure 20) that all of the study wetlands are a mosaic of different habitat types. This is important to recognise as it indicates that the Columbia Wetlands are complex systems with different vegetation communities supporting different wildlife and that throughout the year the fluctuating water levels change the habitat availability of the wetlands.

Ecotypes including shrubs and trees, which are associated with the parts of the wetlands that receive the least long-lasting inundation, such as the high points of the levees, are not in the top five ecotypes. The sixth most common ecotype is Sitka Willow - Red-Osier Dogwood - Horsetail low bench floodplain, comprising 7.79% or 188.21 ha of the total wetland area (Appendix 6). Cottonwood - Spruce - Dogwood mid-bench floodplain 4.26% or 102.89 ha of the wetland study areas (Appendix 6). This ecotype is of interest because large Cottonwoods are not common in the Columbia Wetlands Complex and they provide important wildlife trees; CWSP projects are underway in the Columbia Wetlands to protect some of these wildlife trees. The tree and shrub ecotypes are likely more common in the whole Columbia Wetlands Complex than this data indicates as we defined our study wetlands to include only areas that are regularly inundated, thus excluding those ecotypes that require drier conditions.

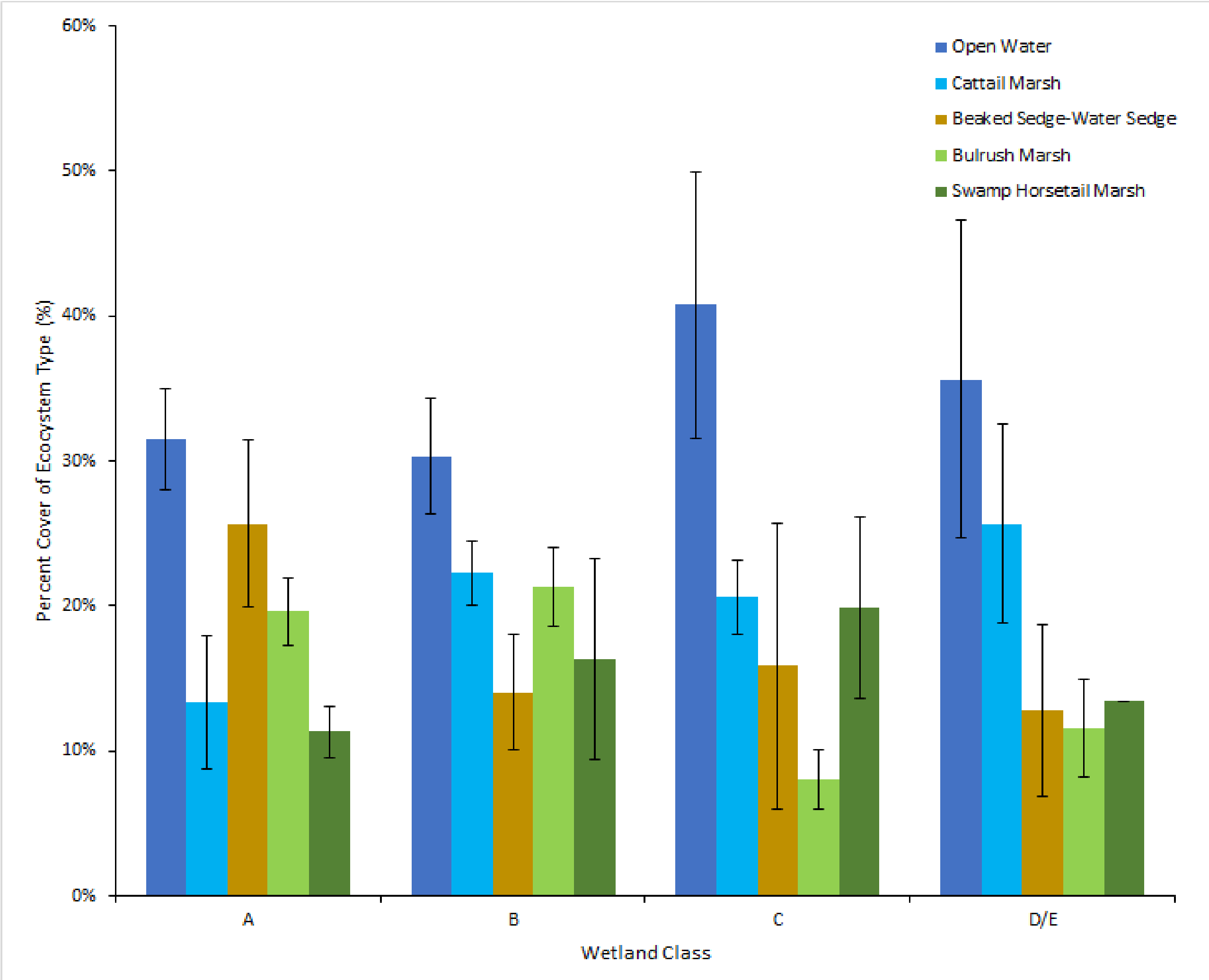

Figure 20. The mean percentage of the five most common ecotypes in each of the wetland groups. Error bars are standard error. (Note: groups D and E were combined for this figure and accompanying analysis, as there are only two wetlands in group D and four in group E; group D and E are both not connected wetlands).

4.1.2 Water and Sediment

Sediment samples were collected from each wetland in 2022 which were then dried and ground before conducting a Loss On Ignition protocol to determine the amount of organic content in the wetland sediment for each site. Wetland groups D and E had the highest mean sediment organic content, significantly higher than wetland groups A and B (Figure XXX:), while wetland group A had the lowest mean sediment organic content, significantly lower than group B and D/E. Wetland group C does not have significantly different sediment organic content than any of the other wetland groups, which was not the expected result. High organic sediment content indicates that the wetland is retaining much of the organic matter that grows and then decomposes in it, whereas low sediment organic content indicates that the wetland flushes frequently and organic content does not build up in the soil due to being washed out by flood action. Thus, the group A wetlands having the lowest mean organic content fits with them being continuously connected to the Columbia River; organic content washes out as the flood pulse recedes. Similarly, group D and E wetlands having the highest mean organic content fits with the hydrological classification of them being not connected to the Columbia River, allowing for organic content to be retained within the wetland.

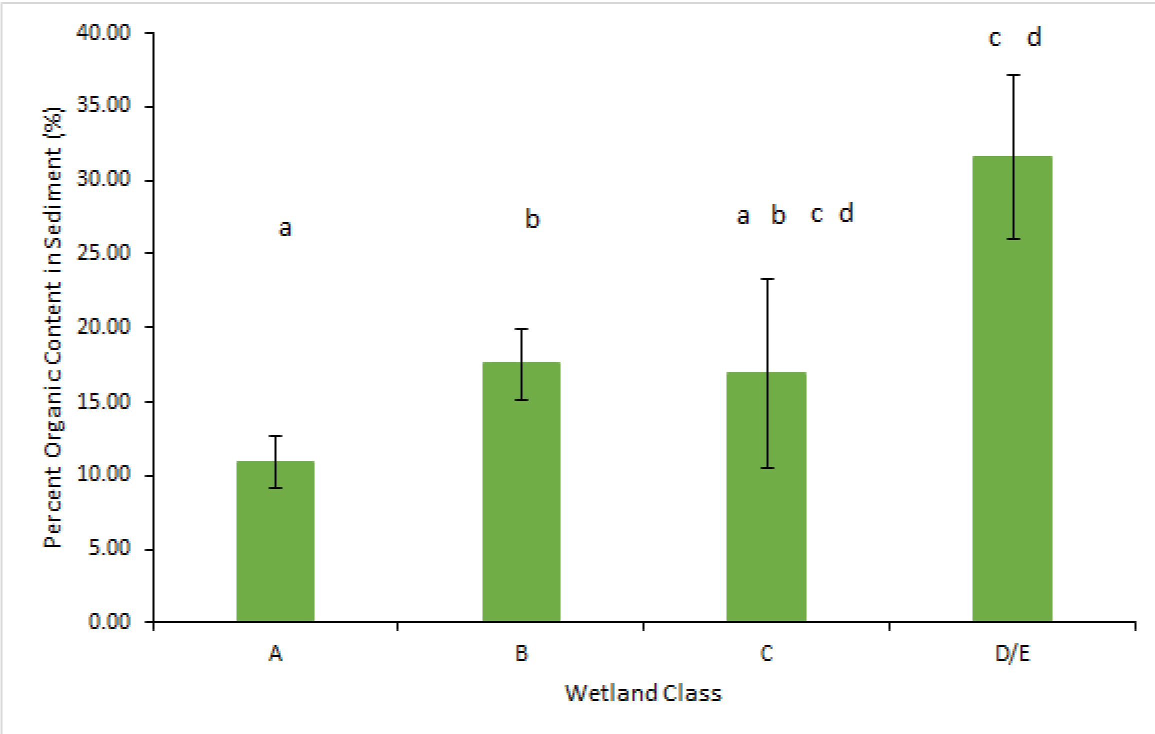

Figure 21. The mean percent of organic sediment content in each wetland class. Error bars are standard error, and the different letters represent a significant difference.

We collected water quality measurements (turbidity and conductivity) from each of the study wetlands multiple times through 2021 and 2022, these data remain to be analysed.

4.1.3 Beaver Activity

Using remotely sensed imagery, we identified 205 beaver dams within 30 m of 38 of the study wetlands (Appendix 8). We then assessed each wetland and its beaver dams in person to determine which of these beaver dams are impacting the majority of the wetlands and then measured them in detail. For example, in Site 30, there are three beaver dams that form a deep pond in a small section of the wetland; however, the majority of the wetland is unaffected by beaver dams and a large gap in the levee allows for continuous connectivity with the Columbia River.

Group A wetlands all have gaps in the levee that allow for continual connectivity to the Columbia River (Figure 22). Groups B, C, and D/E wetlands have a combination of levee gaps that are blocked by beaver dams and entirely enclosing levees (Figure 22). Thus, beaver dams are essential to maintaining these wetland groups; without the dams, only the six wetlands entirely surrounded by levees would be retaining water over the winter and into the spring. However, because of the beaver dams, eighteen more sites retain water over this period. This allows these wetlands to be used by migratory waterfowl (as discussed in section 4.2 below) and also provides the right conditions for different vegetation (as discussed in section 4.1.1 above).

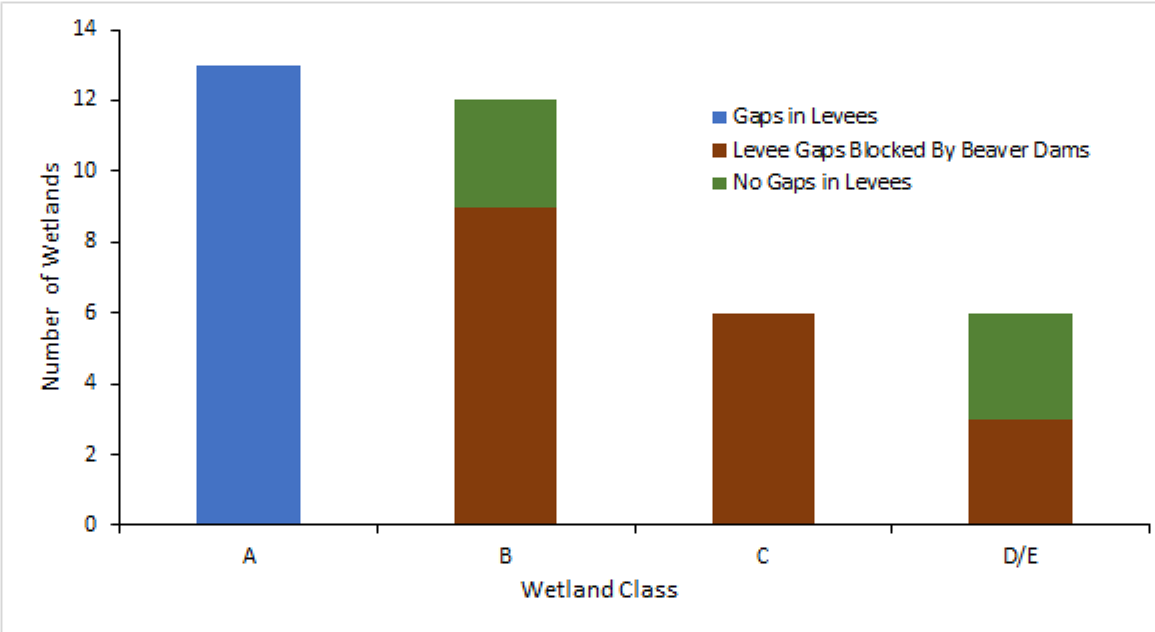

Figure 22. The number of wetlands in each wetland group which have unblocked gaps in the levees (blue), gaps in the levees blocked by beaver dams (brown), and no gaps in the levees (green). This includes 38 of the study wetlands.

While some group A wetlands do have beaver dams blocking gaps in the levees, they also all have unblocked gaps; group A wetlands have more gaps than they do beaver dams (Figure 23), resulting in the continuous connectivity that defines them. Group B wetlands have more beaver dams than gaps, while group C and D/E wetlands have no unblocked levee gaps (Figure 23). This suggests that most of the aquatic organisms, including migrating birds, will use group B and C/D wetlands in the spring, except for the deeper pools in group A wetlands.

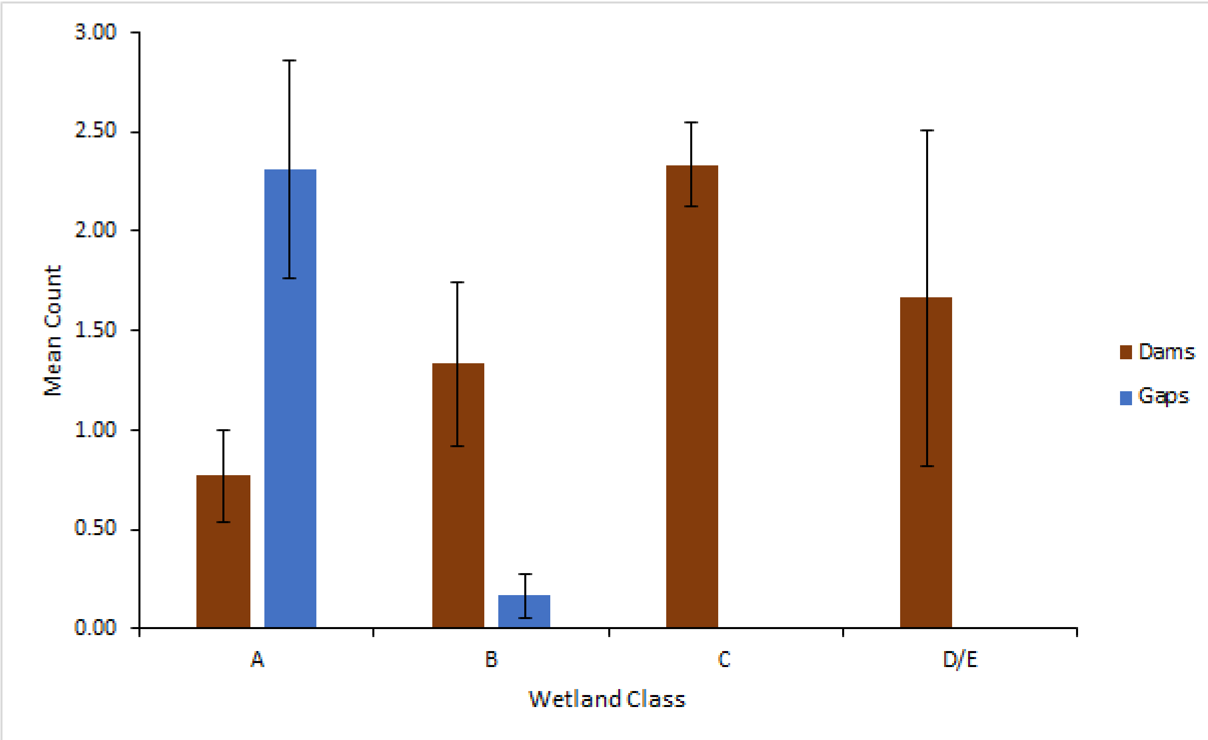

Figure 23. The mean count of dams (brown) and gaps (blue) in the wetland groups. Error bars are standard error.

