Conservation and Climate Change Mitigation in Columbia Wetlands: the role of beaver

March 31, 2022

By

Catriona Leven, Dr. Rebecca Rooney & Dr. Suzanne Bayley

In partial fulfillment of agreement SRA# 088420, University of Waterloo

Submitted to Columbia Wetlands Stewardship Partners

The Columbia Wetlands Stewardship Partners

Columbia Basin trust

Regional District of East Kootenay

Kootenay Connect

Environment and Climate Change Canada
Environnement et Changement climatique Canada

University of Waterloo

Contents

1.0 Executive Summary

As part of the 4-year study into the Columbia Wetlands, we are conducting research into the impacts of beaver dams on individual wetlands within the Columbia Wetlands complex. As this is a 2-year project, in this report we present preliminary results and describe the completed and ongoing work. 38 study wetlands are being studied for this research, covering 2395.61 ha or approximately 9% of the total area of the Columbia Wetlands.

Between May and October 2021, fieldwork was conducted in the 38 study wetlands to collect data on hydrology, location and geomorphology of beaver dams and beaver lodges, location and geomorphology of levee gaps, emergent and submerged aquatic vegetation, water quality, and migratory waterfowl. We used a combination of remote sensing and in-person techniques to assess the beaver dams and gaps in the natural levees of the 38 wetlands.

We detected and measured 79 gaps in the levees of the 38 wetlands, totaling 1063.12 m of gaps in 161,802.16 m of total wetland perimeter. We found that 90% of the 79 levee gaps measured provided a hydrological connection to the wetland. We found that only 9 of 38 wetlands had no beaver dams within them or within a 30m buffer zone; in total we detected and measured 273 beaver dams using remote sensing methods. Of that 273, we measured and assessed 86 in person, with more to be measured and assessed in person in 2022.

Using vegetation mapping we determined there are 22 ecosystem types that occur across the 38 study wetlands, the most common being Open Water, covering 664.99 ha or 27.76% of the total wetland area, and the least common being Modified Shrub Swamp, covering only 0.44 ha or 0.02% of the total wetland area. Water quality data were varied, and need further analysis in relation to connectivity data to draw conclusions from, however all wetlands are freshwater and water conductivity generally increased during the flood pulse with the addition of river water.

We built two artificial beaver dams in a wetland site to assess the feasibility of such an activity and the benefits to the wetland. This will help to retain water overwinter in a 54 ha wetland, water that is essential to a local farmer for household and livestock water, as well as for returning migrating birds.

We think that beaver dams and their artificial analogues can be used in the Columbia Wetlands to adapt to the impacts of climate change and to improve the maintenance of Species At Risk (SAR), particularly migratory and breeding birds, in the Columbia Wetlands. Artificial beaver dams can be built to retain water. To choose wetlands for this purpose, SAR and other data relevant

to the species of interest must be considered, as must physical characteristics of the wetlands and their levee gaps, landowner permission and wetland accessibility, and potential benefit of water retention to landowners and nearby residents. Further work planned for 2022 will allow for better conclusions and recommendations.

2.0 Introduction

2.1 Background

Wetlands are important ecosystems for many reasons; they are rich in biodiversity, they are of cultural importance to many people, and they provide ecosystem services including flood control, groundwater recharge, carbon storage, water storage and purification, and direct economic benefits through harvesting (Blackwell and Pilgrim, 2011; Gardner and Finlayson, 2018). They are also among the world's most threatened ecosystems; wetlands are threatened by human development and climate change, and global estimates suggest 30% of wetland habitat has been lost between 1970 and 2015 and a 49.8% decline since the 19th century (Davidson, 2014). Twenty-five percent of over 19,500 wetland-dependent species assessed by the IUCN Red List are threatened by extinction (Gardner and Finlayson, 2018).

The Columbia River is the largest river in the Pacific Northwest, and the largest by volume entering the Pacific from the Americas. It starts in the Rocky Mountain Trench in the British Columbian Rocky Mountains and flows for 2000 km before reaching the sea in Oregon, draining seven US states and one Canadian province along its way. As with many North American rivers, it has been heavily dammed, with 14 dams on the main stem of the Columbia River, and 60 more on its tributaries.

The Columbia Wetlands, stretching from Columbia Lake in the south to Donald in the north, remain the only undammed portion of the Columbia River, and are one of the longest contiguous wetlands in North America. As floodplain wetlands in an undammed system, they are maintained by the natural flood cycle of water flowing over the river banks and advancing and retreating across the valley, a process that has major effects on all aspects of the wetlands (Hopkinson *et al*., 2020; MacDonald Hydrology Consultants Ltd., 2021). The wetland system is approximately 180 km long and over 26,000 ha in area (Environment and Climate Change Canada, 2018), and provides important habitat and many ecosystem services. These wetlands provide many other important ecosystem services, such as groundwater recharge, water for agriculture and residential use, flooding mitigation, and recreational use, and are important culturally to both the First Nations, whose territories they are on, and white settlers in the Columbia Valley. They are located on the traditional territories of the Ktunaxa Nation, Secwepemc First Nation, Shuswap First Nations Band and Metis Nation Columbia River.

Among the many ecosystem services they provide, the Columbia Wetlands are habitat for a tremendous diversity of organisms. For example, a 2004 survey found 4 species of fungi, 268 species of plants, 34 species of invertebrates, 2 species of amphibians, 1 species of reptile, 112 species of birds, and 17 species of mammals within the Columbia National Wildlife Area, which comprises 1,001 ha of the entire Columbia Wetlands complex (Environment and Climate Change Canada, 2018). The Columbia Wetlands provide habitat for many wetland-dependent mammals such as North American river otter (*Lontra canadensis*), American beaver (*Castor canadensis*), and muskrat (*Ondatra zibethicus*), as well as important habitat for species that use wetlands for at least part of the year such as elk (*Cervus canadensis*) and American black bear (*Ursus americanus*) and provide corridors to traverse the valley for upland animals such as grizzly bear (*Ursus arctos*).

The Columbia Wetlands are particularly vital habitat for migrating birds. They comprise an important part of the Pacific Flyway; one of North America's four major migratory routes (Environment and Climate Change Canada, 2018). They provide a stopover for migratory birds, including provincially listed species such as tundra swan (*Cygnus columbianus*) which is on the BC List 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, found that in 2019, across three dates, 41,095 birds of 90 different species were present in the wetlands, and across 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).

This importance is recognized provincially, federally, and globally: the Columbia Wetlands have been designated a RAMSAR site since 2004, qualifying under all 8 RAMSAR criteria (Zimmerman, 2004), are being proposed as an Important Bird Area (Darvill, 2020), and are protected variously as the Columbia Wetlands Wildlife Management Area under the British Columbia (BC) Wildlife Management Act, the Columbia National Wildlife Area under the Canada Wildlife Act, and as Nature Trust of Canada and Nature Conservancy of Canada properties.

The Columbia Wetlands face many threats, despite these protections and recognitions. Although the Columbia Wetlands remain undammed, there is nonetheless rapid residential, agricultural, and recreational growth in the Columbia Valley (Environment and Climate Change Canada, 2018) which threatens the wetlands and the organisms living within them, from disturbances due to boat or ATV users to water being removed from the wetlands for agricultural irrigation or residential use.

They are also threatened by climate change (Hopkinson *et al.*, 2020; Utzig, 2021). The Columbia Wetlands are particularly sensitive to climate change for several reasons. It has been suggested that mountainous regions are more sensitive to climate change and are experiencing faster temperature increases and changes to precipitation than the global land average. While results globally are inconclusive (Rangwala and Miller, 2013), in western North America glaciers are shrinking 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). Annual temperatures in the Columbia Wetlands have already increased by 1˚C and further increases of +2˚C to +4˚C are projected. Changes to precipitation amounts, timing, and form are also predicted by models, with less snow and more rain falling in the valley (Utzig, 2021). Being undammed and dependent on the natural flood pulse, which is primarily driven by snowmelt, the decreasing snowpack and glaciers of the Canadian Rockies are a direct and urgent threat. There is less water in the Columbia Wetlands today than historically, and projections indicate that there will be increasingly less water in the future (Hopkinson *et al.*, 2020; Utzig, 2021).

