Economic, Social, and Environmental Benefits of Riparian Rehabilitation as a Climate Change Adaptation Strategy for Agriculture

Final Project Report
submitted to
BC Agriculture & Food Climate Action Initiative

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ABSTRACT

The findings from a three-year study on “Economic, Social, and Environmental Benefits of Riparian Rehabilitation as a Climate Change Adaptation Strategy for Agriculture” are summarized in this final project report, which is accompanied by several appendices that provide in-depth discussions of the data and results (Appendix 1 – 3). Appendix 4 consists of four Fact Sheets that provide high-level summaries of the key findings, intended for public distribution.

The study was an interdisciplinary, multi-faceted undertaking that examined several small land-holdings on two small watersheds (Alderson Creek and Kendry Creek) near Armstrong, BC, both of which are dominated by agricultural activities. Questionnaires were distributed and interviews conducted to elicit responses on a range of topics dealing with climate change knowledge, social network structure, personal attitudes, and the range of barriers and opportunities faced by landowners when contemplating climate change adaptation strategies. Data were collected on the relative costs and benefits to the individual (and to society more broadly) for participating in stream rehabilitation as one possible mechanism for climate change adaptation. In addition, a variety of biophysical parameters were measured to assess aquatic health of the streams in relation to land management practices at the farm scale. The overall objective was to provide sound empirical evidence in support of beneficial management practices and for improving future development of more efficient and effective collaborative programs addressing the challenge of climate change adaptation in the agricultural sector.
Introduction

Climate change is a reality that is recognized by most people around the globe, especially with regard to the potential negative consequences for humans and societies at large\(^1,2\). Depending on geographic location, political stability, economic status, and cultural norms, the impacts may be immediate or delayed, severe or mild, detrimental or beneficial, and of critical or minimal concern. In part, one's response to climate change will depend on how informed one is about the potential severity of future impact (i.e., the relative risk or opportunity) and about the available options for adaptation to anticipated threats to personal livelihood that a changing climate may pose for the individual.

In the southern interior of British Columbia, the anticipated effects of global climate change will be a regional shift in weather conditions towards\(^3\):

1. warmer temperatures in winter and summer, with a projected province-wide increase of 1.3 to 2.7\(^\circ\)C by 2050;
2. less snow accumulation in the higher altitudes;
3. faster snow melt and an earlier onset of the freshet in the spring;
4. larger flood discharges and higher peak stages;
5. longer, hotter growing season with less water in reservoirs and streams; and
6. more extreme weather fluctuations (e.g., more intense storms).

In practical terms, this implies greater likelihood of agricultural fields being flooded or staying water-logged during the planting season, increased soil loss due to floods and extreme wind storms, greater heat stress on livestock and crops during the growing and harvesting seasons, heightened risk of wildfires, greater incidence of pests and infectious disease, more pronounced wind and hail damage, as well as greater need for irrigation water and more upland storage, all of which will lead to the likelihood of increased costs of production and overall effort devoted to agricultural activities.

The loss of ‘stationarity’ in climatic conditions also implies increased uncertainty as regards the effectiveness of traditional farming methods and protocols (e.g., when and what to plant, when to harvest), and hence, unstable planning processes and disrupted scheduling. Thus, it seems inherently sensible to begin adapting to the impending impacts of climate change. And yet, it is not immediately apparent how this should be done and by whom. What are the relative roles of individuals and government agencies when contemplating adaptive strategies to mitigate or avoid the impacts of future climate change? These questions remain largely unanswered, but this case study provides some insights that may be of interest to planning agencies.

\(^1\) [http://www.pewglobal.org/2015/07/14/climate-change-seen-as-top-global-threat/]
\(^3\) [https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/impacts]
Study Background

The motivation for the study arose in light of a Group Environmental Farm Plan (GEFP) that was being organized in 2014 by a group of landowners on Alderson Creek, with BC Cattlemen’s Association as the proponent and assistance from Mr. Peter Spencer (EFP Planning Advisor, BC Ardcorp) and Mr. Lee Hesketh (Lead Consultant, and Program Manager, Farmland-Riparian Interface Stewardship Program). Eight property owners joined to form a not-for-profit society called the "Alderson Creek Rehabilitation Environmental Society (ACRES)" and committed to participate in the Group Environmental Farm Plan application process.