4.2 Bird use of different wetland groups, and links to beaver activity

In April 2022, we conducted point count surveys for waterbirds and raptors at 16 of the study wetlands (Appendix 1). Six rounds of surveys were conducted, starting on April 2nd and ending on May 1st, resulting in 12 days of surveys. Over that period, 35 waterbird and 5 raptor species were recorded, with a total of 7573 individual birds counted across all days and wetlands (Appendix 9).

The most abundant species were American Wigeon (1259 individuals), Canada Goose (910 individuals), Mallard (1309 individuals), Ring-necked Duck (854 individuals), and Northern Pintail (787 individuals). The species encountered the most were Bufflehead (recorded on 50 counts), Canada Goose (recorded on 83 counts), Common Goldeneye (recorded on 53 counts), Hooded Merganser (recorded on 49 counts) and Mallard (recorded on 84 counts). In contrast, Canvasback, Eared Grebe, Eurasian Wigeon, and Sora were each only recorded once.

Group A Wetlands had the lowest mean number of species found in the wetlands (Figure 24), with group C wetlands having the highest mean number of species counted in the wetlands (Figure 24). Group C wetlands had a mean of 18.33 species in them; given that the total number of species recorded was 40, this indicates that there was a range of species found across the wetlands, with no wetland containing all of the recorded species. No species were found in group A wetlands that were not found in other groups of wetlands, but two species were found only in group B wetlands, seven species were found only in group C wetlands, and two species were found only in group D wetlands (Appendix 10).

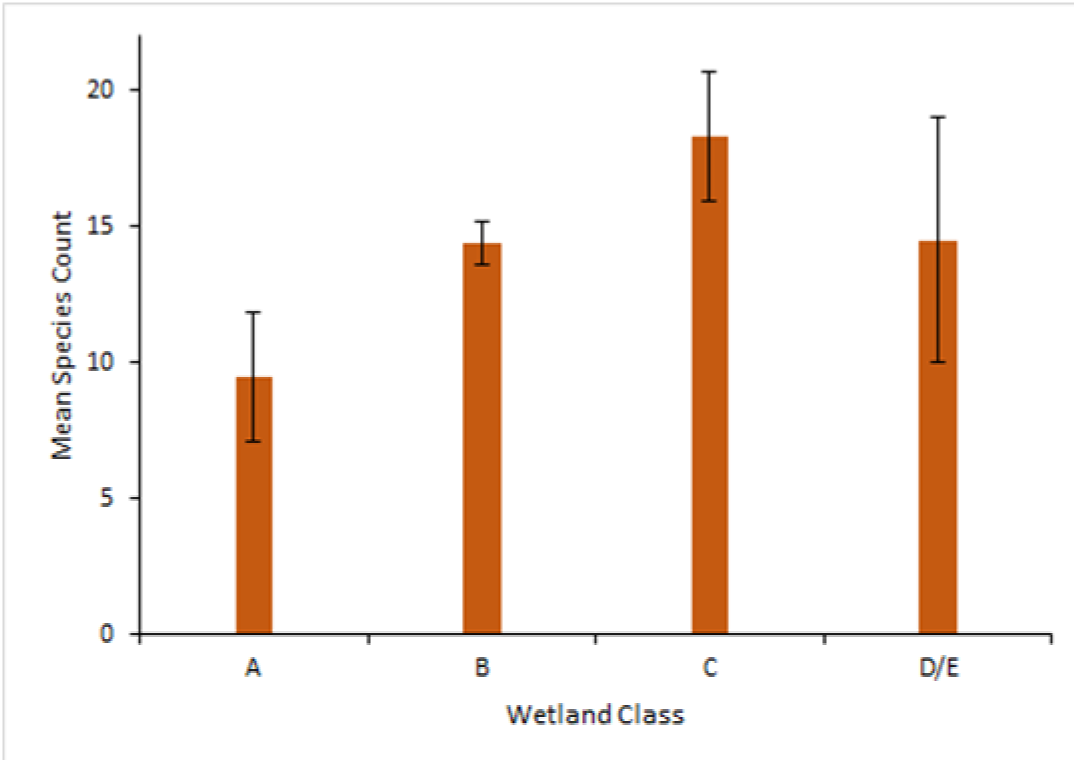

Figure 24. The mean number of species of waterbirds and raptors found in each of the wetland classes.

The mean number of individual birds counted in the different wetland groups showed no clear differences and varied across individual wetlands and individual dates (Figure 25); further detailed analysis is needed to determine if there are differences in the number of individual birds recorded between the wetland groups.

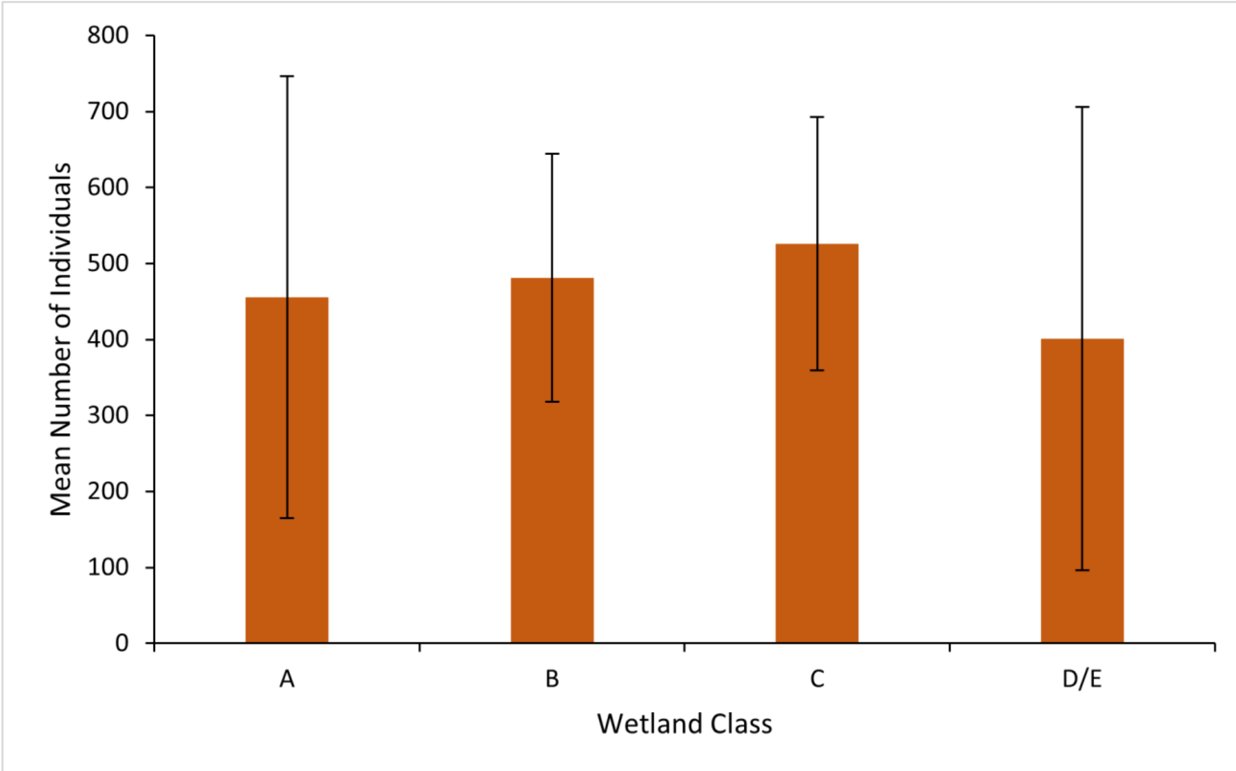

Figure 25. The mean number of individual birds counted in the different wetland classes. Error bars are standard error.

The species composition of birds differed between the different wetland groups. Feeding strategies of birds are often used as a way to classify them, as depending on their feeding strategy they need different wetland conditions. Broadly speaking, ducks and similar birds like geese and coots can be divided into dabbling feeders and diving feeders. Dabbling birds are those that feed on the surface of the water and on land, grazing on vegetation and invertebrates that they can reach near the surface of the water. Diving birds, on the other hand, dive under the water to feed, and are capable of swimming underwater.

The most common waterbird species in group A wetlands were all dabbling feeders (Table 4), while group B, C, and D/E wetlands all had a mix of dabbling and diving species. While dabbling species like Mallards, American Wigeon, and Canada Goose were common across all the wetland classes, diving species like Common Goldeneye, Bufflehead, and Ring-necked Duck were more common in group B, C, and D/E wetlands, because these wetlands contain more water in the spring and thus provide these birds with the conditions they need to hunt successfully. Bufflehead, for example, have been observed to prefer diving in water 1-3m deep (Sandilands, 2005). This difference in the use of wetland classes by species with different feeding strategies was often stark, with only one Ring-necked Duck counted in a group A wetland, while 512 Ring-necked Ducks were counted in group C wetlands (Appendix 10).

Table 4. The five most common species of waterbird found in each of the wetland classes in descending order from the top, as well as the type of feeding strategy each species employs.

Group A	Group B	Group C	Group D/E
American Wigeon (Dabbling)	American Wigeon (Dabbling)	Ring-necked Duck (Diving)	American Coot (Diving)
Mallard (Dabbling)	Mallard (Dabbling)	Common Goldeneye (Diving)	Mallard (Dabbling)
Green-winged Teal (Dabbling)	Canada Goose (Dabbling)	Canada Goose (Dabbling)	Canada Goose (Dabbling)
Northern Pintail (Dabbling)	Northern Pintail (Dabbling)	Bufflehead (Diving)	Ring-necked Duck (Diving)
Canada Goose (Dabbling)	Ring-necked Duck (Diving)	Mallard (Dabbling)	Common Goldeneye (Diving)

Beaver dams appear to play a large part in maintaining the hydrology of group B, C, and D/E wetlands (Section 4.1.3) and are therefore playing a part in increasing species diversity within the Columbia Wetlands complex. Without these wetlands that retain water into the spring, there would be no habitat for diving waterbirds to use on their spring migration.

A particularly striking example of the differences between migratory waterbird use of group A wetlands and group C wetlands can be seen between Site 21 (group C) and Site 24 (group A). Though geographically close (Figure 1), we observed twenty-three species of waterbird and raptors in Site 21 and only nine in Site 24 (Table 5). There were also fewer individual birds observed in Site 24, with 100 individuals observed in Site 24 and 372 observed in Site 21; the most numerous species in Site 24 was American Wigeon (34 individuals observed), while in Site 21 it was Ring-necked Duck (115 individuals observed; Appendix 9). In Site 21, twelve of the species found are diving feeders, and five are dabbling feeders, while in Site 24, two are diving feeders and five are dabbling feeders. Due to Site 24 being a group A wetland, it had little water in it for the first half of the counting period, and so did provide habitat for Killdeer, a shorebird species.

Table 5. Waterbird and raptor species observed during migratory waterbird surveys in April 2022 in Site 21 & Site 24. For Anatidae (ducks, geese, & swans), their feeding strategy is noted.

Site 21 (group C) contained water in spring	**Site 24 (group A)- naturally drained in spring**
American Coot (Diving)	American Wigeon (Dabbling)
American Wigeon (Dabbling)	Canada Goose (Dabbling)
Bald Eagle	Common Goldeneye (Diving)
Bonaparte's Gull	Green-winged Teal (Dabbling)
Bufflehead (Diving)	Hooded Merganser (Diving)
Canada Goose (Dabbling)	Killdeer
Common Goldeneye (Diving)	Mallard (Dabbling)
Common Loon (Diving)	Osprey
Common Merganser (Diving)	Wood Duck (Dabbling)
Greater Scaup (Diving)	
Green-winged Teal (Dabbling)	
Horned Grebe (Diving)	
Hooded Merganser (Diving)	
Lesser Scaup (Diving)	
Mallard (Dabbling)	
Northern Pintail (Dabbling)	
Osprey	
Pied-billed Grebe (Diving)	
Ring-necked Duck (Diving)	
Red-necked Grebe (Diving)	
Red-tailed Hawk	
Sandhill Crane	
Trumpeter Swan (Dabbling)	

Breeding bird surveys were also conducted between May 20th and June 30th, 2022, on the same 16 wetlands (Appendix 1). Six fifteen-minute point counts were completed at each wetland, with counts starting no earlier than half an hour before dawn and finishing no later than four hours after dawn, as per Darvill and Westphal (2020), which uses a Birds Canada Marsh Birds Monitoring Protocol (Birds Canada, 2010). Birds were identified and counted visually and aurally. Eighty-three species of bird were observed during these surveys and active breeding-related behaviour such as singing, copulating, nest-building, nest-sitting, carrying food, and young fledgelings being present were observed for many of these species.

These data have not yet been fully analysed, but species such as Common Loon and Red-necked Grebe were observed nesting in group C wetlands, while species such as Red-winged Blackbird and Common Yellowthroat were observed nesting in all the wetland classes. As these surveys counted birds from across different taxonomic groups, feeding strategies, and nesting strategies, analysing these data needs to take all these factors into account because cavity nesting ducks like Bufflehead require different wetland conditions than small songbirds like Common Yellowthroats. The vegetation within each wetland and surrounding each wetland will also be an important influence in the birds breeding within the different wetlands. For example, Wood Duck are cavity nesters, meaning that they rely on trees with large holes in to build their nests in, while Marsh Wren require dense Bulrush or Cattails in which to build their nests (Cornell Lab of Ornithology, 2019).

Interestingly, Canada Geese, which are ground nesting birds, were observed nesting during the migratory waterbird counts conducted in April, and by May many of the geese already had goslings. This means that they had finished nesting by the time the flood pulse caused the wetland to fill with water, and so did not suffer from their nests being flooded. This indicates a nesting strategy timed to avoid disruption by the natural flood pulse and perhaps to reduce risk of predation, as by the time that raptor species such as ospreys and eagles were raising their young, and thus hunting more, many of the goslings were fairly large and therefore less tempting prey.