Beavers may provide some natural mitigation of climate change’s effects 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), from decreasing temperature extremes to providing carbon storage, and from increasing the diversity and abundance of other organisms across many taxonomic groups to 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 structure to wetlands that is achievable in no other way, and are increasingly important parts of wetland and water course re-naturalization and management plans (Colleen and Gibson, 2001; Nummi and Holopainen, 2020).

Beavers in large river valleys with extensive floodplain wetlands, such as the Columbia River, have not been well studied. Most beaver research occurs on small streams or in the boreal, which both function differently hydrologically and ecologically (Hood and Bayley, 2008; Westbrook *et al.*, 2006) from the Columbia Wetlands. Beavers in the Columbia Wetlands are not damming the Columbia River directly, but are damming across the floodplain of the river, resulting in very different hydrological and ecological dynamics. For example, most beaver dams only hold water on their upstream side, essentially delaying or preventing waterflow downstream (e.g., Ronnquist and Westbrook, 2021). Yet beaver dams in the Columbia Wetlands have the unusual function that they both prevent water from entering the wetlands prior to the flood pulse, and then prevent water from leaving the wetlands after the flood pulse has overtopped the levees and the dams alike. In other words, these beaver dams influence water flow in both directions.

Overall, the floodpulse in the Columbia Wetlands either flows over the natural levees, or in through the gaps in the levees. In ~55% of years, the flood waters are not high enough to go over the natural levees, and hence the water must flow into the wetlands through gaps in the levees. The gaps in the levees vary greatly among the different wetlands. They vary in width, depth, and length of the channel to the wetland. Beaver can influence all those characteristics and hence the hydrology of the wetlands.

The hydrologic impacts of beaver dams and their ecological consequences in the Columbia Wetlands have not been previously studied. For example, what are the effects of beaver activity on the stopover ecology of migratory waterbirds in the Columbia Wetlands? This question is important given the crucial role these wetlands play in avian migration and the sensitivity of migrating waterbirds to springtime open water availability. Our main goals for this project were to identify vulnerable wetlands within the Columbia Wetlands complex, determine how beaver dams impact these wetlands, and determine how beaver dams and artificial beaver dam analogues may be used to adapt to climate change impacts on wetlands.

2.2 Objectives

To achieve these goals, we chose 38 study wetlands based on prior research and local expert knowledge (Figure 1.1). At 2395.61 ha, the 38 study wetlands are approximately 9% of the total area of the Columbia Wetlands. Our specific research objectives were to:

1) determine the distribution and activity of beaver across the wetlands;

2) describe the differences in ecosystem characteristics between those wetlands dominated by active and inactive beaver dams compared to those without beaver dams;

3) install and monitor three artificial beaver dams;

and **4)** ensure results will inform Year 4 (2022-2023) mitigation efforts using natural and artificial beaver dams to buffer the effects of climate change and mitigate drought.

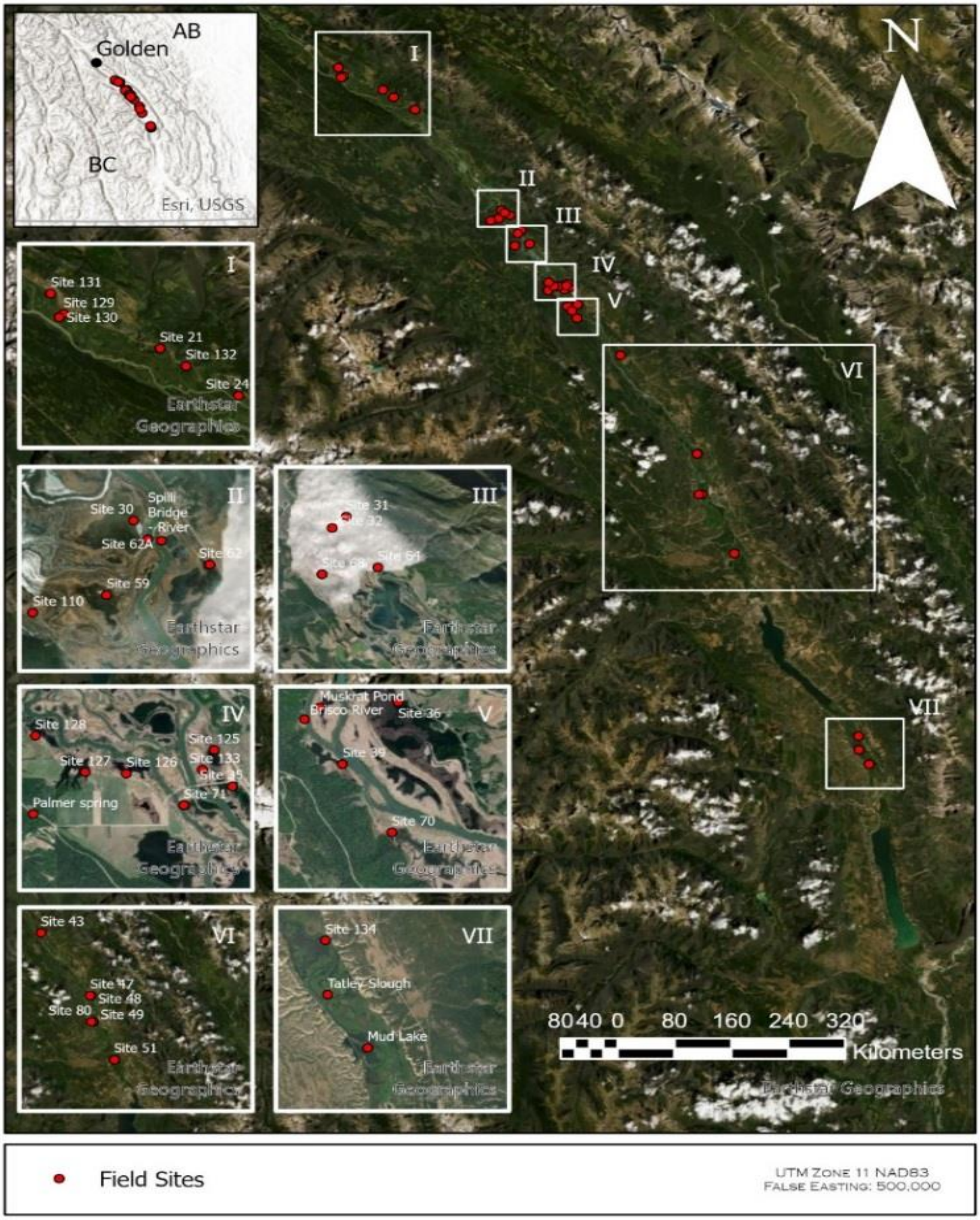


Figure 2.1 The 38 study wetlands within the Columbia Wetlands complex.

3.0 Objective 1: determine the distribution and activity of beaver across the wetlands

3.1 Background

Between May and October 2021, using a combination of remote sensing and in-person fieldwork, we mapped and recorded the geomorphology of beaver dams and channel gaps leading to the Columbia River in the 38 study wetlands. Not all beaver dams and gaps were accessible due to high water levels, so some dams and gaps remain to be mapped and assessed in 2022.

3.2 Measurable Outcomes

1. Beaver status and gaps in the levees will be assessed in the 38 instrumented wetlands with HOBOs (per hydrology subproject).
2. Geomorphology of the beaver dams will be assessed to help determine the characteristics of the different types of wetlands.