The GEFP program enables producer groups to assess agricultural impacts on their surrounding environment (e.g., water quality, biodiversity, nutrient loading) and to propose and implement project works in accord with the Canada-British Columbia Beneficial Management Practices Program, which provides financial incentives. The key difference between a standard Environmental Farm Plan (EFP) and the Group Environmental Farm Plan (GEFP) is that the former is for individual landowners whereas the intent of the GEFP is to involve multiple producers that collectively span a large geographic area and who are able to organize themselves in a collaborative group. This collaborative dimension of the GEFP was particularly relevant to our study for several reasons.

Firstly, implementation of beneficial management practices such as riparian rehabilitation along an entire water course, rather than on a small segment of a stream bounded by property lines, would seem to have a better chance of leading to overall improvements in water quality and ecosystem health. If one landowner invests time and effort to enhance the health of the riparian zone on their property, but the immediate property downstream is not managed effectively, then all benefits accruing to the riparian rehabilitation project would remain localized upstream and not be transferred downstream.

This idea regarding inter-connectivity of adjacent properties and their land management practices seems reasonable, but has not been tested stringently. In particular, there is little guidance in the literature as to the minimal scale at which riparian rehabilitation is likely to be (in)effective. Clearly, this could have implications for how collaborative co-management programs might be evaluated and delivered in the future--perhaps leading to changes to the overall requirements for minimal acreage eligibility and the need for contiguous landholdings to become participants.

Accordingly, we undertook a series of monitoring studies to assess the biophysical status of Alderson Creek at numerous locations on every property beginning at the source and extending to the confluence of Alderson Creek with Fortune Creek.
We also duplicated our methods on a ‘control’ stream (Kendry Creek), which was similar in size and character but not participating in a GEFP or of any collaborative action leading to climate change adaptation. **Detailed findings may be found in Appendix 1 and Fact Sheet 1 (Appendix 4).**

**Secondly**, the question of what motivates people to participate in activities that yield positive environmental benefits looms large. Producers are very pragmatic and attentive to the economic viability of their operations. However, they also have a strong land stewardship ethic that goes beyond the purely utilitarian aspects of their land holdings. Environmental improvements are often consistent with this ethic and they may take the form of minimizing the impact on nutrient loading and water quality degradation or improving the visual aesthetics attached to their properties or supporting biodiversity, just because it is the ‘right thing to do.’

Individual producers will make decisions about (non-)participation using a complex, personalized calculus that includes a range of direct and indirect costs and benefits. Some of these are relatively easy to quantify (e.g., yield per acre, cost of equipment and fuel, etc.) whereas others are notoriously difficult to put numbers on (e.g., the value of having a healthy, functioning aquatic ecosystem on a producing landscape).

Accordingly, we undertook a detailed cost-benefit assessment of the proposed project works (i.e., those with financial support from the Beneficial Management Practices Program) using contingent valuation and benefit transfer methods (see Appendix 2 for definitions and discussion of methods). The intent was not to decipher what any particular landowner’s decision-making calculus involves, but rather to adopt a broad perspective on whether riparian rehabilitation is ‘cost effective’ if one considers (and properly values) the societal and ecological benefits that may accrue as a consequence of environmental improvements. If the case can be made that such projects offer net benefits to society (expressed in real dollars), and also to the landowner, then a system of publically-funded incentives may be appropriate to initiate collaborative actions that lead to overall improvements for everyone. **Detailed findings may be found in Appendix 2 and Fact Sheet 2 (Appendix 4).**

**Thirdly**, the collaborative requirement of the GEFP is important to our study because it is critical to understand the degree to which people have access to information and knowledge. It is equally important to understand how people obtain this knowledge, whether through social networks or by individual means (e.g., reading newspapers, blogs, exchanging e-mails, etc.). Participants in the study had different degrees of ‘inter-connection’ as a consequence of being neighbours (adjacent or distant), owning land that was joined hydrologically by common streams, participating in similar farming activities (full-time or part-time), and belonging to groups that may have
enabled casual or formal exchange of information and knowledge. In addition, the Alderson Creek landowners were ‘connected’ through participation in the GEFP process, whereas the Kendry Creek landowners were not. Accordingly, we asked participants to fill out a questionnaire on climate change knowledge and we conducted extensive one-on-one interviews to elicit responses about attitudes and motivations for participating in climate change adaptation strategies. **Detailed findings appear in Appendix 3 and Fact Sheets 3 and 4 (Appendix 4).**