4.3 Restoration of wetlands using beaver dam analogues (BDAs)

While there is extensive research on the impacts of beaver dams on wetlands (see above), though as noted above the impacts of beaver dams on extensive floodplain wetland complexes is a novel aspect of this research, there is far less research available on the impacts of Beaver Dam Analogues (BDAs). As a small-scale, low-tech way to restore streams and wetlands they are currently very popular as a restoration technique; however, we don't clearly know if they will mimic natural beaver dams (Lautz *et al*., 2019). Munir and Westbrook (2021) found that in small mountains streams they did mimic the impacts of natural beaver dams in raising the water table and retaining water on the landscape, but Wolf and Hammill (2023) found that BDAs did not support the same diversity of amphibians as natural beaver dams, perhaps because the natural dams were far older than the BDAs and biodiversity does not respond instantly. Thus, understanding how BDAs will impact wetlands within the Columbia Wetlands complex and if and how we can use them as a restoration technique is important for effective wetland management.

We hope that BDAs will, much like natural beaver dams, increase the amount of water retained in wetlands, particularly over the winter, so that open water habitat is available for migratory waterbirds when they migrate through the Columbia Valley before the Columbia River flood pulse begins. In order to determine whether BDAs are a feasible and effective way to increase wetland water retention and thus make different habitats available, we are trialing BDA installation in wetlands within the Columbia Wetlands complex.

In October 2021, two beaver dam analogues were installed in Site 38 (Figure 26); in May 2022, the larger of those dams required repair as it had burst when the wetland ice melted. This repair has held and the BDA is still holding water into Site 38 as of March 2023, resulting in 54 ha of wetland area with increased water retention.

Figure 26. An aerial view of Site 38 in early May 2021. Circled in yellow are the locations where we built two artificial beaver dams in October 2021. At the nearer location, a natural beaver dam can still be seen; this dam blew out in the 2021 flood pulse.

Site 38 was chosen for our first BDAs as a natural beaver dam had blown out in May 2021, and because access was relatively easy. After the BDA was constructed, 0.73 m of water was recorded at the water level logger in October 2022, as compared to only 0.42 m of water being recorded at the water level logger in October 2021 (Figure 27). The decrease in water after the peak of the flood pulse in late June and early July was much less steep in 2022 compared to 2021, suggesting that Site 38 is no longer a group A wetland after the installation of the BDAs, but a group B or C wetland. An increase of ~0.3 m of water across the entire wetland transformed what was open mudflat in late summer and fall 2021 to open water with *Nuphar* sp. growing during the same period in 2022. This is a substantial increase in water that we expect will have impacts on the migratory waterfowl using the wetland in April 2023 (bird surveys will be conducted during this period), based on the differences in migratory waterfowl we saw between wetlands with more and less water retained in April 2022 (see Section 4.2 for details).

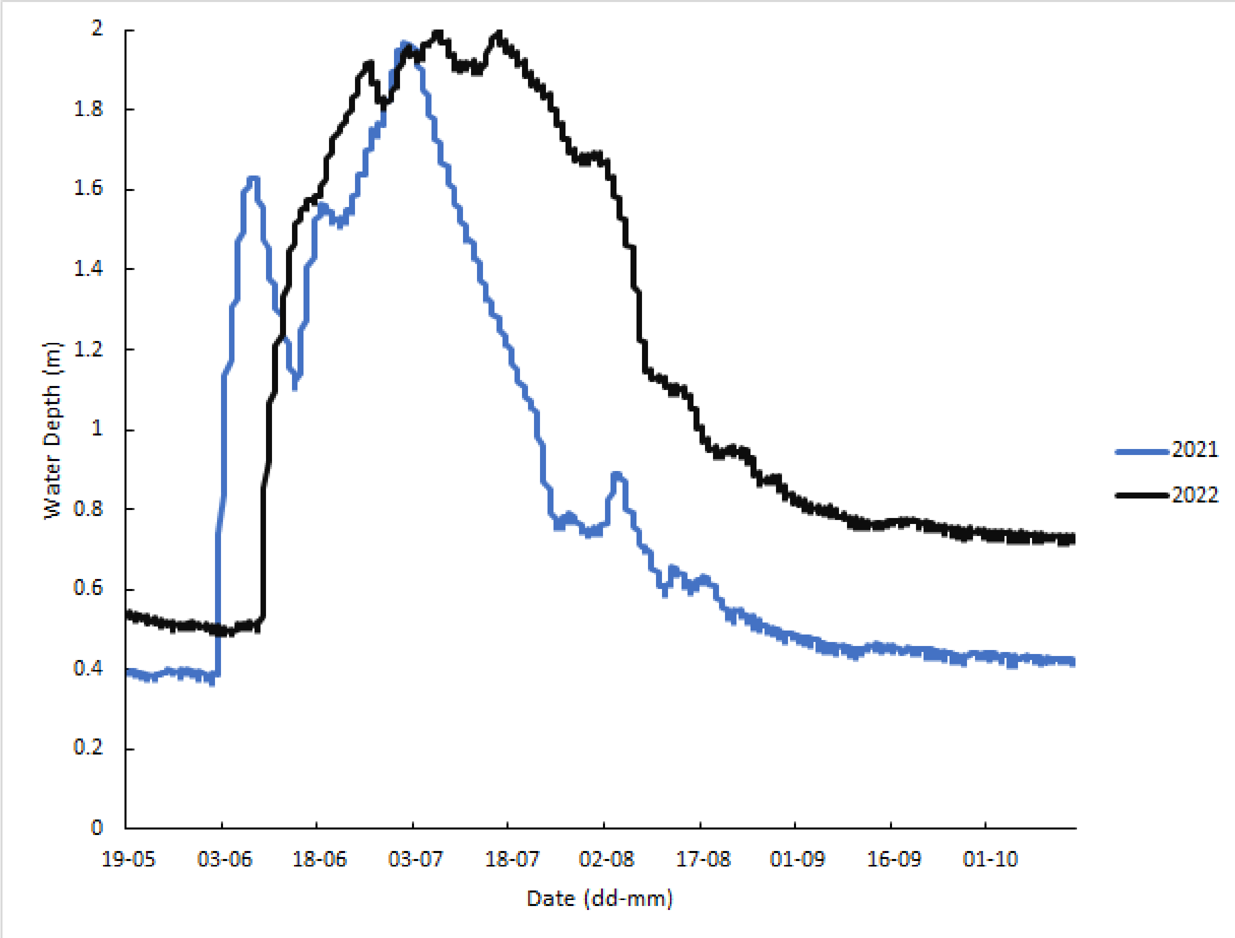

Figure 27. Water depth in metres at the water level logger in Site 38 in 2021 (blue) when the BDA was not present, and 2022 (black) when the BDA was present.

Sites 24, 71, and 145 are being assessed for future BDA construction and a more comprehensive monitoring program in collaboration with Living Lakes Canada, that will also build upon the three years of data already collected through this project. These sites have been identified as being in group A (continuously connected to the Columbia River) so installing BDAs will allow water to be retained in these wetlands where it otherwise would not be. As can be seen in Figure 28, currently these wetlands have very little water in them in the spring and fall. They are also relatively accessible and have levee gaps that are a feasible size to be dammed with BDAs (Table 6). Site 71 had a beaver dam that blew out in spring 2022, so with a BDA we would be repairing that beaver dam.

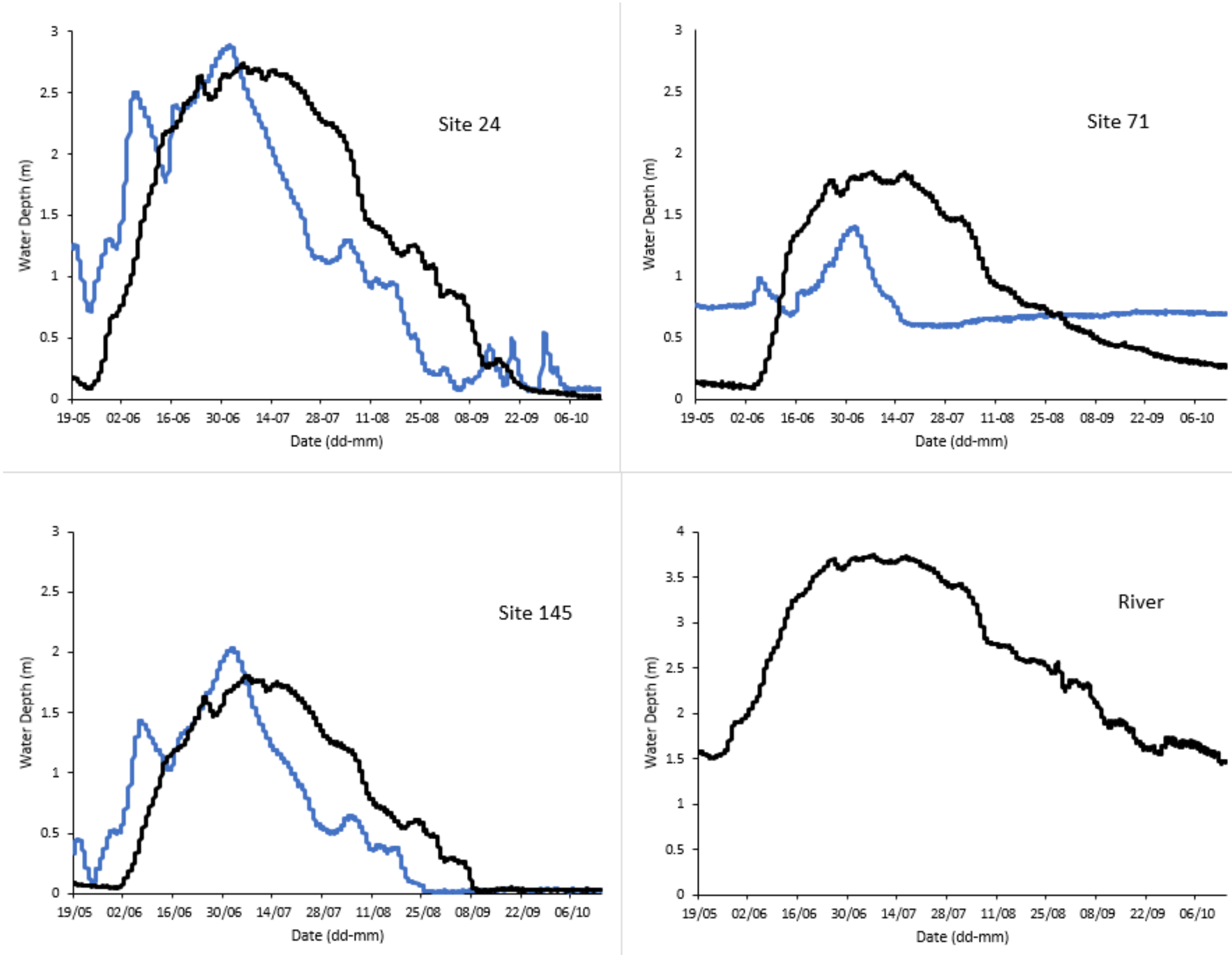

Figure 28.Water depth in 2021 (blue) and 2022 (black) in Sites 24, 71, and 145, and the River, as a comparison for the water depth throughout the year (Note the vertical scale water depth for Sites 24, 71, and 145 is 3m, while for the River it is 4m).

Table 6. Site details for the three sites being assessed for BDA restoration potential

Site Number	Total Levee Gaps	Total Levee Gap Width (m)	Size of Wetland (ha)
24	3	22.5	45.77
71	1	5.6	22.28
145	1	10.5	12.52

The BDA in Site 71 is being planned in collaboration with The Nature Trust (TNT) and ECCC who currently manage this 22.5 ha wetland as part of the federal Columbia National Wildlife Management Area. CWSP has provided all the hydrologic and ecological data on the site and had extensive consultation with TNT and ECCC. ECCC and their consultant Humane Solutions have applied for a permit and construction is anticipated in spring 2023.

We hope that the construction of this BDA in Site 71 will, much like the construction of the BDAs in Site 38, improve the quality of the habitat for waterbirds. During migratory waterbird counts in April 2022, 12 species and 371 individual birds were observed in Site 71 (Table 7; **Appendix** 9). Nine of these species are dabbling feeders (Table 7) and the most common species was Mallard with 119 individuals counted (**Appendix** 9). We anticipate that the BDA retaining more water in the wetland will increase the number of diving species that use the wetland.

Table 7. List of species observed during migratory waterfowl surveys in April 2022 and Site 71. For Anatidae (ducks, geese, and swan), feeding strategy is noted.

Site 71
American Wigeon (Dabbling)
Bufflehead (Diving)
Cinnamon Teal (Dabbling)
Canada Goose (Dabbling)
Green-winged Teal (Dabbling)
Hooded Merganser (Diving)
Mallard (Dabbling)
Northern Pintail (Dabbling)
Northern Shoveler (Dabbling)
Pied-billed Grebe (Diving)
Ring-necked Duck (Dabbling)
Trumpeter Swan (Dabbling)

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5 Acknowledgements

We are very grateful to the funders of this project, Kootenay Connect, Environment and Climate Change Canada, Columbia Basin Trust, and the RDEK’s Columbia Valley Local Conservation Fund. We received abundant help from local landowners who permitted us to access their properties in Columbia Valley. Our field and lab crew of Annie Pankovitch, Jennifer Bowes, Spencer Cairns, Trevor Hahn and incidental helpers were greatly appreciated.

6. Appendices

Appendix 1

List of sites, with associated coordinates, river connectivity, hydrological class, and whether migratory waterbird surveys were conducted.

Site	Easting	Northing	River Connectivity	Hydrological Class	Migratory Waterbird Surveys
21	532535	5652873	Discontinuous	C	Yes
24	535422	5651111	Continuous	A	Yes
29	543167	5641399	Discontinuous	B	No
30	544030	5639666	Continuous	A	Yes
31	545913	5637403	Discontinuous	B	Yes
32	545543	5637069	Continuous	A	No
35	550776	5630949	Discontinuous	B	Yes
36	551130	5630189	Continuous	A	No
38	549892	5630542	Continuous	A	Yes
39	550531	5628689	Discontinuous	B	No
43	555476	5623684	Discontinuous	B	No
47	563287	5612893	No Connectivity	E	No
48	562874	5612685	No Connectivity	E	No
49	563443	5608264	Discontinuous	C	Yes
51	567072	5601686	Continuous	A	No
59	543772	5638706	Continuous	A	No
62	544859	5639039	No Connectivity	D	Yes
64	546804	5635861	Continuous	A	No
68	545273	5635944	Continuous	A	No
69	544325	5639373	No Connectivity	E	Yes
70	551389	5627697	Continuous	A	No
71	550149	5630945	Continuous	A	Yes
110	542996	5638520	No Connectivity	D	No
126	549517	5631250	Discontinuous	B	No
127	549090	5631267	Discontinuous	B	Yes
128	548571	5631699	Discontinuous	B	No
129	528755	5654469	Discontinuous	C	No
130	528565	5654310	Continuous	A	No
131	528247	5655396	Discontinuous	B	Yes
132	533588	5652117	Continuous	A	Yes
137	550568	5629167	No Connectivity	E	No
140	543498	5641456	Discontinuous	C	No
141	540750	5645785	Discontinuous	B	Yes
142	536898	5649710	Discontinuous	B	Yes
143	531008	5653564	Discontinuous	C	Yes

144	523973	5657202	Discontinuous	B	No
145	523706	5657294	Continuous	A	No

Appendix 2

All 76 gaps in the 38 wetlands located during this project, including their length (m), coordinates, the type of flow they allow (from a creek, from the Columbia River, or between different wetlands), the wetland they are associated with, and an estimate of how much flow they allow.