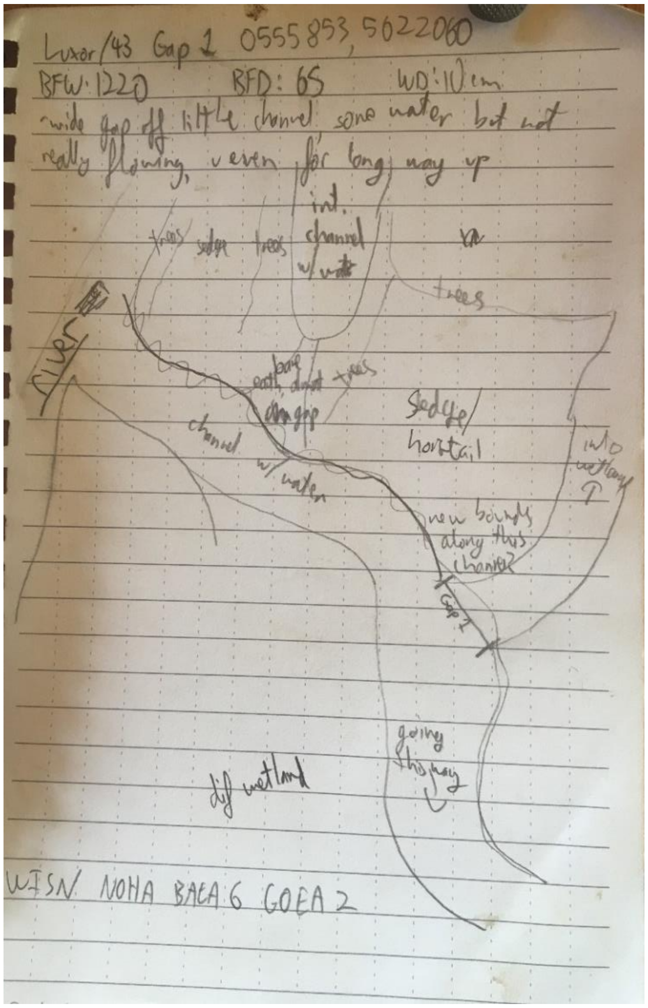
3.3 Methods

Using ArcGIS Pro 2.8.0 and Google Earth, we used our best judgment to determine the location of beaver dams, lodges, and gaps within and close to the 38 study wetlands. Beaver dams and lodges visible on ArcGIS Pro 2.8.0 and Google Earth were located within the wetland itself and within 10 m, 20 m, and 30 m of each wetland. These buffer distances were included as in several instances we found that the dam(s) responsible for holding water into the wetland were not within the boundaries of the wetland itself. The length of all located beaver dams was measured. Wetland area and perimeter was also determined this way and amended based on ground truthing.

Gaps between the Columbia River and our wetland sites were measured on ArcGIS Pro 2.8.0 and Google Earth using a combination of digital elevation models, orthophotos, and satellite imagery. All gaps were included to determine the total gap width (m) in each wetland, regardless of whether these gaps influence water levels in the wetlands. Gaps that do not influence wetland water levels were then removed and ‘Inflow Gaps’ were summarized to determine the width of gaps influencing water levels within each wetland. Inflow gaps were determined based on characteristics visible on ArcGIS (i.e., water colour, whether there is visible flow, gap size, vegetation presence, visible obstructions).

Once we had determined the locations of beaver dams and gaps through remote sensing, we conducted in-person fieldwork at each wetland site. For some wetlands we walked the whole perimeter to determine where beaver dams and gaps were, but for others we used a targeted approach, where we identified areas of interest for beaver dams, gaps, and other features in each wetland from aerial imagery, LiDAR, and other remote data sources, as well as on the experience and advice of Dr. Suzanne Bayley, President of the Columbia Wetland Stewardship Partners. Once at a dam or gap location, we measured dimensions of the feature (length, width, height, water depth, bankfull depth on both sides of the beaver dam, bankfull width on both sides of the beaver dam, as relevant) (Figure 3.1), took notes on building material, beaver activity, water flow, and its influence on the wetland, as well as drawing a rough sketch of the feature (Figure 3.2). This in-person fieldwork was essential, as not all dams and gaps were visible from remote sensing sources, and measuring all the dam dimensions we are interested in, as well as determining how the dams or gaps affected the wetland itself, was not possible without in-person fieldwork.

Figure 3.1: Measuring bankfull width on riverside (below) of beaver dam at north end of Site 49.



Luxor/43 Gap 1 0555853, 5022060

BFW: 1220 BFD: 65 WD: 10cm

~wide gap off little channel some water but not really flowing, v even for long way up

Figure 3.2: Example of field sketch of gap in Site 43, including water flow information.

All dams, lodges, and gaps were located and measured (as far as possible) using GIS methods. While we did measure many dams and gaps in-person in the summer and fall of 2021, some dams and gaps remain to be investigated and measured in 2022 due to time constraints and difficulties caused by high water levels after the flood pulse. These dams and gaps will all be measured within the same ‘flood year’, between the spring flood of 2021 and the spring flood of 2022.

3.4 Results

The full results of the GIS-derived beaver dam counts and length measurements for each of the study wetlands are presented in the appendices (Appendix 1) including the Goodbrand and Hopkinson (2022) hydrograph response and wetland typology associated with each wetland (for all wetlands except site 63, where the hobo data logger malfunctioned, and no water depth data was collected). We plan to analyze these data using generalized linear models, contingency table data, and PCA analysis. The area of the study sites varies greatly; Site 110 is the smallest at 4.28 ha, and Site 70 the biggest at 326.89 ha (Table 3.1).

Table 3.1: Area in hectares of each of the 38 study sites.

Site Number	**Area (ha)**
21	49.02
24	45.77
29	8.25
30	111.09
31	40.22
32	134.60
35	15.73
36	207.44
38	53.77
39	11.74
43	74.54
47	78.16
48	53.40
49	61.29
51	225.76
59	55.63
62	55.26
63	13.13
64	14.39
68	134.77
69	11.56
70	326.89
71	22.28
110	4.38
126	19.22
127	12.71
128	12.12
129	31.59
130	271.52
131	29.05
132	75.16
137	16.96
140	16.76

141	24.03
142	38.77
143	8.04
144	18.69
145	12.54
Total Wetland Area	2395.61

We detected 273 beaver dams using remote sensing methods, of which we measured and assessed 56 in person, with more to be measured and assessed in 2022. We determined that 12 wetlands have no beaver dams within them, 17 have between 1 and 5 beaver dams, and 9 have more than 6 beaver dams (Table 3.2). Most beaver dams were within 10m of a wetland; extending the buffer to 20m and 30m did not drastically change the preliminary categorisation of wetlands as having no beaver dams, some beaver dams (1 – 5), or many beaver dams (6+) (Table 3.2). For example, 9 wetlands had 6+ beaver dams within them or within 10m of them, while 15 had 6+ beaver dams within 30m. However, the number of dams included in the 6+ category changed; Site 130 has 10 dams within the wetland, but 64 dams within a 30m buffer. The majority of beaver dams captured when incorporating beaver dams from the surrounding buffers (10 m, 20 m, and 30 m) were within 10 m of the wetland boundary.

Using remote sensing methods we detected 74 beaver lodges within the 38 study wetlands (Appendix 4). These were not assessed in-person, and do not include bank beaver lodges, as these are not visible using GIS.

Table 3.2: Number of wetlands that have 0 beaver dams, 1 – 5 beaver dams, or 6+ beaver dams, within the wetland, within the wetland and a 10 m buffer, within the wetland and a 20 m buffer, and within the wetland and a 30 m buffer. All of the 38 wetlands are included at each stage.

	Number of Wetlands with Beaver Dams			
Number of Beaver Dams	**Within Wetland**	**Within Wetland and 10 m Buffer**	**Within Wetland and 20 m Buffer**	**Within Wetland and 30 m Buffer**
0	12	10	10	9
1 – 5	17	14	14	14
6 +	9	14	14	15
Total number of wetlands	38	38	38	38

Using GIS methods, we detected and measured 79 gaps in the levees of the 38 wetlands, totaling 1063.12 m of gaps in 161,802.16 m of total wetland perimeter (Appendix 4). We measured

51 of those gaps in person, with more to be measured in 2022. We found that 90% of the 79 levee gaps measured provided a hydrological connection to the wetland, and only 9 wetlands had no levee gaps at all (Table 3.3). The total width of all gaps in a wetland varied widely, with Site 71 having 2 gaps summing to 4.89 m in width and Site 131 having 15 gaps summing to 174.62 m in width (Appendix 4).