**Study Site**

The study site is located just east of the town of Armstrong in the south-central interior of British Columbia (Figure 1). Alderson Creek runs in a northerly direction with the mainstem portion of the creek arising from groundwater emanating from beneath a small housing subdivision. These houses are on a municipal water supply, but there is no central sewer system. The extent to which the household septic systems contribute to groundwater flow and nutrient contamination is not known.

![Aerial view of the study location. The landholdings under investigation are adjacent to the mainstem branch of Alderson Creek (solid red line).](image-url)
There is a lesser branch of Alderson Creek that flows in from the east with its source in the mountainous terrain to the south-east (dotted red line on Figure 1). The steep natural channel transitions to a linear drainage ditch (flowing towards the north) along the property boundaries between a large field and a dozen or so housing lots and then to another drainage ditch running alongside McLeod Road (flowing towards the west). During the summer, this tributary typically ceases to flow. Both the mainstem and the tributary branches drain into culverts beneath McLeod Road, and they join in a wetland area with mature trees immediately to the north of the road. Partial blockage of these culverts is a recurring problem, often leading to localized flooding upstream. The municipality has responsibility for culvert maintenance, but landowners report general unresponsiveness to requests for maintenance action.

Figure 2: Oblique view looking up the alluvial fan complex (to the south), showing the relative position of Alderson Creek and Fortune Creek.

Figure 2 shows an oblique perspective of the landscape looking toward the south-east, and it shows the gently sloping nature of the alluvial fan complex upon which Alderson Creek flows. Fortune Creek is the primary stream in this area, and it drains through a deeply incised canyon with steep gradient before flowing on to the broad alluvial fan that aprons the main valley. Alluvial fans are depositional features
comprised of boulders, gravels, and overlapping lenses of sand, silt and clay. They evolve over thousands of years, through a process of progressive sedimentation, stream avulsion (course switching), and incision. As a consequence, the hydrogeology is extremely complex.

There are numerous zones where flowing surface water infiltrates into the substrate, often drying up the stream completely, only to re-surface somewhere downslope as a spring or marshy area. Alderson Creek is sourced from exactly such a process, where some of the water flowing in the Fortune Creek canyon infiltrates into the shallow gravel and sand substrate, migrates along the shallow aquifer system, and comes back to the surface immediately downslope of the small housing subdivision at the head of Alderson Creek. The bare (brown) field just to the north-west of the subdivision has a visible wet (dark) spot that is indicative of shallow groundwater in this area. Similar perennially wet zones have been reported by landowners across this alluvial fan, and these water-logged areas pose significant risks and liability for animals, machinery, and production. A detailed hydrogeologic study of the aquifers in the alluvial fan complex has not been performed to our knowledge.

In addition to the swampy areas that impede normal farm operations on this alluvial fan complex, landowners face a range of other management challenges. Although Alderson Creek flows all year around, its groundwater source from within the alluvial fan matrix implies that the stream is not prone to major fluctuations in discharge, as is Fortune Creek, which is snow-melt dominated. Although the spring freshet may lead to flooding of low-lying land, it serves an important function in the long-term evolution of many river systems. Specifically, large discharge during the freshet implies fast flowing water, which in turn, leads to scour of the channel bottom. In this way, the capacity of most river channels to convey water and sediment is sustained naturally.

However, since Alderson Creek is not fed directly by snow-melt in the headwaters, the discharge volume does not fluctuate seasonally by any significant measure. Indeed, extreme rainfall events seem to have as much effect on increasing water levels as does the spring snow-melt period. The consequence of this is that there is insufficient flow capacity to keep the channel adequately scoured.