Site	Length (m)	Easting	Northing	Flow Type	Wetland	Flow
71	6.141517	533161.2565	5652049.257	Creek	21	Partial
15	24.893359	534921.5953	5651029.603	River	24	Yes
16	25.458515	535083.1347	5650985.545	River	24	Yes
17	6.376966	536163.5906	5650166.597	River	24	Yes
24	6.901693	535748.6244	5650446.176	River	24	Yes
25	9.590938	535778.3825	5650426.466	River	24	Yes
26	7.612752	535843.7784	5650368.078	River	24	Yes
27	2.548828	536219.5641	5650128.851	River	24	Yes
60	35.005776	536553.798	5649934.089	Between	24	Partial
29	5.92368	543007.8592	5639809.519	Creek	30	Partial
55	25.460025	544233.2534	5639644.455	River	30	Yes
31	6.712468	545243.1177	5637345.398	River	31	Yes
30	22.286735	545364.125	5637022.36	River	32	Yes
65	90.932422	546563.0816	5634839.68	Between	32	Yes
66	11.090475	545807.7941	5636503.909	Between	32	Yes
67	10.915157	545886.1436	5636462.485	Between	32	Yes
53	13.81519	550362.9299	5631117.131	Between	35	Partial
40	6.372885	550496.387	5628803.98	River	36	Partial
44	9.932595	552486.9529	5627571.369	River	36	Partial
45	13.764772	552882.7755	5627313.8	River	36	Partial
46	9.175271	550792.1145	5629304.904	River	36	No
68	3.448838	550938.0983	5629906.766	River	36	Yes
38	6.180095	550328.1779	5630502.364	River	38	Partial
39	5.682428	550426.4626	5629776.155	River	38	Partial
43	10.395809	550941.2605	5630123.205	River	43	Yes
47	8.422075	555290.5646	5623790.791	Between	43	Partial
74	12.408544	555846.0435	5622058.364	River	43	Yes
48	5.038287	564090.6818	5609438.731	River	49	Partial
49	15.135733	566874.8332	5603116.979	River	51	Yes
50	11.169073	567431.2574	5601792.353	River	51	Yes
51	9.42228	566951.0646	5601236.576	Between	51	Partial
52	17.65629	566628.6165	5601069.848	Between	51	Partial
56	14.508731	544030.7112	5638909.891	River	59	Yes
61	18.565673	543815.6679	5638138.925	Between	59	No
62	9.017384	543940.6325	5638161.662	Between	59	No
57	9.321968	544283.8698	5638429.969	River	62	No
63	19.773274	544647.267	5639259.107	River	62	No

Site	Length (m)	Easting	Northing	Flow Type	Wetland	Flow
64	25.447703	544727.0034	5637161.61	Between	63	Partial
34	4.95868	546774.903	5635830.832	River	64	Partial
32	32.859154	545496.9046	5636754.946	River	68	Yes
33	24.892575	545622.712	5634678.128	Between	68	Partial
73	30.805878	545434.7426	5636060.411	River	68	Yes
22	8.435164	544508.4034	5639453.13	River	69	No
41	13.579639	551086.4541	5628003.038	River	70	Yes
42	15.196324	553932.9556	5624641.712	Between	70	Partial
36	3.19426	550147.9652	5631070.201	River	71	Yes
37	1.699973	550166.2158	5631075.159	Partial	71	Partial
35	4.966876	549376.9647	5631479.321	River	127	Partial
70	66.068981	528665.9996	5654545.691	Creek	129	Yes
2	10.272638	527262.3422	5655875.896	River	130	Yes
3	3.195472	527616.9515	5655757.668	River	130	Partial
4	4.431353	527674.8569	5655710.678	River	130	Partial
5	11.556243	527814.753	5655586.71	River	130	Partial
8	10.122296	531115.3832	5652772.752	River	130	Partial
9	12.429047	529844.7854	5653178.558	River	130	Partial
10	26.648345	529539.1244	5653655.251	River	130	Yes
23	10.111973	529186.4756	5653585.359	River	130	Yes
69	14.077658	528631.501	5654545.482	Creek	130	Yes
7	9.093137	528604.1391	5654472.792	Between	130	Partial
11	8.191307	528703.558	5654367.217	Between	130	Partial
6	2.510863	528325.2174	5654688.984	Between	130	Partial
59	6.942217	528473.9195	5654653.568	Between	130	Partial
12	9.707181	531033.2481	5653404.33	Between	130	Partial
58	18.746356	527837.3383	5655567.668	River	131	Partial
13	24.523959	533369.6824	5651651.661	River	132	Yes
14	8.567115	533162.634	5652045.141	Creek	132	Partial
54	3.363489	533069.5823	5651968.738	River	132	Yes
20	13.946944	543150.5186	5641657.533	River	140	Partial
21	14.440718	543647.7704	5640911.673	River	140	Partial
28	6.947139	543589.7137	5640935.59	River	140	No
19	10.277599	540555.085	5645966.617	River	141	Partial
72	16.271294	541065.888	5644627.837	River	141	Partial
18	23.926546	536517.5835	5649725.708	River	142	Partial
0	10.579563	523410.1608	5657727.71	None	145	No
1	10.782324	523617.572	5657580.718	River	145	Yes

Appendix 3

GIS analysis of wetlands on the west benches of Columbia Valley

March 29th, 2023

Camille Des Rosiers-Ste.Marie

Columbia Wetland Stewardship Partners (CWSP) has been contracted to restore a wetland in the headwaters of the Columbia River between Canal Flats and Spillimacheen. A desktop reconnaissance exercise was necessary to scope potential wetland clusters which could be further investigated via a helicopter flight. Wetland selection was narrowed based on criteria for greatest long term restoration success. Criteria included:

1. Located in the west benchlands between Canal Flat and Spillimacheen;
2. Small wetland or lake between 3 – 35 hectares;
3. Not on private or municipal land, and;
4. Not a DIFFUSE wetland; meaning has its own basin and is not on the edge of creek or lake.

The latest provincial spatial databases of wetlands polygons, lake polygons, landownership polygons and hydrologic clusters were used for this exercise (Appendix A). A step-by-step walk through the process is outlined in Appendix B including the narrowing of available polygons per each step. To summarize, the number of available wetland polygons dropped significantly (from 13,185 polygons to 606 polygons) once selected by location (west benchlands). Of these, 592 were found to be less than 35 hectares and 459 of these were less than 3 hectares. Lake polygons were also selected by location (west benchlands) identifying 286 polygons of 11,129 polygons. Of these 286 polygons, 276 were less than 35 hectares. Local knowledge of the area was used to identify 5 zones taking into account hydrologic clusters and private/municipal/conservation land ownership.

These zones are a broad scale method to narrow down the search for the appropriate wetland for restoration. The area of the zones varies therefore further investigation of the individual wetlands are required to further narrow down the zones helicopter reconnaissance.

Appendix A. Provincial data sources used for wetland selection exercise.

Source Name	Description
FWWTLNDSPL_poly_UCRB	Known wetland polygons in the Upper Columbia River, adapted from CHARS works.
EAUBC_Lake_Subset	Known Lake polygons in the Upper Columbia River, adapted from CHARS works.
PMBC_SSpili	Provincial landownership spatial polygons; area south of Spillimacheen
RyanRunoff_BC_Clusters_LT500km^2	Ryan Macdonalds' hydrologic model clusters

Appendix B: Process

- FWWTLNDSPL_poly_UCRB; Select by Location; WestBench polygon
  - 606 out of 13,185 selected
  - Exported WestBenchWetlands.shp
- Select by Attribute; less than 35 hectares
  - 592 out of 606 are less than 35 hectares.
  - Exported WetlandsLess35.shp
- Select by Attribute; less than 3 hectares
  - 459 out of 592 are less than 3 hectares.
- Lakes; Select by Location; WestBench polygon
  - 286 out of 11,129 selected.
  - Exported as LakesWestBench.shp
- LakesWestBench; Select by Attribute; less than 35 hectares
  - 276 out of 286 selected.
- Total 592 Wetlands + 276 Lakes = 868 polygons.

Appendix 4

GIS analysis of wetlands on the west benches of Columbia Valley: Process Used to ID wetland groupings

- FWWTLNDSPL_poly_UCRB; Select by Attribute; AREA_HA <= 5
  - 11721 out of 13185 Selected
  - Exported WetlandSize.shp
- WetlandSize; Select by Location; West side South of Spili polygon titled West.
  - Completely within West polygon; 946 out of 11721 Selected.
  - Exported WestWetlandSize.shp
- WestWetlandSize; Select by Location;
  - Intersect PrivateMunicipal source layer; 141 out of 946 Selected; includes wetlands that only have partial touching into the boundary of Private Municipal; Y in InterPriv
  - Completely within PrivateMunicipal; 75 out of 946 Selected; Y in WithinPriv
- Wetland3; Does not include InterPriv and WithinPriv total 805 polygons
  - Intersect with FishBaseSPili; identification of diffuse wetlands surrounding creek; Creek line intersects wetland poly; some are at terminus of creek (these wetlands ok). 436 of 805 polygons; Y in InterStrea
  - Intersect with EAUBC_Lake_Subset; identification of diffuse wetlands surrounding lakes; 164 of 805 polygons; Y in InterLakes
  - Select by Attribute InterStea Y OR InterLakes Y; 505 out of 805 Selected
  - Select by Attribute more than 3 hec. 66 out of 805 selected; QA these polygons; Wetland6.shp
  - Export 300 remaining polygons to Wetland4.shp
- Wetland4; 300
  - Includes some diffuse wetlands along valley bottom/adjacent to stream.
  - Select by Attribute more than 3 hec. 11 out of 300 selected; Wetland5.shp
- Wetland5; QA/QC 11 wetland polygons

- 705005838; 70500930; adjacent to Columbia River; Y to InterStea
- 705005940; adjacent to Horsethief River; Y to InterStea
- 705014472; 705074363; adjacent to Spillimacheen River; Y to InterStea
- 705014430; In Bugaboo Provincial Park
- 705014389; In Bugaboo Provincial Park; adjacent to Spillimacheen River; Y InterStea
- 705000619; Lake/Pond in middle; Bobby Burns Crk;
- 705005859; In Purcell Wilderness Conservancy
- 5 of 11 were isolated wetlands and not adjacent to creek; Wetland8.shp

· Wetland6; QA/QC 66 wetland polygons

- Isolated; found at terminus of creeks; or creek runs through; pertains it's own basin;
- How large a body of water for it to be diffuse surrounding; Or just open water in the wetland.
- 39 of 66 wetlands were isolated; Wetland7.shp

· Wetland7 and Wetland8 Merge Wetland9.shp; 44 polygons

· Wetland9 with a 5km buffer Wetland9_Buffer

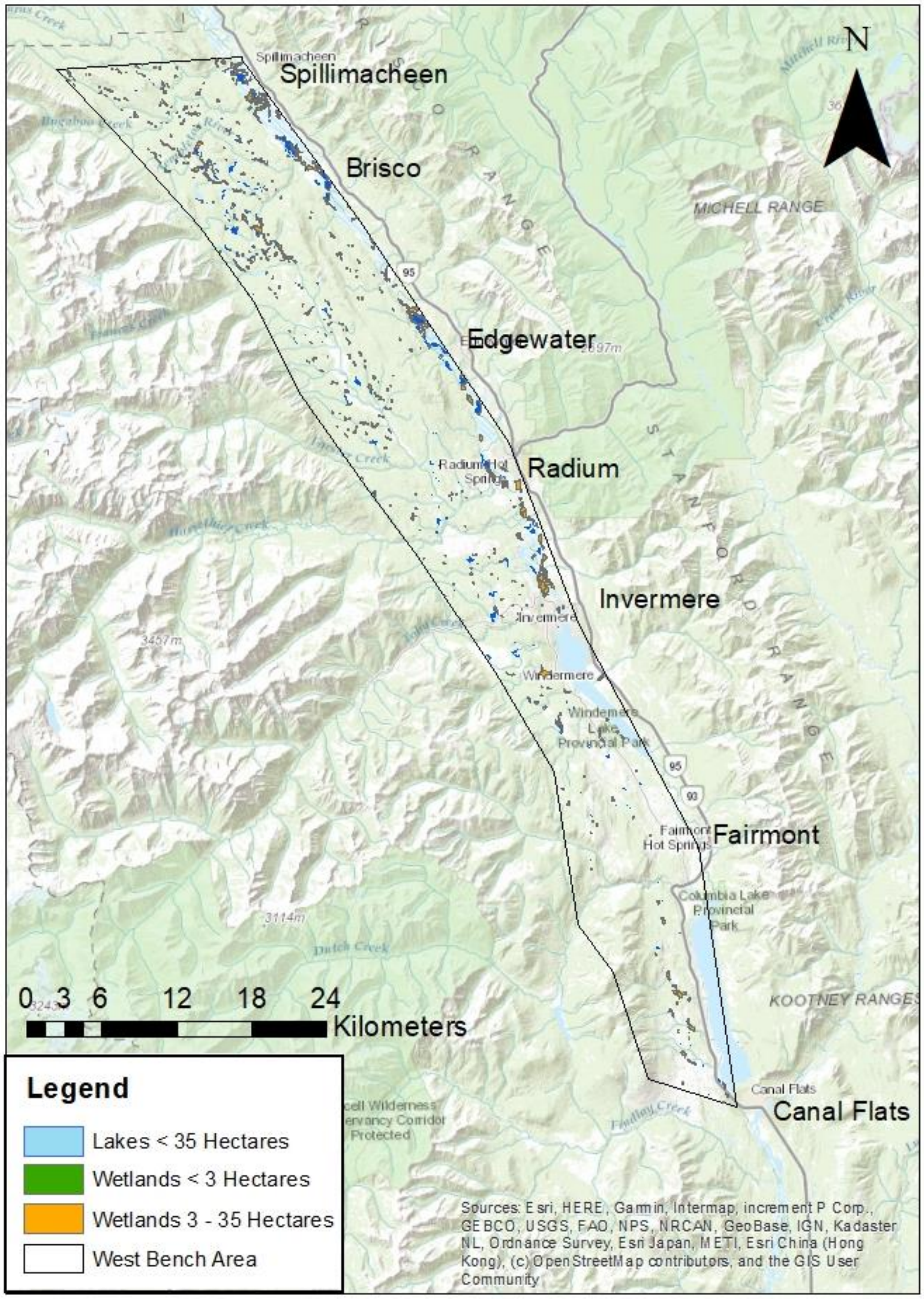
· Wetland9 with a 2.5km buffer Wetland9_Buffer2