We defined six categories of gaps in our wetland:

1. Total Number of Gaps: This is the total number of gaps we saw and classified through GIS-methods. They may or may not allow water flow in or out of the wetland sites.
2. No Flow Gaps: These are gaps that we do not believe allow any water to flow in or out of the wetland sites.
3. River Flow Gaps: These are gaps that we believe allow water to flow in and out of the wetland sites from the Columbia River or a major side channel.
4. Creek Flow Gaps: These are gaps that we believe allow water to flow in and out of the wetland sites directly from a creek, not from the Columbia River or side channels.
5. Between Wetland Flow Gaps: These are gaps that we believe allow water to flow in and out of the wetland sites from another wetland site.
6. Open Gaps: These are gaps that allow some form of flow (River, Creek, or Between Wetland) into and out of the wetland sites.

We present this data in Table 3.3. From this, we can see that there are 9 wetlands that have no gaps allowing water flow into or out of them at all. Of the remaining 29 wetlands, the maximum number of gaps is 15 in Site 130, and there are many wetlands that have only one gap. The most common type of gap is River Flow Gaps, with 22 wetlands having at least one River Flow Gap. The least common type of gap is Creek Flow Gaps, with only 4 wetlands having at least 1 Creek Flow Gap. Twenty-five wetlands have some form of Open Gap, meaning that they get some inflow or outflow of water through a gap; 90% of the gaps identified and measured are Open Gaps.

Table 3.3: The number of gaps of each of the six types (defined above) in each of the 38 study sites.

Site Number	**Total Number of Gaps**	**Number of No Flow Gaps**	**Number of River Flow Gaps**	**Number of Creek Flow Gaps**	**Number of Between Wetland Flow Gaps**	**Number of Open Gaps**
21	1	1	0	0	0	0

Site Number	**Total Number of Gaps**	**Number of No Flow Gaps**	**Number of River Flow Gaps**	**Number of Creek Flow Gaps**	**Number of Between Wetland Flow Gaps**	**Number of Open Gaps**
24	7	0	6	0	1	7
29	0	0	0	0	0	0
30	2	0	1	1	0	2
31	1	0	1	0	0	1
32	1	0	1	0	0	1
35	1	0	1	0	0	1
36	5	0	5	0	0	5
38	2	1	1	0	0	1
39	1	0	1	0	0	1
43	1	1	0	0	0	0
47	0	0	0	0	0	0
48	0	0	0	0	0	0
49	1	0	1	0	0	1
51	3	0	3	0	0	3
59	4	0	4	0	0	4
62	1	1	0	0	0	0
63	2	1	1	0	0	1
64	1	0	1	0	0	1
68	2	0	2	0	0	2
69	1	1	0	0	0	0
70	2	0	2	0	0	2
71	2	0	2	0	0	2
110	0	0	0	0	0	0
126	1	0	1	0	0	1
127	0	0	0	0	0	0
128	0	0	0	0	0	0
129	5	0	0	2	3	5
130	15	0	9	1	5	15
131	3	1	0	0	2	2
132	3	0	2	1	0	3
137	0	0	0	0	0	0
140	2	0	2	0	0	2
141	3	0	3	0	0	3
142	4	0	3	0	1	4
143	0	0	0	0	0	0
144	0	0	0	0	0	0
145	2	1	1	0	0	1

The field-based measures of beaver dams will be completed during the 2022 field season.

3.5 Discussion

From our preliminary analyses, the concentration of dams is situated within a 10 m buffer around each wetland, supporting the interpretation that their effects are local. Within this 10 m buffer, we have a pretty even distribution of dam intensity among our 38 study sites: 10 with no dams, 14 with few dams (1-5) and 14 with abundant dams (>6). The GIS-derived indices of dam character require field-validation, which will be completed in spring and early summer 2022, before the July 2022 flood pulse. Using GIS-methods, we are less able to determine which of these dams is actually holding water within the wetland and which are not. Once we have a complete dataset of the in-person assessments of the dams, we will be able to draw more conclusions about how dams are impacting these wetlands, and if dam condition (active, inactive, relict) and other dam characteristics plays a role.

In terms of characterizing gaps between the Columbia River and our wetland sites, only 8 wetlands had a single No Flow Gap, whereas 90% of the 79 gaps measured via GIS provide hydrologic connection to the wetlands. The most common form of gap was the River Flow type, with 68% of gaps belonging to this category. The next most common gap type was the Between Wetland type (22%), indicating high connectivity directly between wetlands.

4.0 Objective 2: describe the differences in ecosystem characteristics between those wetlands dominated by active and inactive beaver dams compared to those without beaver dams

4.1 Background

Between May and October 2021, as well as determining the activity of beavers across our 38 study wetlands by locating and assessing beaver dams using a combination of remote sensing and in-person fieldwork, we also deployed water depth loggers to constantly record water depth, surveyed submerged aquatic vegetation (SAV), and tested water quality. We also used a previously created vegetation model to assess emergent vegetation and used data from Darvill (2020) to assess how migratory waterfowl are using the study wetlands.

4.2 Measurable Outcomes

1. The depth of water in the flood basins will be measured to help calculate the volume of water retained in the wetlands and to monitor how water overwinters in selected areas to inform restoration approach(es).
2. Emergent and submersed aquatic vegetation will be surveyed in the different wetland classes.
3. Dominant wetland classes will be defined based on hydrology, beaver dam characteristics, geomorphology and vegetation to assess the vulnerability of the Columbia Wetlands
4. A preliminary assessment of the wetland classes will be related to the existing maps of SAR and bird data from Darvill (2020) and reported in the Summary Report (per #8).

4.3 Methods

To measure the depth of water in the flood basins of the 38 study wetlands, we installed hobo water loggers in early to mid-May in all 38 study wetlands and collected them in mid-October (Figure 4.1). This work was conducted in collaboration with Dr. Ryan MacDonald, Dr. Amy Goodbrand, and their team, as has been covered in their report (Goodbrand and Macdonald, 2022).

Figure 4.1. Collecting hobo water logger from Site 30.

To classify emergent vegetation, we are using the vegetation map made by Ryan Durand for CWSP in 2020. For this, the Columbia Wetlands were mapped using airphoto interpretation on digital orthophotos with LiDAR controls where available. The mapping was done using heads up delineation with a target scale of 1:1000. Each mapped ecosystem was classified as per the BC Biogeoclimatic Ecosystem Classification (BEC) system, with wetlands and floodplains classified to the Site Association level, terrestrial ecosystems classified to the site series level, and all other features described as per the TEM standard. Classification followed the Wetlands of BC (MacKenzie & Moran, 2004) and A Field Guide to Ecosystem Classification and Identification for Southeast British Columbia; The East Kootenay (MacKillop *et al.*, 2018), with undescribed communities mapped to the wetland-class level. Each mapped polygon, at the minimum, contains the ecosystem type, a decile (increment of 10% indicating how much of the polygon the ecosystem covers if more than one type is contained within a mapped area), structural stage (herb, graminoid, aquatic, low shrub, tall shrub, and young to old forest), and canopy composition (broadleaf, conifer, mixed) (Ryan Durand, pers. comm. 2022).

We classified submerged aquatic vegetation in all 38 study wetlands in August 2021. We placed ten 1 m^2 quadrats across each wetland to capture a representative sample of the open water areas (Figure 4.2), unless restricted by the absence of adequate open water area to sample. In each quadrat, we recorded water depth and estimated total infestation (% of the water column occupied by vegetation, by volume). We then collected and identified all submerged vegetation to the lowest taxonomic level possible and ranked infiltration of each individual species using the system developed by (Rooney *et al*, 2013) to be able to calculate both absolute and relative abundance. For species where we were unsure of identification in the field, we took voucher photographs or samples to aid in later identification.

Figure 4.2. Conducting submerged aquatic vegetation surveys by kayak.

To survey water quality, we measured conductivity, dissolved oxygen, temperature, total suspended solids, water depth, and Secchi depth multiple times between May and October 2022, though not in all wetlands at all time periods, due to differences in equipment and personnel available for data collection (Table 4.1). Water depth was measured with a meter stick or a Secchi disc, depending on depth, and the Secchi disc was also used to take Secchi depth measurements in all wetlands as a measure of turbidity. Water samples were taken three times in all wetlands (if water was present) to be later filtered for total suspended solids, determined gravimetrically. Conductivity, dissolved oxygen, and temperature were measured with a YSI probe.