As shown in Figure 3, there is an annual growth of watercress and other aquatic vegetation that effectively chokes the channel. This leads to enhanced deposition of fine-grained silt and clay, which might normally move right through the system. The problem is exacerbated when livestock are given access to the stream (for watering purposes) because the stream banks are destabilized, leading to large, unnatural inputs of sediment to the stream system. This excess sediment can only be conveyed a short distance downstream because the flow capacity is not there to sustain sediment transport. Deposition occurs thereby progressively raising the channel bed.
Figure 3: Management challenges faced by landowners along Alderson Creek. Left panels show annual recurrence of in-stream aquatic vegetation in Alderson Creek, which slows water flow and chokes the creek (just south of the intersection of Hwy 97 and Mountain View Rd). Right panels provide examples of livestock access to creek and watering pond (in upper section of Alderson Creek near McLeod Rd).

The fine-grained sediments on the bed are ideal locations for plant seeds to germinate, especially when the flow is shallow and there is ample sunlight to stimulate growth. Beds of thick watercress are very effective in slowing water flow, which enhances further sedimentation and leads to progressive degradation of channel capacity. Eventually, even a small precipitation event will lead to overbank flows and flooding of low-lying land. In this state, the stream has intimate connectivity with the adjacent production landscape. In other agricultural watersheds, this has caused water quality concerns having to do with nitrogen, phosphorous, and toxic chemical introductions to the stream. Healthy riparian buffer zones have been demonstrated to mitigate these negative impacts, and they are essential to the proper ecological functioning of fluvial landscapes.

Alderson Creek and the hydrology that determines its flow cause a variety of financial impacts on the landowners. Springs, seeps and groundwater-fed wetlands are generally problematic for land management. Livestock is more prone to hoof rot and other diseases. Land that is perpetually wet often has limited capacity to produce
profitable crops and tends to be quickly degraded if used for grazing. Often the plant species that grow preferentially on wet land out-compete the planted crops, and the harvested mix of plants has lower feed value than forage crops grown on drier land.

Beyond the direct crop production impacts, wetlands and water courses break up the landscape in ways that makes it hard to use modern farm equipment. Managing water courses to minimize their impact on agricultural operations is often an objective of land owners. Unfortunately, what is optimal from a landowner's perspective may degrade the natural processes, reducing environmental services enjoyed by society at large, and in the long run may also undermine some of the productivity benefits that landowners are seeking to maximize.

Animal grazing (cattle and horses) and forage production (primarily hay) are the main agricultural activities taking place on the land under investigation. The land holdings are relatively small, with their primary household income from sources other than agriculture. These landowners live where they do and manage the land the way they do to achieve a lifestyle that they value. Their attachment to the land is therefore not strictly as an input to an economic activity. This complicates understanding the incentives that motivate the landowners in the Alderson Creek watershed.

**Timelines and Caveats**

The original framing of this research study was based on an experimental methodology that relied on ‘before’ versus ‘after’ treatment conditions, which would have allowed for an evaluation of changes in biophysical conditions in the stream and in participants’ attitudes and knowledge as a consequence of the project works (i.e., riparian rehabilitation, fenced cattle exclosures, off-stream watering, cattle crossings, field drainage tile installation). The three-year time frame for the research study was recognized as being only marginally long enough for such an examination, allowing for one year of baseline data collection and at best, two years of monitoring of after-treatment effects. Table 1 provides the approximate dates of key milestones for our research study alongside those for the landowner project works, which have yet to be completed as of the writing of this report.

The primary issue that was faced in our research study was that the GEFP-initiated project works weren’t started until the end of year two of our study. Although funding from the Beneficial Management Practices Program was approved in the summer of 2015 and initial permitting secured by the fall of 2015, there was a long delay in initiating the recommended in-stream works (e.g., hiring skilled contractors, securing services of qualified professionals). In part, the delay may have been due to project management lapses or to budgetary limitations, which ultimately led to the involvement
of the Splatsin Indian Band who provided additional financing and labour via grants that they had access to. Moreover, there were additional regulatory hurdles to surmount, all of which delayed timely initiation of the project works. Regardless, the fact that some of the riparian buffer zones weren’t completed until the Fall of 2017 (while remaining works are scheduled for spring, 2018) means that there was no opportunity to assess the after-treatment conditions to determine the effect of the works.