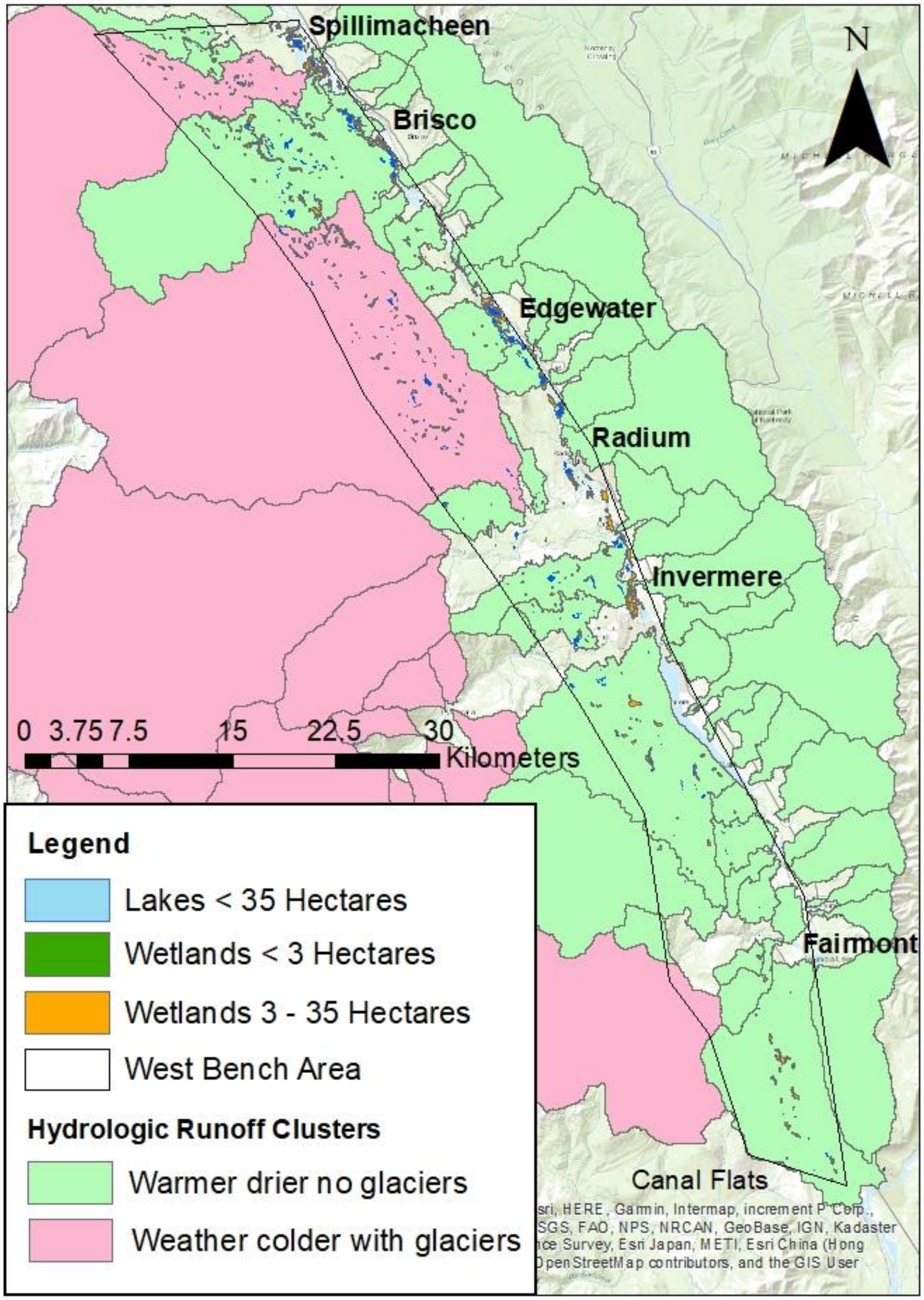
· When Buffers overlayed ZONE polygon created to identify 5 clusters of wetlands within similar Ryan Macdonald's hydrologic model clusters.

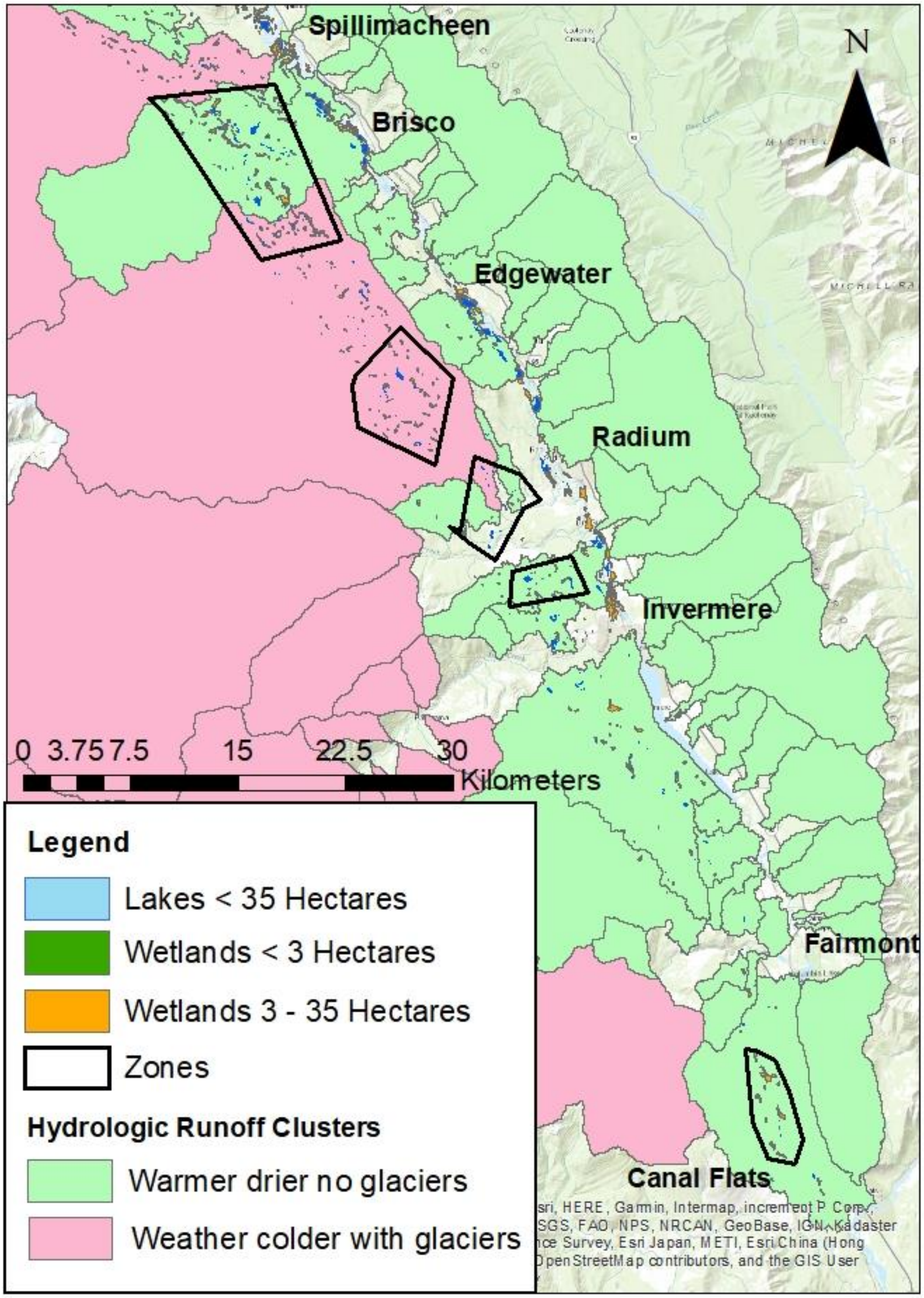
· Intersect Wetland9 with Veg_Comp_Poly for BEC descriptions of wetland polygons.

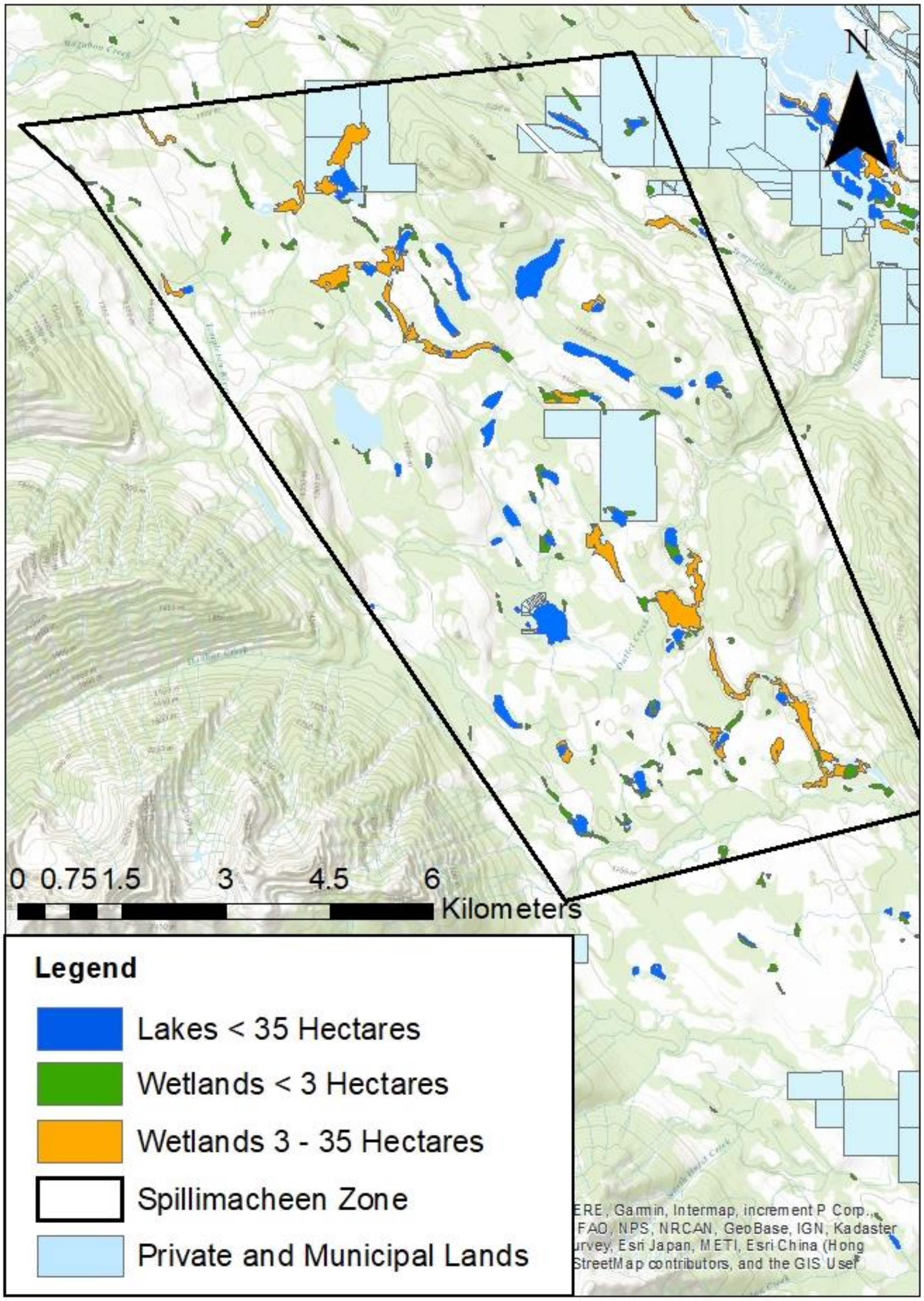
Appendix 5

Desktop survey of small lakes and wetlands (<35ha) on the west side of Columbia Valley. Sites were selected in terms of size, ownership, and hydrologic criteria.