In the May, August, and October sampling periods, we sampled water quality at or near the Hobo depth logger. In the June/July sampling period, multiple water depth measurements were taken across the wetland to provide an idea of the general shape of the wetland basin, and water quality was measured at one of those points. We recorded coordinates of all sampling points.

Table 4.1. Dates of variable measurement.

Variable	**Measurement Period**			
	May	**June/July**	**August**	**October**
Conductivity	All	All	All	All
Dissolved Oxygen	None	All	All	Some

Temperature	None	All	All	Some
Total Suspended Solids	None	All	All	All
Water Depth	All	All	All	All
Secchi Depth	None	All	All	All

Beaver dam and gap characteristics were recorded as detailed under Objective 1.

4.3 Results

The depth of water in the flood basins and resulting water budget and water volume calculations and analysis have been conducted by Dr. Goodbrand and Dr. MacDonald, as detailed in Goodbrand and MacDonald (2022).

From the emergent vegetation mapping, we can determine that 22 ecosystem types are found within the 38 study wetlands. The most common ecosystem type across all the wetlands is Open Water, covering 27.76% of the combined area of all 38 study wetlands, or 664.99 ha (Table 4.2). Beaked Sedge – Water Sedge Marsh and Bulrush Marsh also cover more than 10% of the total study wetland area, at 14.29% and 11.68%, respectively. Twenty-five wetlands have Open Water as their most common ecosystem type, with Site 21 having the highest proportion of Open Water at 71% (Appendix 2). The least common ecosystem type is Modified Shrub Swamp, covering only 0.44 ha or 0.02% of the total wetland area.

Table 4.2. Breakdown of ecosystem types across the study region.

Rank	Eco. Type	Type Area (ha)	Type %	**Description**
1	OW	664.99	27.76%	Shallow Open Water
2	Wm01	342.27	14.29%	Beaked Sedge – Water Sedge Marsh
3	Wm06	279.85	11.68%	Bulrush Marsh
4	Wm02	214.53	8.95%	Swamp Horsetail Marsh
5	Wm05	196.25	8.19%	Cattail Marsh
6	Fl04	185.13	7.73%	Sitka willow – Red-osier dogwood – Horsetail low-bench floodplain
7	Ws	179.34	7.49%	shrub swamp (site association not known)
8	Wm15	146.22	6.10%	Bluejoint Reedgrass Marsh
9	Fm02	102.50	4.28%	Cottonwood – Spruce – Dogwood mid-bench floodplain
10	Ws04	18.32	0.76%	Drummond’s willow – Beaked sedge swamp
11	PD	16.06	0.67%	Pond

Rank	Eco. Type	Type Area (ha)	Type %	**Description**
12	Fa	12.12	0.51%	Active channel flood class
13	Fl06	10.07	0.42%	Sandbar willow low-bench floodplain
14	RI	9.39	0.39%	River
15	Wm.mo	6.76	0.28%	modified marsh
16	Fm07	3.73	0.16%	Aspen – Dogwood – Water birch mid-bench floodplain
17	MU	2.73	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
	Total Area	2395.61	100.00%	

The water quality data is presented in Appendix 3. Total suspended solids will be determined once water samples are received in Waterloo from Brisco. All wetlands were freshwater (Figure 4.3-4.4), with conductivity ranging from a low of 121 uS/cm in wetland 145 (Zigzag North) to a maximum of 796 uS/cm in wetland 35 (Brisco Mill Pond/ Loon Pond) but averaging 246 uS/cm across all measurements between June 21 and September 1, 2021. With the exception of 3-4 sites which are likely groundwater influenced, conductivity generally increased with the addition of river water through the flood pulse (Figure 4.4), yet conductivity was unrelated to water temperature (Figure 4.5). Dissolved oxygen was temperature dependent, but averaged 61.4% saturation, with highly vegetated sites being supersaturated at midday (e.g., wetland 51 – Wilmer – was measured in September at 1:16 pm as 140% saturation). However, some sites had extremely low dissolved oxygen levels, even at mid-day. For example, sites 47 (Inner Taggert), 137 (Muskrat Pond), 49 (Radium), 126 (Peter Trescher N), 32 (Perry's Lake), 43 (Luxor), and 21 (Quinn Creek South) were all below 25% saturation when measured between 10 am and 3 pm. Water depth was unrelated to dissolved oxygen levels. Water depths fluctuated through time and are better characterized by the hobo depth measures than our field measurements. Secchi depths were also variable through time and among sites (Figure 4.5 & 4.6), ranging from 14 cm in site 64 on August 24th to 204 cm in site 47 (Inner Taggert) measured June 30th. Interestingly, wetlands spanning the full range of Secchi depths were present both before and after the flood pulse took place in July (Figure 4.6).

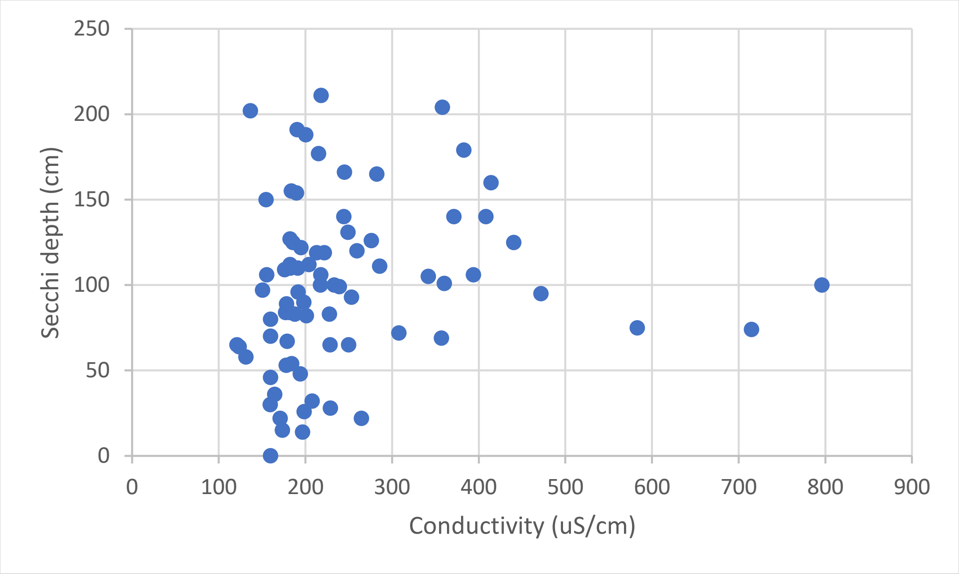


Figure 4.3. Variation in Secchi depth with respect to wetland conductivity.

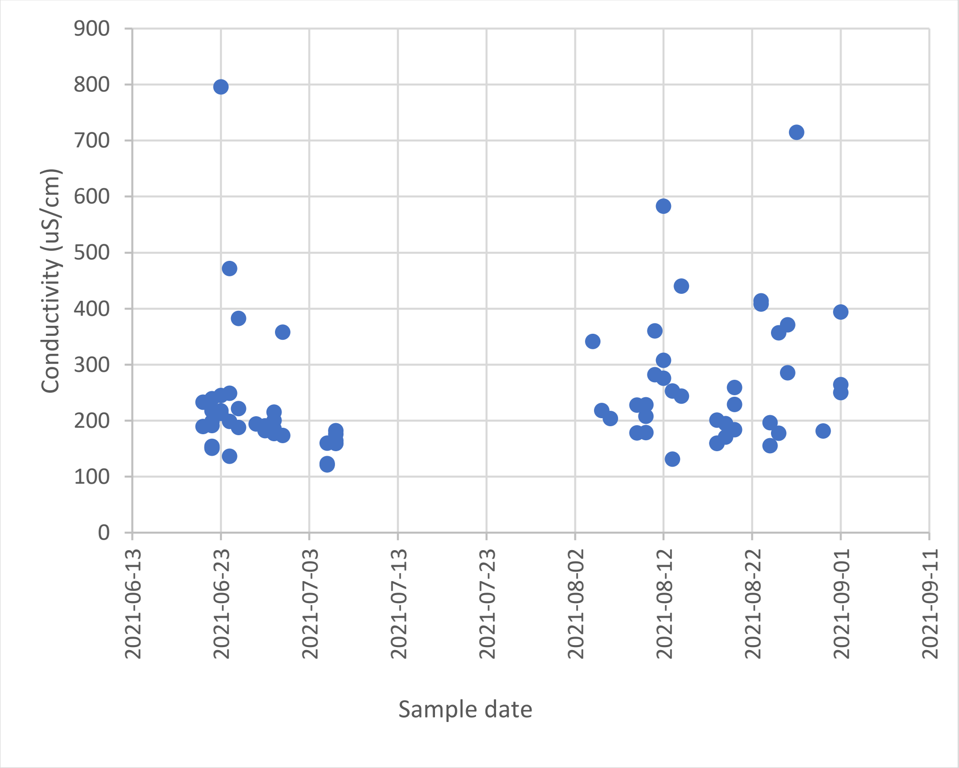


Figure 4.4. Conductivity through time, before and after the flood pulse in July.