At this time, we are unable to make any assessment about whether the riparian rehabilitation project has had any impact on stream health. Even under ideal circumstances, this would have been a challenging task given the inherent natural variability in the hydro-climatic conditions (as discussed below). As a consequence, the biophysical component of the research project was re-focused on quantifying and understanding the natural variability in the pre-treatment conditions, both temporally and spatially. Such an understanding is critical if a determination is to be made that stream rehabilitation actually makes a difference in the long run. So there is still great utility in the results even if the original intent of the research was not achieved. Continued monitoring is recommended given the depth of understanding of the pre-treatment state of the watershed. Fortunately, the delayed completion of the in-stream works does not affect the cost-benefit analysis, which was based on the projected budgetary costs (as outlined in the GEFP application) rather than on the actual expenses incurred.

Similarly, the social components of the project were geared toward an understanding of the barriers and constraints faced by landowners when engaging in collaborative activities that enable climate change adaptation. Thus, there is an evident reality to this case study that is legitimate, pertinent and informative, despite the fact that the project works were slow to be realized.
<table>
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<th>TIMELINE</th>
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<th>UBC Research Study</th>
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<tr>
<td><strong>2014</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer, 2014</td>
<td>Alderson Creek Rehabilitation Environmental Society (ACRES) formed</td>
<td></td>
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<tr>
<td>Fall, 2014</td>
<td>GEFP Application</td>
<td>Climate Action Initiative Proposal submitted</td>
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<tr>
<td><strong>2015</strong></td>
<td></td>
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<tr>
<td>March 15, 2015</td>
<td>IAF funding approved</td>
<td>Field monitoring initiated</td>
</tr>
<tr>
<td>Summer, 2015</td>
<td>Project funding approved</td>
<td>Field monitoring initiated</td>
</tr>
<tr>
<td>September 8, 2015</td>
<td>Certificate of Approval – Research Ethics Board, UBC O</td>
<td>Field monitoring initiated</td>
</tr>
<tr>
<td>Fall, 2015</td>
<td>FLNRO approval for in-stream works</td>
<td>Questionnaire distributed and participant interviews conducted</td>
</tr>
<tr>
<td><strong>2016</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring, 2016</td>
<td>Field drainage ditching initiated</td>
<td>Year 1 Project Report</td>
</tr>
<tr>
<td>Summer, 2016</td>
<td>Creek excavated in upper reaches</td>
<td>Field monitoring continued</td>
</tr>
<tr>
<td>Fall, 2016</td>
<td>Fence posts installed; no wire strung Splatsin Indian Band involvement</td>
<td>Cost-Benefit Analysis I</td>
</tr>
<tr>
<td><strong>2017</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring, 2017</td>
<td>Wire strung and fencing completed on upper section of reach; some trees planted</td>
<td>Year 2 Project Report</td>
</tr>
<tr>
<td>Summer, 2017</td>
<td>Field monitoring continued</td>
<td>Cost-Benefit Analysis II</td>
</tr>
<tr>
<td>Fall, 2017</td>
<td>Wire strung and fencing completed on upper reach; more trees planted</td>
<td>Follow-up interviews</td>
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<tr>
<td>Winter, 2017</td>
<td>Fencing completed on two properties; other properties not yet addressed; offstream watering and cattle crossings yet to be completed</td>
<td></td>
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<tr>
<td><strong>2018</strong></td>
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<td>February 15, 2018</td>
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<td>Final Project Report</td>
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Table 1: Relative timelines of the project works undertaken as part of the GEFP by landowners and the research study by UBC faculty and students showing key milestones.
Results and Findings

Biophysical Assessments

Appendix I provides a detailed discussion of the field site, experimental methods, data collected, and results. The primary contribution from this component of the study is that there are three years of baseline data on the natural variations in these small stream systems (i.e., Alderson Creek and Kendry Creek). Based upon these data, it is possible to conclude the following:

a. **Alderson Creek and Kendry Creek are well suited for a study using paired watersheds** because both creeks drain the same regional geology (an extensive alluvial fan complex) and traverse similar agricultural landscapes (mostly pasture and forage crops). Alderson Creek arises from an extensive groundwater seepage zone at a mid-fan location with a small housing development immediately upslope of the seepage zone. Kendry Creek is sourced from a mountainous headwater ravine at much higher elevations and follows a natural channel through most of its course. Despite having different sources, the streams acquire similar water quality characteristics based on the landscapes they flow through. Thus, the water tends to be of similar character by the time it reaches the valley bottom. Figure 4 shows average water temperature trends at the bottom of Alderson Creek and Kendry Creek (near Hwy 97), indicating that **there is similarity in the absolute temperatures as well as the daily fluctuations and seasonal trends.** It should be possible to use these two watersheds in the context of understanding the potential benefits of a riparian rehabilitation project, with Kendry Creek serving as the ‘control’ stream and Alderson Creek as the ‘treated’ stream.