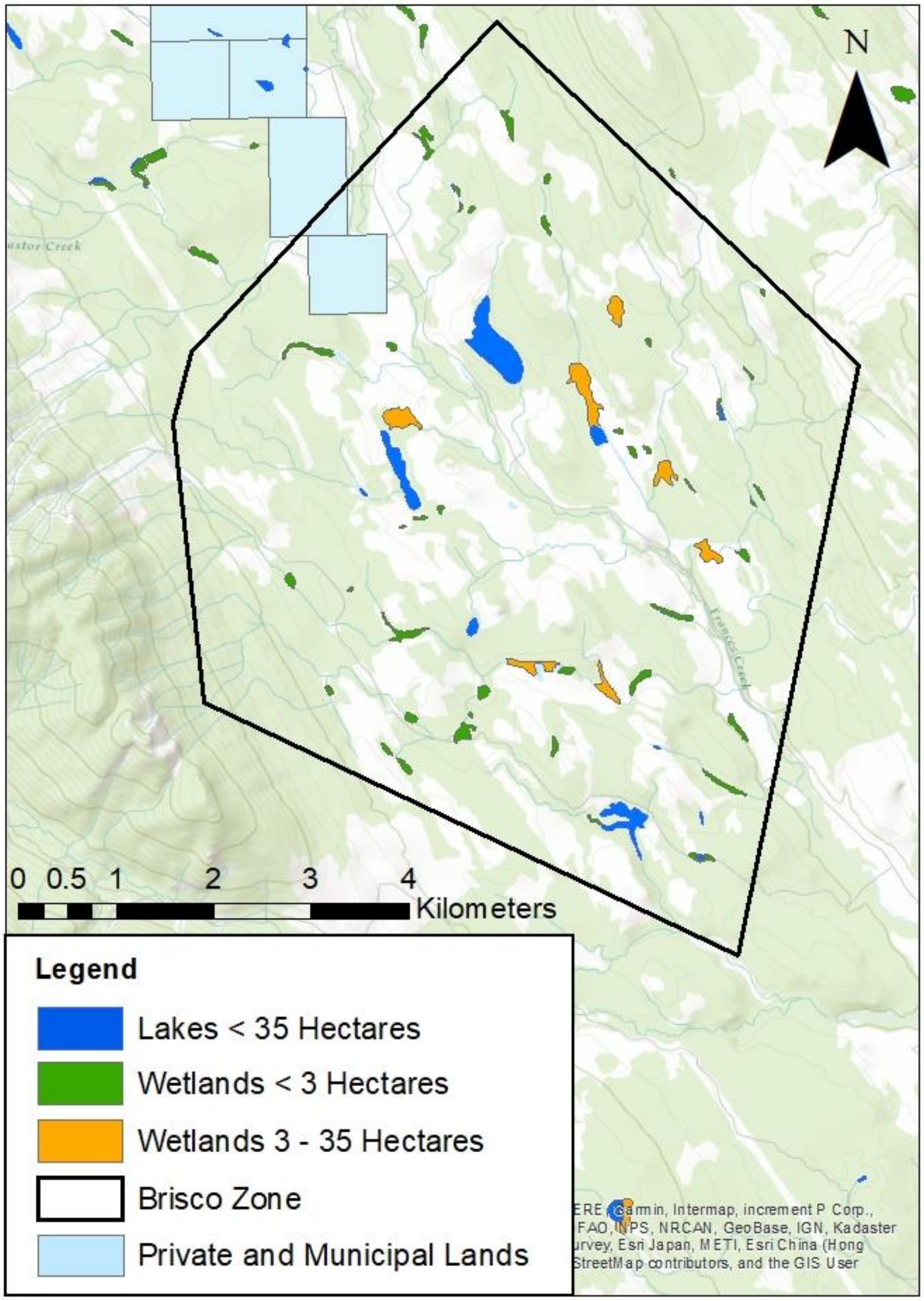


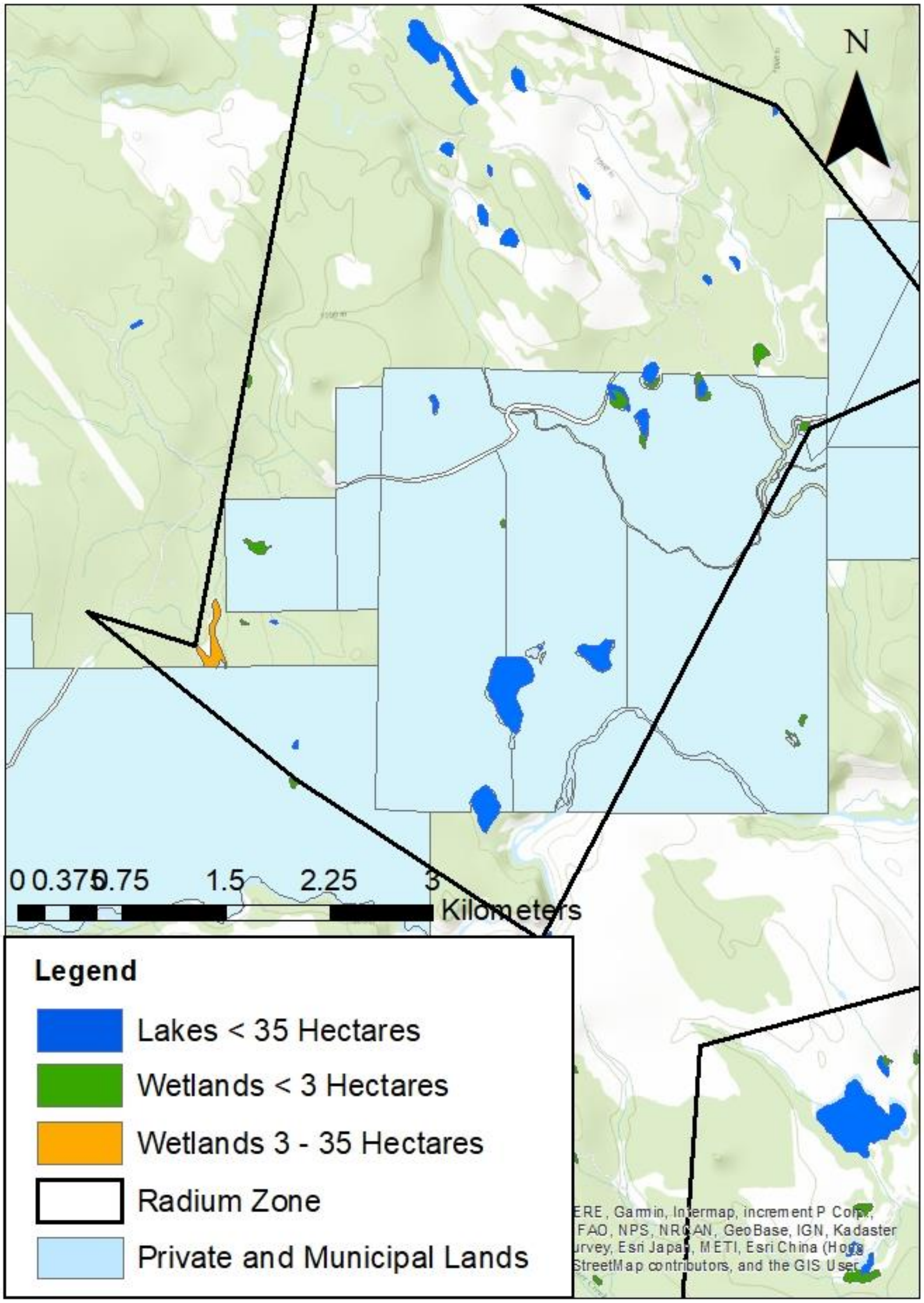

Spillimacheen
N
Brisco
Edgewater
Radium
Invermere
Fairmont
Canal Flats
0 3.75 7.5 15 22.5 30
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
West Bench Area
Hydrologic Runoff Clusters
Warmer drier no glaciers
Weather colder with glaciers

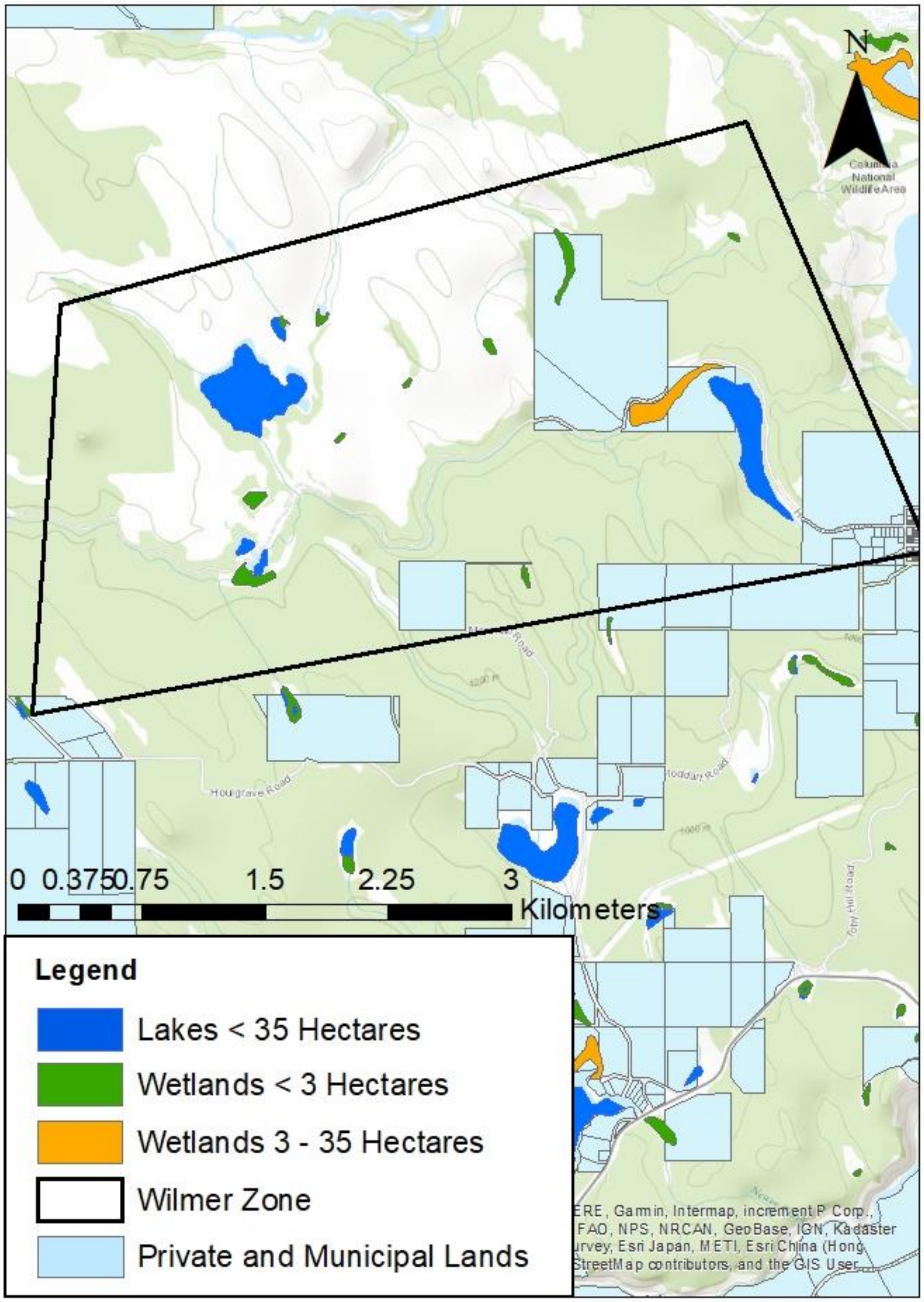

Spillimacheen
Brisco
Edgewater
Radium
Invermere
Fairmont
Canal Flats
N
0 3.75 7.5 15 22.5 30
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
Zones
Hydrologic Runoff Clusters
Warmer drier no glaciers
Weather colder with glaciers

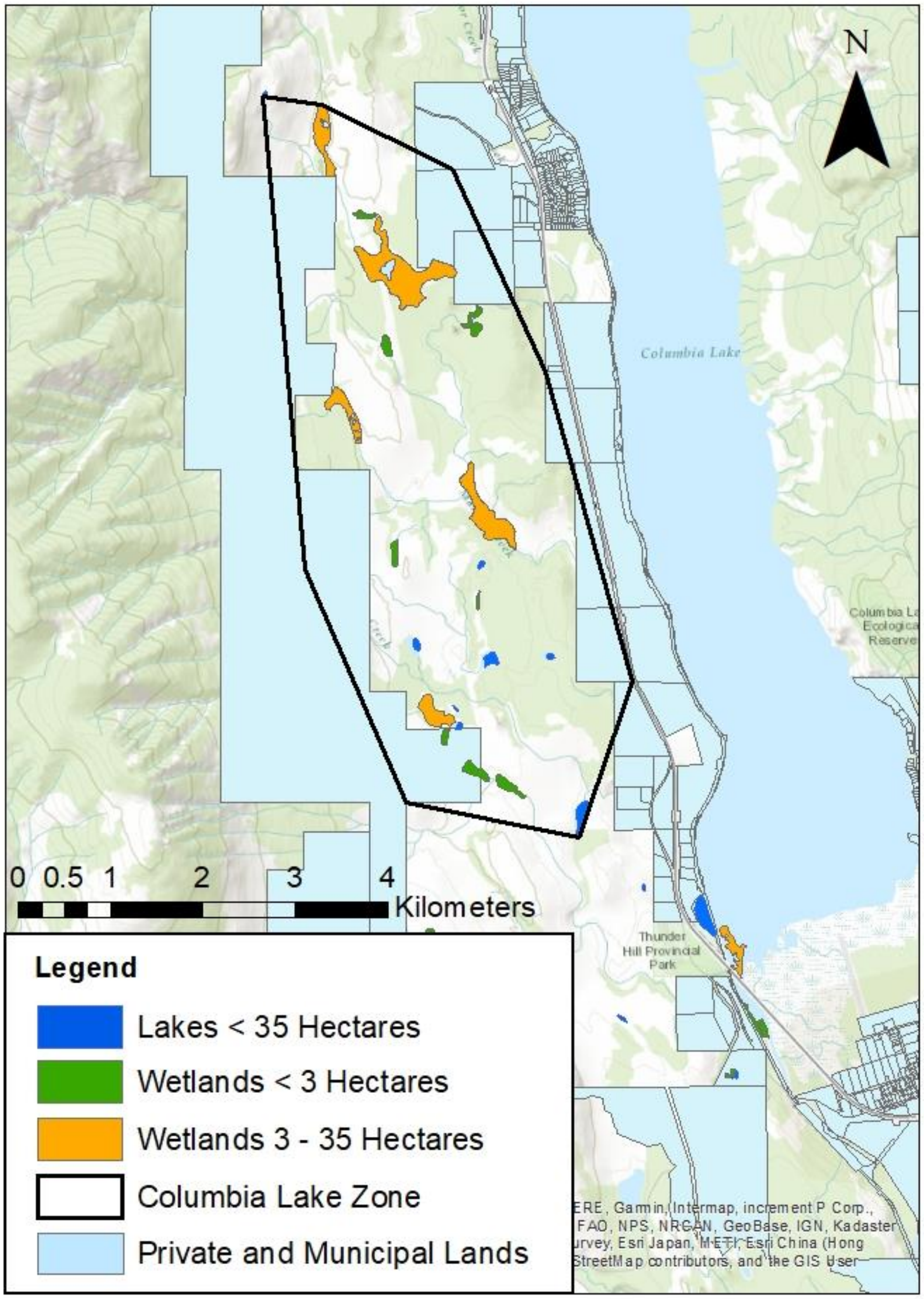


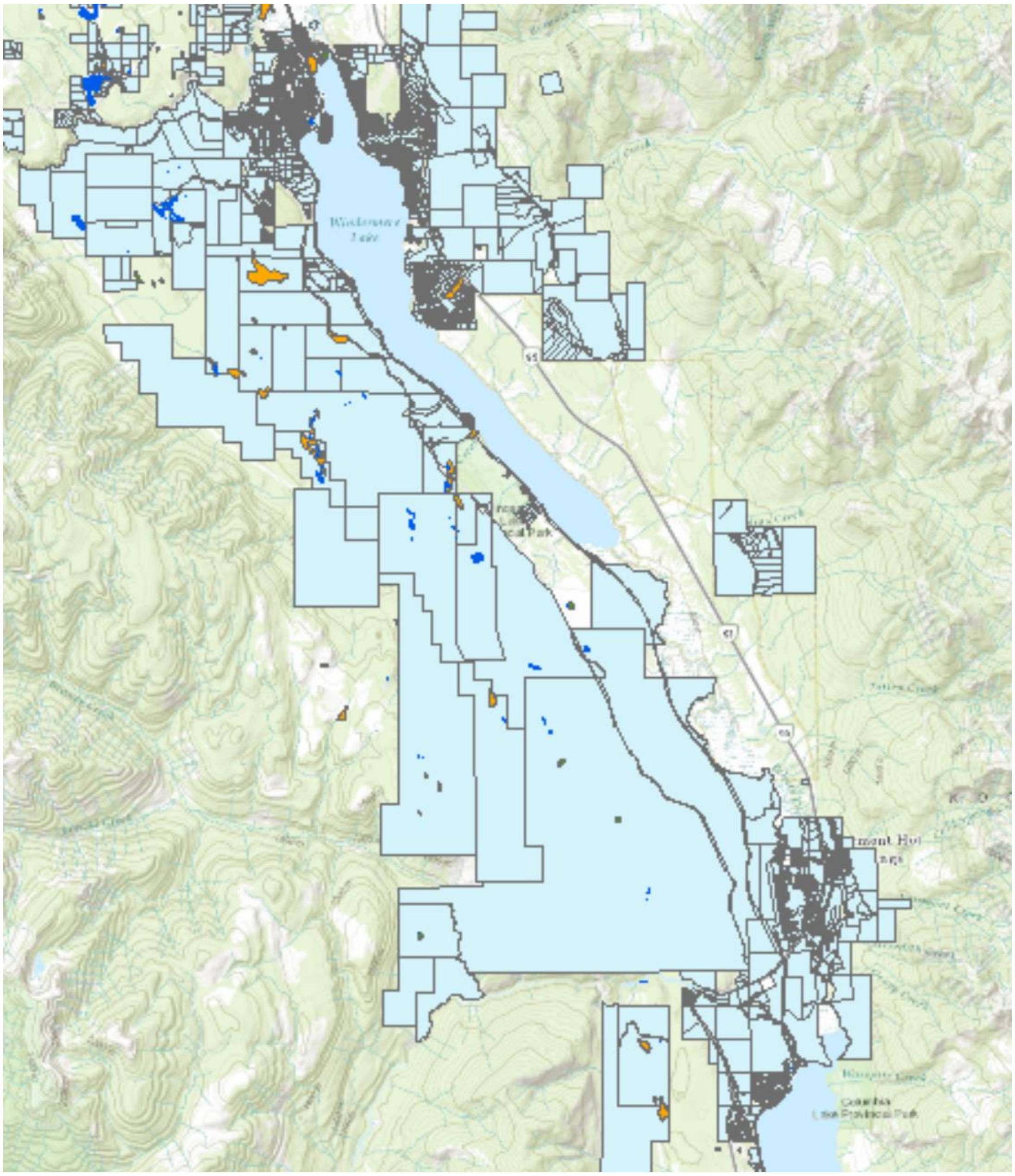
N
0 0.75 1.5 3 4.5 6
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
Spillimacheen Zone
Private and Municipal Lands
ERE, Garmin, Intermap, increment P Corp.,
FAO, NPS, NRCAN, GeoBase, IGN, Kadaster
urvey, Esri Japan, METI, Esri China (Hong
StreetMap contributors, and the GIS User


N
0 0.5 1 2 3 4
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
Brisco Zone
Private and Municipal Lands


N
0 0.375 0.75 1.5 2.25 3
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
Radium Zone
Private and Municipal Lands


N
Columbia National Wildlife Area
Hoodoo Road
Hollgrave Road
0 0.375 0.75 1.5 2.25 3
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
Wilmer Zone
Private and Municipal Lands


N
Columbia Lake
Columbia Lake Ecological Reserve
Thunder Hill Provincial Park
0 0.5 1 2 3 4
Kilometers
Legend
Lakes < 35 Hectares
Wetlands < 3 Hectares
Wetlands 3 - 35 Hectares
Columbia Lake Zone
Private and Municipal Lands



Appendix 6

The top five ecotypes found in the 38 study wetlands, with area in hectares and percent area of each ecotype.