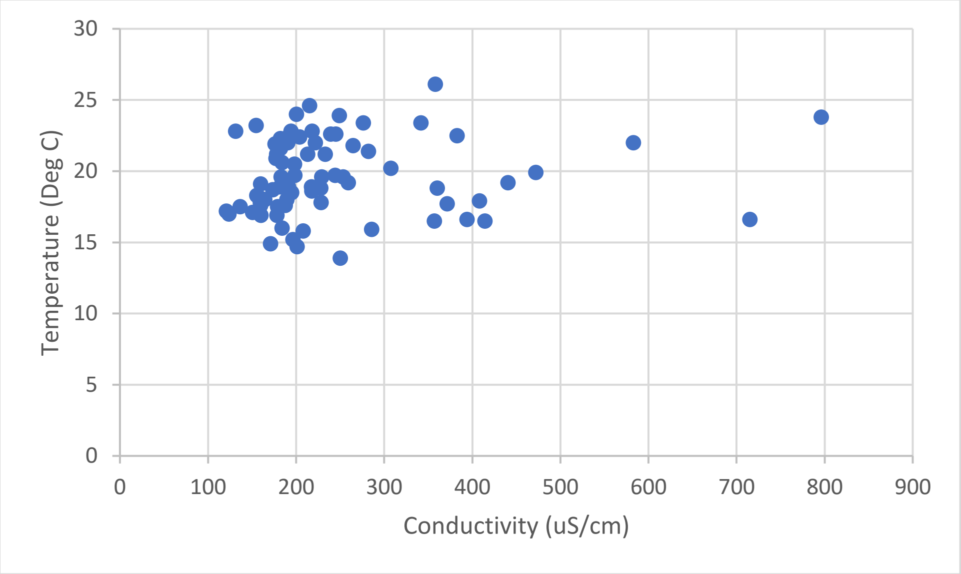


Figure 4.5. Variation in temperature with respect to wetland conductivity

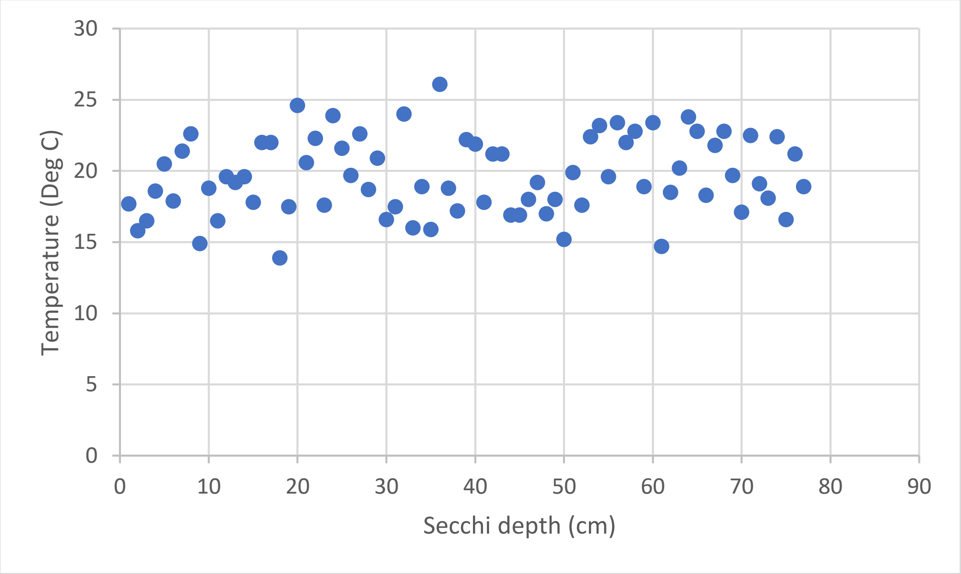


Figure 4.6. Variation in wetland temperature with respect to wetland Secchi depth.

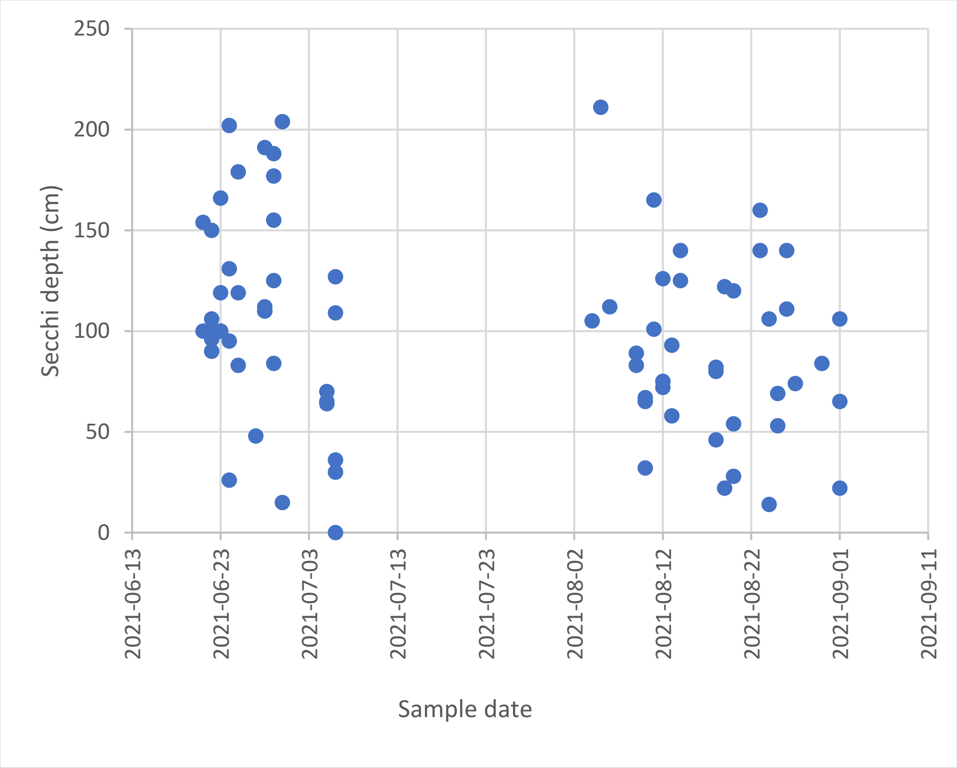


Figure 4.7. Variation in Secchi depth through time, before and after the July flood pulse.

Application of bird monitoring data collected in Darvill (2020) to our study wetlands is challenging because Darvill (2020) recorded all birds observed from a single vantage point, which in several instances included multiple wetlands and it is not possible to parse those observations to individual wetland basins. In Figure 4.8, for example, the Brisco Road observation site would have counted birds in both Sites 71 and 35, as well as on the north side of the road. However, our data has been collected in Site 71 and Site 35 separately, and we have no data for the wetlands on the north side of the road. Consequently, direct comparison of bird use will require spring migratory bird sampling, using points situated in each wetland, rather than repeating the survey points used by Darvill (2020). Migratory bird surveys were conducted in October 2021 and will be repeated in April 2022 to sample both fall and spring migration of waterfowl and to allow assessment of wetland usage by waterfowl during these two periods.

Figure 4.8. Aerial photo of Sites 35 and 71; the red point is the Darvill (2020) survey point, and the pink area is the area of sites 35 and 71 as defined in this project. The green points are the locations of the hobo water loggers in each site.

4.4 Discussion

The 38 study wetlands are all freshwater, but with conductivity, temperature, dissolved oxygen, and Secchi depth all highly variable. Generally, we anticipated water temperatures, Secchi depth, and conductivity would all decline following inputs of river water from the flood pulse, but the pattern in water quality is not so simple. A more sophisticated analysis accounting for the role of dams and gaps in the dams and levees is necessary to better resolve patterns in water quality among our study sites.

5.0 Objective 3: install and monitor three artificial beaver dams

5.1 Background

To investigate the feasibility of building artificial beaver dams, and the potential impacts of such structures on wetlands in the Columbia Wetlands, we built artificial beaver dams with the help of community members and will continue to monitor their hydrological impacts into the future.

5.2 Measurable Outcomes

Artificial beaver dams were installed in 2 locations to retain water overwinter for migrating birds.

5.3 Methods

Beaver dams were constructed at two locations on site 38 (Figure 5.1 and 5.2). We consulted The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains by Pollock *et al.*, 2017 for advice. We used locally sourced and biodegradable materials to build both dams, and tried to use repurposed materials as much as possible (e.g., the hessian sacks we used has previously been used to transport coffee beans).

At one of these locations, a natural beaver dam had been present as recently as spring 2021; the dam had been abandoned for approximately ten years, but did not blow out until the 2021 flood pulse. During the fall of 2021 we saw evidence of beavers being active in Site 38, caching vegetation and using one of the old beaver lodges that we had previously identified in the site.

Figure 5.1. 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.

Figure 5.2. Beaver dam at location one in Site 38 on May 29th 2021, before it was destroyed by the 2021 July flood pulse (left panel), contrasted with the same location in October 3rd 2021. We constructed the artificial beaver dam shown in Figure 5.3 at this location.

5.4 Results

Building the artificial beaver dams was a success (Figure 5.3), however it is too soon to say what the impacts on water retention in Site 38 will be, and how the artificial beaver dams will survive winter conditions and future flood pulses. The water levels in Site 38 (54 ha in area) were very low prior to the building of the artificial beaver dams, so hopefully restoring the dam will also restore these water levels. We will be installing a water logger in Site 38 in May 2022 to monitor these hydrological effects and will visually monitor the condition of the artificial beaver dam. We will also monitor whether the beavers noted moving into Site 38 in the fall of 2021 will maintain the artificial beaver dam we have built.

Figure 5.3. Building an artificial beaver dam at Site 38; the middle picture shows one of the completed dams.

5.5 Discussion

Building the artificial beaver dams proved to be a great success, both practically and from a community outreach perspective, as the landowners whose land we were building the dams on were very keen to be involved and we had other community members volunteering with us helping to build the dam. Without a dam to retain water over the winter, a local farmer who is one of the landowners would not have had household drinking water or water available for livestock, as the wetland would have mostly drained out and whatever water remained would have been shallow enough to freeze to the bottom. Thus, they were an enthusiastic supporter of the project.

We have demonstrated that it is possible to build artificial beaver dams in the Columbia Wetlands, in a fairly low-tech and non-invasive fashion; we did use a chainsaw to cut willows to weave into the dam, but no heavy machinery was involved and we used entirely locally-sourced, biodegradable materials, many of which were recycled from previous uses (e.g. hessian sacks that had previously been used by a local coffee roastery to hold coffee beans).

While it is too soon to say how the artificial dam will fare in comparison to natural beaver dams through the winter, the flood pulse, and other inclement conditions, we are keen to observe it and see what happens. Serendipitously, as we were building the dam, we noted that a pair of beavers (Figure 5.4) were setting up a food cache and were using an old beaver lodge in Site 38. Site 38 had previously been occupied by beavers, who had built three lodges and two dams (both of which we rebuilt), however the site has been unoccupied for approximately ten years (Suzanne Bayley, pers. comm.). It will therefore be particularly interesting to see if this beaver pair successfully establish in the site and if they will choose to maintain the artificial dams we have built.

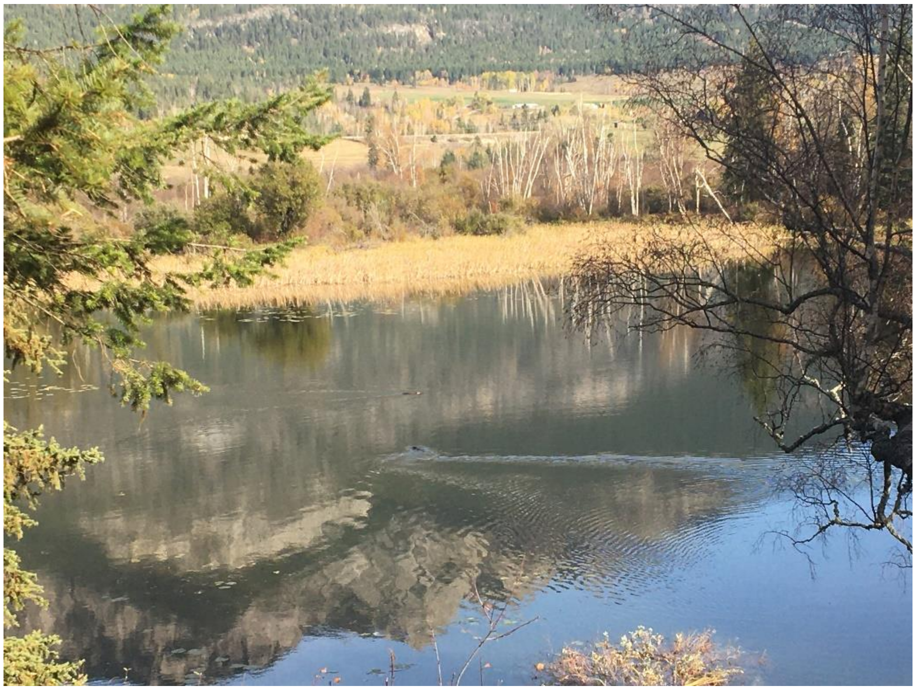


Figure 5.4. Beaver pair observed in site 38, while we were building the artificial beaver dams.

6.0 Objective 4: ensure results will inform Year 4 (2022-2023) mitigation efforts using natural and artificial beaver dams to buffer the effects of climate change and mitigate drought

6.1 Background

This research was conducted as part of a 4 year research project. To leverage the results and conclusions of our 2021 field season, here we describe recommendations for the 2022 project year.

6.2 Measurable Outcomes

All the wetlands in the Columbia Wetland are hydrologically vulnerable to climate change and reductions in the magnitude of the flood pulse. The most vulnerable seem to be those that receive floodwaters only rarely and have no gaps in the levees. While they may retain water in overwinter, they also may be filling with vegetation, and receive less water input from the river except in high flood years. Once our surveys of spring avian migration and breeding birds are complete, we will have a better sense of the consequences of beaver activity for avian habitat.

6.2 Future Work and Recommendations

As this is an ongoing project, work will be continued in 2022, and stronger conclusions and recommendations will be possible at the end of 2022.

Using the beaver dam and hydrology data collected in 2021, 16 sites were chosen to conduct migratory waterfowl surveys at in October 2021 and April 2022. These data will be analyzed to determine how waterfowl are using wetlands with a high beaver dam impact differently to wetlands with a low beaver dam impact. Breeding bird surveys will also be conducted in May and June 2022 to determine how wetland breeding birds are using these wetlands differently. As spring is the time when the water levels are lowest, being prior to the yearly flood pulse, it is a vital time for habitat to be available for both migratory and breeding birds. It is important to understand how the retention of water by beaver dams affects the use of wetlands by these birds; this will allow for better management of habitat using beaver dams as a tool to adapt to the impacts of climate change.