Please refer to Appendix 7 for ecosystem code explanation.

Wetland	**Area_ha**	**1**	**%_1**	**2**	**%_2**	**3**	**%_3**	**4**	**%_4**	**5**	**%_5**
All	2416.45	OW	27.8%	Wm01	14.2%	Wm06	11.6%	Wm02	8.9%	Wm05	8.3%
21	49.47	OW	70.4%	Wm05	13.5%	Wm06	5.6%	RI	4.3%	Fl04	3.6%
24	45.77	OW	31.4%	Fl04	12.1%	Wm01	11.8%	PD	10.5%	Wm06	10.0%
29	8.25	Fm02	33.6%	Wm02	26.2%	Fl04	22.4%	Wm01	11.8%	Wm06	6.0%
30	111.09	OW	26.8%	Ws	22.9%	Wm01	16.2%	Wm02	9.9%	Fm02	7.6%
31	40.22	Ws	26.3%	OW	26.1%	PD	11.5%	Wm06	11.2%	Wm02	9.0%
32	134.60	Wm01	39.1%	OW	15.8%	Wm15	15.7%	Wm02	10.8%	Fl04	6.5%
35	15.73	OW	31.5%	Wm05	28.7%	Wm06	23.4%	Fl04	8.3%	Ws	7.1%
36	207.42	OW	32.2%	Wm06	25.9%	Wm05	9.7%	Wm01	9.7%	Ws	6.5%
38	53.77	OW	65.8%	Wm01	12.3%	Wm02	6.4%	Wm05	5.1%	Fl04	4.8%
39	11.74	OW	35.2%	Wm06	31.9%	Fl04	18.2%	Wm01	9.6%	Ws	2.6%
43	74.54	Ws	23.4%	OW	21.5%	Wm02	16.5%	Wm06	14.5%	Wm01	10.6%
47	78.15	OW	74.3%	Wm05	21.8%	Wm06	3.6%	Ws	0.2%	0.00	0.0%
48	53.40	OW	25.2%	Wm05	24.5%	Fl04	20.7%	Wm06	17.1%	Wm01	8.7%
51	225.76	Wm01	25.7%	OW	18.6%	Wm02	13.6%	Ws	12.2%	Wm06	9.5%
49	61.29	OW	38.3%	Wm05	31.0%	Fl04	7.2%	Fm02	6.9%	Ws	6.7%
59	55.63	Wm01	26.5%	Fl04	26.1%	OW	22.0%	Fm02	10.8%	Wm02	5.1%
62	55.26	OW	28.6%	Wm05	27.0%	Wm06	17.4%	Ws	9.5%	Fl04	5.8%
63	13.13	OW	47.6%	Fm02	14.0%	Wm02	13.1%	Wm06	8.1%	Wm15	6.9%
64	14.39	OW	40.0%	Wm06	17.1%	Fl04	16.3%	Ws	13.2%	Wm05	7.5%
68	134.77	OW	27.4%	Fl04	19.0%	Wm15	16.5%	Wm02	14.3%	Wm01	13.3%
69	11.56	OW	40.9%	Fl04	35.2%	Fm02	9.7%	Wm01	7.2%	Wm05	6.9%
70	326.85	Wm01	24.8%	Wm15	17.0%	OW	15.6%	Ws	11.9%	Wm02	8.6%
71	22.28	OW	34.6%	Wm02	15.6%	Ws04	12.0%	Fl04	11.6%	Fm02	9.4%
110	4.38	Wm05	56.9%	Ws	27.0%	OW	9.1%	Wm01	4.8%	Wm15	1.6%
126	14.49	Wm.mo	21.1%	OW	17.3%	Wm05	15.9%	Ws04	14.0%	Fm02	13.8%
127	16.14	OW	54.6%	Fl04	10.8%	Wm02	8.9%	Wm.mo	8.6%	Ws04	5.8%
128	12.12	Wm02	43.0%	Wm05	18.4%	Ws	17.2%	Fl04	15.0%	Fm02	3.8%
129	31.59	OW	33.3%	Wm05	22.3%	Wm06	17.4%	RI	7.8%	Fl04	7.3%

Wetland	Area_ha	1	%_1	2	%_2	3	%_3	4	%_4	5	%_5
130	275.55	OW	24.3%	Wm06	20.4%	Wm02	19.8%	Fl04	12.6%	Wm01	8.6%
131	29.05	OW	33.7%	Wm05	28.5%	Wm06	21.0%	Ws	10.0%	Wm02	4.4%
132	75.16	OW	30.3%	Wm06	24.4%	PD	8.8%	Fl04	7.8%	Wm05	6.6%
137	16.96	Wm01	30.4%	Fl04	19.4%	Wm05	17.0%	Wm02	13.4%	Fm02	12.9%
140	16.76	OW	41.8%	Wm05	25.3%	Ws	18.6%	Wm06	7.1%	Fm02	3.3%
141	26.73	OW	49.5%	Wm05	27.9%	Fl04	12.3%	Fm02	5.8%	Fm07	3.1%
142	38.76	Wm06	28.0%	Fl04	18.7%	Wm05	16.0%	Wm15	9.1%	Fm02	9.0%
143	22.47	OW	44.7%	Wm05	21.3%	Ws	16.7%	RI	12.7%	Wm06	2.7%
144	18.72	Wm01	22.0%	Wm05	20.4%	Wm06	19.1%	Ws04	18.1%	Fm02	10.1%
145	12.52	Wm01	40.7%	Wm06	19.7%	111.00	11.2%	Wm.mo	9.2%	Fm02	8.6%

Appendix 7

List of ecosystem code descriptions

Key	
Code	**Ecosystem code descriptions**
OW	Shallow Open Water
PD	Pond
LA	Lake
Wm01	Beaked Sedge – Water Sedge Marsh
Wm02	Swamp Horsetail Marsh
Wm05	Cattail Marsh
Wm06	Bulrush Marsh
Wm14	American Common Reed Marsh
Wm15	Bluejoint Reedgrass Marsh
Wm.mo	modified marsh
Wm00	marsh (site association not known)
Ws	shrub swamp (site association not known)
Ws04	Drummond’s willow – Beaked sedge swamp
Ws06	Sitka willow – Sitka sedge swamp
Fa	Active channel flood class
Ff01a	Water birch – Red-osier dogwood – Rose flood fringe phase
Fl04	Sitka willow – Red-osier dogwood – Horsetail low-bench floodplain
Fl06	Sandbar willow low-bench floodplain
Fm02	Cottonwood – Spruce – Dogwood mid-bench floodplain
Fm07	Aspen – Dogwood – Water birch mid-bench floodplain
Fm.mo	Modified mid-bench floodplain
RI	River
GB	Gravel Bar
MU	Mud Flat
RN	Railway
RR	Rural Residential
RZ	Road
CF	Cultivated Field
110	Wet forest class in BGC units.
111	Wet forest class in BGC units.
112	Wet forest class in BGC units.
Ws.mo	Modified shrub swamp

Appendix 8

All 205 dams located within 30m of the 38 study wetlands, with dam length, coordinates of the dam, and the wetland site each dam is associated with.

Dam Number	Dam Length (m)	Easting	Northing	Associated Site
20	20.8219584	531883.763	5652677.912	21
21	11.39934415	531978.9127	5652660.135	21
22	20.31248109	532851.3925	5652160.366	21
27	33.19528593	536501.8172	5649965.472	24
174	33.66709333	536554.0442	5649934.658	24
176	17.02980097	543189.4583	5641619.852	29
178	14.92235967	543196.4549	5641518.565	29
180	9.276479187	543287.2168	5641269.487	29
48	11.15434956	543873.456	5639170.111	30
49	10.40400206	543690.7206	5639187.546	30
50	16.81915898	543164.106	5639339.055	30
51	8.015539931	543074.206	5639329.597	30
52	5.89055246	543217.3644	5639535.729	30
53	13.00617205	543243.6689	5639551.691	30
54	9.107756952	543266.6029	5639551.674	30
61	12.14082268	543667.3552	5639023.156	30
62	11.03226342	543525.3371	5638998.476	30
63	6.86692438	543442.8365	5639017.687	30
64	10.42536672	543366.6392	5639014.366	30
116	5.686822136	543773.9585	5639012.369	30
121	8.512432109	543199.7454	5638928.689	30
77	4.81703026	550898.9843	5629291.457	36
78	54.51498142	551344.1479	5629675.399	36
102	65.77696483	551281.9703	5628600.907	36
103	43.67775788	551259.5096	5628663.639	36
104	19.41177395	551281.0703	5628651.242	36
141	6.6073602	551082.6947	5630128.154	36
142	5.993427486	551020.0212	5630143	36
75	7.924097346	550321.1071	5630444.188	38
76	7.417059888	550382.5851	5629757.37	38
86	36.78732812	555312.0122	5623770.693	43
87	14.54871336	555362.2538	5623790.679	43
88	16.71290972	555447.464	5623861.632	43
89	11.64297555	554923.2589	5623014.049	43
90	11.33253435	555557.9768	5622395.689	43
91	7.848812175	555639.9451	5622188.972	43
92	8.529403068	555684.0803	5622196.326	43
93	9.358097658	555694.3948	5622159.458	43
94	15.88105345	567469.8721	5602066.744	51
95	11.09950639	567407.2258	5602415.197	51

Dam Number	Dam Length (m)	Easting	Northing	Associated Site
96	2.894392402	567127.1647	5603019.04	51
97	4.098537607	567116.4702	5603032.042	51
98	6.414713671	567105.6035	5603039.289	51
99	3.468287799	567079.4919	5603049.383	51
100	3.183615736	567053.3735	5603043.13	51
101	2.413332695	567038.4292	5603035.78	51
60	23.63264852	544045.1273	5638933.77	59
65	5.989028575	543244.3873	5638768.674	59
66	57.51260437	543219.1668	5638345.196	59
68	40.1929364	543434.6751	5638342.349	59
69	44.4268921	543990.5852	5638152.667	59
114	14.21757911	543966.5013	5638575.959	59
115	10.76350855	544029.4582	5638661.38	59
117	15.28150443	544030.4311	5638683.173	59
118	12.48353632	544033.6107	5638712.062	59
119	12.71246471	544037.2764	5638737.524	59
120	16.70067332	544060.2815	5638853.157	59
122	8.512432109	543199.7454	5638928.689	59
153	15.86880136	543214.4561	5638358.738	59
154	3.678419304	543925.4048	5638181.04	59
155	21.75688029	543832.4946	5638157.112	59
184	57.51260437	543219.1668	5638345.196	59
188	228.0726982	543119.9831	5638566.982	59
204	15.86880136	543214.4561	5638358.738	59
182	17.21511562	544648.1146	5639260.023	62
190	27.24707926	544687.3913	5639144.577	62
192	10.747736	544355.0377	5638693.968	62
194	11.59548056	544631.993	5639044.945	62
196	6.19959464	544657.8396	5639068.016	62
70	24.87238694	544728.1912	5637160.225	63
71	5.289120051	544702.1047	5636965.053	63
72	6.894809305	544885.8892	5636806.865	63
124	14.0621532	544594.2665	5637403.192	63
125	8.787594013	544542.9251	5637385.145	63
126	46.71025985	544375.4659	5637396.877	63
127	38.01554249	544384.0746	5637349.99	63
128	53.48549909	544379.8144	5637282.288	63
129	26.60420881	544227.0492	5637125.653	63
130	15.61112965	544099.6712	5637044.168	63
131	34.0255288	544508.612	5636869.505	63
132	38.50734726	544552.9115	5636899.399	63
133	11.26289945	544578.4121	5636968.023	63
134	10.08308518	544592.924	5636914.852	63
135	22.12927304	544589.1667	5637036.304	63
136	38.18154177	544599.1273	5637259.571	63

Dam Number	Dam Length (m)	Easting	Northing	Associated Site
137	24.98998627	544414.9181	5637468.998	63
138	14.57267652	544570.2991	5637539.647	63
139	14.24518645	544583.5215	5637546.482	63
140	4.473474703	546779.6422	5635830.403	64
73	6.340880715	544909.851	5635599.701	68
55	16.97718033	544519.2008	5639457.443	69
56	10.90865858	544499.9303	5639445.723	69
57	12.20493873	544560.4434	5639394.434	69
58	12.95008525	544568.8819	5639380.114	69
59	14.14523678	544606.6882	5639315.849	69
123	7.832788083	544282.0306	5638428.913	69
183	17.21511562	544648.1146	5639260.023	69
191	27.24707926	544687.3913	5639144.577	69
193	10.747736	544355.0377	5638693.968	69
195	11.59548056	544631.993	5639044.945	69
197	6.19959464	544657.8396	5639068.016	69
79	13.99893496	551584.4135	5627175.14	70
80	22.48690522	552638.8535	5626629.738	70
81	53.95107034	552539.646	5626463.067	70
82	11.47830653	553316.3602	5625483.918	70
83	12.48836419	553782.5229	5624999.733	70
84	13.54537929	553926.9103	5624745.101	70
85	15.74406838	553934.473	5624698.005	70
74	3.330902528	550146.6603	5631065.013	71
67	57.51260437	543219.1668	5638345.196	110
109	20.47997569	543152.4891	5638343.28	110
110	17.56620542	543122.8712	5638370.972	110
111	228.0726982	543119.9831	5638566.982	110
185	57.51260437	543219.1668	5638345.196	110
189	228.0726982	543119.9831	5638566.982	110
205	15.86880136	543214.4561	5638358.738	110
112	24.87036762	548769.4795	5631059.356	127
168	12.83011272	529487.6035	5654136.267	129
198	43.78199591	528884.9565	5654251.95	129
200	8.738730114	528702.7816	5654348.923	129
5	10.10116967	527884.3246	5654915.972	130
9	28.65643836	528666.2969	5654121.042	130
14	23.57765208	529766.6774	5653296.042	130
15	15.7996017	529789.3579	5653245.808	130
16	26.28240642	529807.5457	5653215.552	130
17	4.572128889	529855.9868	5653182.994	130
18	15.33885402	529847.8522	5653153.562	130
143	8.738730114	528702.7816	5654348.923	130
158	15.90090027	527741.5506	5655680.16	130
160	18.67018682	527781.3418	5655648.374	130