We will also map Species At Risk (SAR) in the Columbia Wetlands and compare these data with the beaver dam and hydrology data, to determine how SAR are using highly beaver dam impacted wetlands and less beaver dam impacted wetlands differently. Once we have this mapped, we could expand our data collection on beaver dams outside the 38 study wetlands in order to assess beaver dam status in areas seen to be important for SAR. From these analyses, we will be able to determine the wetlands where artificial beaver dams will have the greatest positive impact for SAR and migratory waterfowl.

All the wetlands in the Columbia Wetland are hydrologically vulnerable to climate change and reductions in the magnitude of the flood pulse. The most vulnerable seem to be those that receive floodwaters only rarely and have no gaps in the levees. While they may retain water in overwinter, they also may be filling with vegetation, and receive less water input from the river except in high flood years. Once our surveys of spring avian migration and breeding birds are complete, we will have a better sense of the consequences of beaver activity for avian habitat.

The use of artificial beaver dams as an adaptation to climate change centers around their capability to retain water within wetlands. To that end, site selection for further should consider multiple factors. Firstly, sites should be selected because water retention within them will have the greatest positive impact on species of interest, which may be SAR, migratory waterfowl, breeding birds, or other categories of organisms. Secondly, sites should be selected for practicality: very large wetlands contain too many gaps that would need to have artificial beaver dams built across them for their to be any impact on water retention. Thus, wetlands with limited numbers of gaps, where building one to three artificial beaver dams will have maximum impact for the amount of effort put in are ideal candidates. Landowner permission and accessibility are also important; being able to access the site and build the dam using limited heavy machinery reduces negative disruptive impacts of building the artificial beaver dams. The benefits to landowners and local residents, such as an artificial beaver dam ensuring that access to drinking water or water required for agricultural purpose will remain, should also be considered. Wetlands where there have previously been beaver dams are also good candidates, as having a partial dam to build from both reduces the amount of materials necessary and provides an indication for the best place to locate a dam to retain water within the wetland.

To this end, in 2022 we bring all these available data together and identify good candidate sites for artificial beaver dam construction. We will then communicate with landowners about whether they would be amenable to this project. If they are, we will apply for permits and build beaver dams to continue to to continue to test the potential for artificial beaver dams as a mitigation technique for the impacts of climate change in the Columbia Wetlands.

7.0 References

Blackwell, M. S. A., & Pilgrim, E. S. (2011). Ecosystem services delivered by small-scale wetlands. *Hydrological Sciences Journal*, *56*(8), 1467–1484. https://doi.org/10.1080/02626667.2011.630317

Bouwes, N., Weber, N., Jordan, C. E., Saunders, W. C., Tattam, I. A., Volk, C., Wheaton, J. M., & Pollock, M. M. (2016). Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (Oncorhynchus mykiss). *Scientific Reports*, *6*(1), 28581. https://doi.org/10.1038/srep28581

Collen, P., & Gibson, R. J. (2000). The general ecology of beavers (Castor spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish – a review. *Reviews in Fish Biology and Fisheries*, *10*(4), 439–461. https://doi.org/10.1023/A:1012262217012

Darvill, R. (2020). *Columbia Wetlands Waterbird Survey* (p. 88). Prepared for: Wildsight Golden.

Davidson, N. C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research*, *65*(10), 934. https://doi.org/10.1071/MF14173

Environment and Climate Change Canada. (2018). *Columbia National Wildlife Area Management Plan*. Environment and Climate Change Canada. https://www.canada.ca/en/environment-climate-change/services/national-wildlife-areas/locations/columbia.html

Gardner, R. C., & Finlayson, C. (2018). *Global Wetland Outlook: State of the World's Wetlands and Their Services to People* (SSRN Scholarly Paper ID 3261606). Social Science Research Network. https://papers.ssrn.com/abstract=3261606

Goodbrand, A. & MacDonald, R.J. (2022). Upper Columbia Wetland Vulnerability Assessment – Interim Report. Prepared by MacDonald Hydrology Consultants Ltd for the Columbia Wetlands Stewardship Partners. 22 pp.

Hood, G. A., & Bayley, S. E. (2008). Beaver (Castor canadensis) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada. *Biological Conservation*, *141*(2), 556–567. https://doi.org/10.1016/j.biocon.2007.12.003

Hopkinson, C., Fuoco, B., Grant, T., Bayley, S. E., Brisco, B., & MacDonald, R. (2020). Wetland Hydroperiod Change Along the Upper Columbia River Floodplain, Canada, 1984 to 2019. *Remote Sensing*, *12*(24), 4084. https://doi.org/10.3390/rs12244084

Larsen, A., Larsen, J. R., & Lane, S. N. (2021). Dam builders and their works: Beaver influences on the structure and function of river corridor hydrology, geomorphology, biogeochemistry and ecosystems. *Earth-Science Reviews*, *218*, 103623. https://doi.org/10.1016/j.earscirev.2021.103623

MacDonald, R., & MacDonald Hydrology Consultants Ltd. (2021). *Year 2 Report—Upper Columbia Wetland Vulnerability Assessment* (p. 26) [Prepared for: Columbia Wetland Stewardship Partners]. Prepared for: Columbia Wetland Stewardship Partners.

MacKenzie, W.H. and J.R. Moran. 2004. Wetlands of British Columbia: a guide to identification. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handb. No. 52.
<http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh52.htm>

Moore, R. D., Fleming, S. W., Menounos, B., Wheate, R., Fountain, A., Stahl, K., Holm, K., & Jakob, M. (2009). Glacier change in western North America: Influences on hydrology, geomorphic hazards and water quality. *Hydrological Processes*, *23*(1), 42–61. https://doi.org/10.1002/hyp.7162

Nummi, P., & Holopainen, S. (2020). Restoring wetland biodiversity using research: Whole-community facilitation by beaver as framework. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *30*(9), 1798–1802. https://doi.org/10.1002/aqc.3341

Nummi, P., Liao, W., Huet, O., Scarpulla, E., & Sundell, J. (2019). The beaver facilitates species richness and abundance of terrestrial and semi-aquatic mammals. *Global Ecology and Conservation*, *20*, e00701. https://doi.org/10.1016/j.gecco.2019.e00701

Pollock, M.M., G.M. Lewallen, K. Woodruff, C.E. Jordan & J.M. Castro (Editors) 2017. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 2.0. United States Fish and Wildlife Service, Portland, Oregon. 219 pp. Online at: https://www.fws.gov/oregonfwo/promo.cfm?id=177175812

Rangwala, I., & Miller, J. R. (2012). Climate change in mountains: A review of elevation-dependent warming and its possible causes. *Climatic Change*, *114*(3–4), 527–547. http://dx.doi.org/10.1007/s10584-012-0419-3

Ronnquist, A. L., & Westbrook, C. J. (2021). Beaver dams: How structure, flow state, and landscape setting regulate water storage and release. *Science of The Total Environment*, *785*, 147333. https://doi.org/10.1016/j.scitotenv.2021.147333

Rooney, R. C., Carli, C., & Bayley, S. E. (2013). River Connectivity Affects Submerged and Floating Aquatic Vegetation in Floodplain Wetlands. *Wetlands*, *33*(6), 1165–1177. https://doi.org/10.1007/s13157-013-0471-4

Thompson, S., Vehkaoja, M., Pellikka, J., & Nummi, P. (2021). Ecosystem services provided by beavers Castor spp. *Mammal Review*, *51*(1), 25–39. https://doi.org/10.1111/mam.12220

Utzig, G. (2021). *The Columbia Wetlands and Climate Disruption: A Preliminary Assessment* (p. 13).

Westbrook, C. J., Cooper, D. J., & Baker, B. W. (2006). Beaver dams and overbank floods influence groundwater–surface water interactions of a Rocky Mountain riparian area. *Water Resources Research*, *42*(6). https://doi.org/10.1029/2005WR004560

Wohl, E. (2013). Landscape-scale carbon storage associated with beaver dams. *Geophysical Research Letters*, *40*(14), 3631–3636. https://doi.org/10.1002/grl.50710

Zimmerman, E. (2004). *Columbia Wetlands Ramsar Information Sheet* (p. 19). The East Kootenay Environmental Society.