Dam Number	Dam Length (m)	Easting	Northing	Associated Site
162	18.74633477	527837.3383	5655567.668	130
164	251.3677277	527912.9961	5655487.06	130
166	21.1253051	528267.4843	5654710.863	130
169	12.83011272	529487.6035	5654136.267	130
170	9.150838712	530389.5757	5653779.563	130
172	23.7791923	530992.0868	5653454.664	130
186	12.00875519	530479.7264	5653715.657	130
199	43.78199591	528884.9565	5654251.95	130
201	8.738730114	528702.7816	5654348.923	130
202	6.586676318	527724.1915	5655697.445	130
4	251.3677277	527912.9961	5655487.06	131
6	14.9139232	528440.1466	5654698.844	131
7	20.32910335	528468.0097	5654676.731	131
8	4.818749721	528568.8012	5654610.742	131
159	15.90090027	527741.5506	5655680.16	131
161	18.67018682	527781.3418	5655648.374	131
163	18.74633477	527837.3383	5655567.668	131
165	251.3677277	527912.9961	5655487.06	131
167	21.1253051	528267.4843	5654710.863	131
203	6.586676318	527724.1915	5655697.445	131
23	5.313056809	533125.585	5652019.866	132
24	17.13777724	533274.031	5651746.406	132
25	24.01796335	533354.626	5651649.852	132
26	28.16099841	533449.8432	5651388.251	132
106	215.6242279	533946.5331	5651342.992	132
107	175.773267	533995.5524	5651297.784	132
145	57.35882699	533945.8429	5651443.138	132
146	17.19993713	533206.9348	5651792.798	132
147	49.5387546	533360.7547	5651627.191	132
148	33.28321147	533493.9661	5651330.871	132
43	12.70015057	543034.1416	5641994.525	140
44	17.02980097	543189.4583	5641619.852	140
45	14.92235967	543196.4549	5641518.565	140
46	9.276479187	543287.2168	5641269.487	140
47	16.65995123	543625.8396	5641015.326	140
177	17.02980097	543189.4583	5641619.852	140
179	14.92235967	543196.4549	5641518.565	140
181	9.276479187	543287.2168	5641269.487	140
33	16.31483538	540533.3744	5645922.75	141
34	3.39630924	540601.6183	5645961.002	141
35	2.0494965	540639.7599	5645933.78	141
36	27.55144629	540577.2071	5645591.607	141
37	16.69144489	540594.1131	5645549.42	141
38	10.16396624	540769.9248	5644896.073	141
39	26.79618316	540819.0963	5644890.378	141

Dam Number	Dam Length (m)	Easting	Northing	Associated Site
40	97.34567222	540846.2159	5644812.51	141
41	40.70090355	540987.2972	5644724.055	141
42	42.43482589	541085.2463	5644652.003	141
108	3.425558988	540949.4942	5644698.483	141
113	24.60953576	541186.1162	5644590.285	141
151	3.583882357	541073.2268	5644645.278	141
152	8.236681881	540555.1939	5645967.634	141
28	12.64490827	536694.6906	5649848.495	142
29	15.96209287	536730.5913	5649820.146	142
30	7.311350338	536625.7875	5649711.798	142
31	14.61444303	536705.5768	5649668.956	142
32	19.31345963	536787.3652	5649665.789	142
149	8.683565062	536963.1865	5649259.246	142
150	1.828127316	536940.5027	5649246.233	142
175	33.66709333	536554.0442	5649934.658	142
10	9.150838712	530389.5757	5653779.563	143
11	17.9190107	530518.4906	5653638.865	143
12	48.75530072	530858.7329	5653628.088	143
13	23.7791923	530992.0868	5653454.664	143
19	15.75591314	531736.763	5652778.99	143
105	12.00875519	530479.7264	5653715.657	143
144	10.51319622	531411.3112	5652956.871	143
171	9.150838712	530389.5757	5653779.563	143
173	23.7791923	530992.0868	5653454.664	143
187	12.00875519	530479.7264	5653715.657	143
156	33.92988671	523785.8263	5657232.937	144
1	63.44243087	523415.3662	5657702.465	145
2	6.224595358	523599.3211	5657564.161	145
3	45.85672316	523270.1802	5657780.721	145
157	33.92988671	523785.8263	5657232.937	145

Appendix 9

Migratory waterbird data collected

Site	Wetland Group	Round	AMCO	AMWI	BAEA	BAGO	BEKI	BOGU	BUFF	BWTE	CACG	CANV	CITE	CNGO	COGO
21	C	Count of Individuals	4	2	5	0	0	13	22	0	0	0	0	71	78
21	C	Count of Days Recorded	2	1	3	0	0	1	5	0	0	0	0	6	4
24	A	Count of Individuals	0	34	0	0	0	0	0	0	0	0	0	5	6
24	A	Count of Days Recorded	0	1	0	0	0	0	0	0	0	0	0	2	1
30	A	Count of Individuals	0	0	2	0	0	0	0	0	0	0	0	29	0
30	A	Count of Days Recorded	0	0	2	0	0	0	0	0	0	0	0	3	0
31	B	Count of Individuals	2	259	14	0	1	0	14	0	0	0	0	63	20
31	B	Count of Days Recorded	1	3	4	0	1	0	4	0	0	0	0	6	5
35	B	Count of Individuals	0	0	0	0	2	0	0	0	0	0	1	33	9
35	B	Count of Days Recorded	0	0	0	0	1	0	0	0	0	0	1	4	4
38	B	Count of Individuals	0	409	7	0	0	0	29	0	0	0	0	69	4
38	B	Count of Days Recorded	0	6	2	0	0	0	6	0	0	0	0	6	2
49	C	Count of Individuals	70	0	0	10	0	0	116	0	0	0	0	55	146
49	C	Count of Days Recorded	2	0	0	3	0	0	5	0	0	0	0	5	5
62	D/E	Count of Individuals	153	35	0	0	0	0	44	0	0	1	1	103	51
62	D/E	Count of Days Recorded	4	3	0	0	0	0	4	0	0	1	1	6	6
69	D/E	Count of Individuals	2	5	1	0	0	0	12	0	0	0	0	23	6
69	D/E	Count of Days Recorded	1	2	1	0	0	0	3	0	0	0	0	6	3
71	A	Count of Individuals	0	39	0	0	0	0	15	0	0	0	2	13	0
71	A	Count of Days Recorded	0	4	0	0	0	0	5	0	0	0	1	4	0
127	B	Count of Individuals	0	2	0	0	0	0	53	0	0	0	0	41	30
127	B	Count of Days Recorded	0	1	0	0	0	0	5	0	0	0	0	5	5
131	B	Count of Individuals	27	8	6	0	0	0	10	0	2	0	0	107	17
131	B	Count of Days Recorded	3	2	3	0	0	0	3	0	1	0	0	6	5
132	A	Count of Individuals	4	404	4	0	0	0	0	0	0	0	0	58	0
132	A	Count of Days Recorded	1	5	2	0	0	0	0	0	0	0	0	5	0
141	B	Count of Individuals	1	0	2	0	0	0	7	0	2	0	0	36	58
141	B	Count of Days Recorded	1	0	1	0	0	0	4	0	1	0	0	6	6
142	B	Count of Individuals	15	6	0	0	0	0	4	0	0	0	0	152	10
142	B	Count of Days Recorded	6	1	0	0	0	0	2	0	0	0	0	6	3
143	C	Count of Individuals	0	56	1	2	0	0	22	0	0	0	0	48	12
143	C	Count of Days Recorded	0	2	1	1	0	0	4	0	0	0	0	6	4

COLO	COME	EAGR	EUWI	GBHE	GOEA	GRSC	GWTE	HOGR	HOME	KILL	LESC	MALL	NOHA	NOPI	NSHO	OSPR	PBGR	REDH
3	3	0	0	0	0	4	1	2	12	0	4	12	0	1	0	1	1	0
2	1	0	0	0	0	1	1	1	3	0	2	3	0	1	0	1	1	0
0	0	0	0	0	0	0	34	0	5	2	0	11	0	0	0	1	0	0
0	0	0	0	0	0	0	2	0	2	2	0	4	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	18	0	2	151	0	32	0	0	1	0
0	0	0	0	0	0	0	0	0	4	0	1	6	0	2	0	0	1	0
6	0	0	0	0	0	0	0	0	20	0	0	15	0	0	0	4	0	0
3	0	0	0	0	0	0	0	0	4	0	0	4	0	0	0	3	0	0
0	0	0	1	0	0	0	212	0	8	8	0	159	0	423	15	6	0	0
0	0	0	1	0	0	0	5	0	4	3	0	6	0	6	3	3	0	0
2	4	0	0	0	0	0	2	0	26	0	76	17	2	0	0	1	5	5
1	1	0	0	0	0	0	1	0	4	0	2	5	1	0	0	1	3	1
0	0	0	0	0	0	0	6	0	11	0	19	110	1	39	24	0	1	0
0	0	0	0	0	0	0	1	0	4	0	1	6	1	1	2	0	1	0
0	0	0	0	0	0	0	0	0	2	0	2	23	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	1	5	0	0	0	0	0	0
0	0	0	0	0	0	0	21	0	8	0	0	119	0	111	32	0	3	0
0	0	0	0	0	0	0	3	0	2	0	0	5	0	5	2	0	2	0
0	0	0	0	0	1	0	0	0	52	1	12	19	0	0	2	0	0	0
0	0	0	0	0	1	0	0	0	5	1	1	5	0	0	1	0	0	0
0	20	0	0	4	0	0	0	0	4	0	0	196	2	2	0	0	4	0
0	1	0	0	2	0	0	0	0	2	0	0	5	2	1	0	0	2	0
0	2	0	0	0	0	0	310	0	35	3	0	284	0	177	12	1	0	0
0	1	0	0	0	0	0	4	0	5	2	0	6	0	6	2	1	0	0
0	2	0	0	0	1	0	0	0	22	0	2	51	0	0	0	0	1	0
0	1	0	0	0	1	0	0	0	3	0	1	6	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	8	0	0	46	0	1	2	0	9	0
0	0	0	0	0	0	0	0	0	3	0	0	6	0	1	1	0	5	0
0	0	1	0	0	0	0	0	0	9	2	24	75	0	1	0	0	4	0
0	0	1	0	0	0	0	0	0	3	1	1	6	0	1	0	0	3	0

RNDU	RNGR	RTHA	SACR	SORA	TRUS	TUSW	WODU	Total
115	4	2	2	0	10	0	0	372
5	3	1	1	0	4	0	0	23
0	0	0	0	0	0	0	2	100
0	0	0	0	0	0	0	1	9
0	0	0	0	0	0	0	0	50
0	0	0	0	0	0	0	0	3
29	3	0	0	0	9	0	2	620
4	2	0	0	0	4	0	1	16
2	0	1	0	0	1	0	0	94
1	0	1	0	0	1	0	0	11
0	0	1	0	0	6	12	0	1369
0	0	1	0	0	2	1	0	16
314	0	0	0	0	8	0	0	859
5	0	0	0	0	4	0	0	17
95	0	0	0	1	10	0	1	706
6	0	0	0	1	5	0	1	19
20	0	0	0	0	0	0	0	96
4	0	0	0	0	0	0	0	10
1	0	0	0	0	7	0	0	371
1	0	0	0	0	2	0	0	12
72	0	0	0	0	2	0	2	289
5	0	0	0	0	1	0	1	13
102	0	1	0	0	11	0	0	523
5	0	1	0	0	4	0	0	17
0	0	0	2	0	5	0	0	1301
0	0	0	1	0	2	0	0	14
16	0	0	0	0	0	0	1	202
5	0	0	0	0	0	0	1	14
5	0	1	0	0	8	0	2	269
2	0	1	0	0	4	0	1	14
83	0	0	0	0	6	0	0	346
4	0	0	0	0	3	0	0	15

Appendix 10

Number of individual birds of each species observed in each wetland group

Wetland Group	A	B	C	D/E	English Species Name
AMCO	4	45	74	155	American Coot
AMWI	477	684	58	40	American Wigeon
BAEA	6	29	6	1	Bald Eagle
BAGO	0	0	12	0	Barrow's Goldeneye
BEKI	0	3	0	0	Belted Kingfisher
BOGU	0	0	13	0	Bonaparte's Gull
BUFF	15	117	160	56	Bufflehead
BWTE	0	0	0	0	Blue-winged Teal
CACG	0	4	0	0	Cackling Goose
CANV	0	0	0	1	Canvasback
CITE	2	1	0	1	Cinnamon Teal
CNGO	105	501	174	126	Canada Goose
COGO	6	148	236	57	Common Goldeneye
COLO	0	6	5	0	Common Loon
COME	2	22	7	0	Common Merganser
EAGR	0	0	1	0	Eared Grebe
EUWI	0	1	0	0	Eurasian Wigeon
GBHE	0	4	0	0	Great Blue Heron
GOEA	0	2	0	0	Golden Eagle
GRSC	0	0	4	0	Greater Scaup
GWTE	365	212	3	6	Green-winged Teal
HOGR	0	0	2	0	Horned Grebe
HOME	48	132	47	13	Hooded Merganser
KILL	5	9	2	0	Killdeer
LESC	0	16	104	21	Lesser Scaup
MALL	433	637	104	133	Mallard
NOHA	0	2	2	1	Northern Harrier
NOPI	288	458	2	39	Northern Pintail
NSHO	44	19	0	24	Northern Shoveler
OSPR	2	10	2	0	Osprey
PBGR	3	15	10	1	Pied-billed Grebe
REDH	0	0	5	0	Redhead
RNDU	1	226	512	115	Ring-necked Duck
RNGR	0	3	4	0	Red-necked Grebe
RTHA	0	4	2	0	Red-tailed Hawk
SACR	2	0	2	0	Sandhill Crane
SORA	0	0	0	1	Sora
TRUS	12	37	24	10	Trumpeter Swan
TUSW	0	12	0	0	Tundra Swan
WODU	2	7	0	1	Wood Duck