b. There is **considerable temporal variability in the range of water quality parameters monitored (e.g., temperature, conductivity, pH, turbidity).** Figure 5 shows short-term water temperature trends for a 3-week period at the lower end of Kendry Creek and at the lower end (XS1) and middle section (XS19) of Alderson Creek. Air temperature trends from the weather station in Armstrong, BC are also shown. The diurnal (day to night) fluctuations in stream temperature are very apparent, often having a range of 5-10°C, which is quite surprising given that these are relatively steep streams with rapidly flowing water. This is especially true for Alderson Creek, which is spring-fed and therefore originates from a cool water source. What this indicates is that **there is a high degree of heat gain or loss by the water as it flows along the channel,** likely because of direct radiative exchanges (i.e., shortwave input from the sun during the day and longwave loss to the sky at night) as well as direct thermal exchanges by conduction with the stream.
Figure 4: Water temperature time series taken at the bottom of Alderson Creek (black line) and Kendry Creek (green line). Data were collected at similar locations (just before each creek entered the culverts running beneath Hwy 97) using temperature pendants programmed to record data at 10-minute intervals.

The dense cover of watercress during the summer months, for example, will absorb a great deal of radiant energy from the sun during the day, which will warm the plants, and thence the water, which is in intimate contact with the plants. The temperature maxima and minima for water temperature is delayed slightly from the peaks and troughs of the air temperatures, symptomatic of the fact that water takes more energy and more time to heat up (or cool down) than air or soil because of its unique thermal properties. The primary point to be made, however, is that the large temporal variability in the temperature time series (daily, weekly, seasonally) will make it challenging to tease out
information on whether the long-term conditions are warming or cooling, either as a response to global climate change or to implementation of beneficial management practices such as riparian rehabilitation.

Figure 5: Example temperature time series from the lower sections of Alderson Creek (XS1) and Kendry Creek in comparison to air temperature (measured at weather station in Armstrong, BC).

c. In addition to large variability in time, most of the biophysical parameters measured during this study show strong spatial differentiation. For example, Figure 6 shows daily average temperatures at four locations on Alderson Creek for the period May 1, 2016 through to December 11, 2016. The uppermost sampling station (XS35), which is just downstream of the groundwater seep, consistently had the coldest water temperatures during the summer and early fall. This aligns with expectation given that groundwater typically has reasonably cold temperature, although this depends on the underground pathways that it takes before coming to the surface. In contrast, the next sampling station in the downstream direction (XS34), which is only 75 m or so away, consistently had the warmest temperatures of any location on Alderson Creek. The reason for this is that the flow from XS35 goes into a large, shallow pond that was dug as a watering hole for cattle. Because the pond has a large surface area relative to its depth, and because the water moves very slowly through this pond (small discharge to volume ratio), there is ample opportunity for sunlight to heat the stagnant water. During the daytime period in the summer, water temperature at
XS34 (at the outflow from the pond) often exceeds 25°C, which is well above the mortality threshold for salmonids (approximately 21°C). Around mid-October during the onset of the cold season, the temperature differences reverse themselves such that XS35 has warmer water than XS34. Again, this has to do with the radiation balance affecting the pond because at this time of the year there is relatively little sunlight and there is net energy loss from the pond. Thus the pond water becomes colder and colder, whereas the groundwater remains relatively stable throughout the year and is not strongly influenced by the atmosphere. Hence, the water temperature at XS35 remains warmer than the pond water during the winter. The water temperature at other cross-sections are generally in between those at XS35 and XS34, with a slight downstream cooling trend likely due to groundwater influx into Alderson Creek. Conductivity consistently increases in the downstream direction whereas pH shows no obvious trends although certainly locations have consistently larger or smaller values throughout the year (see Appendix I).

Figure 6: Average daily water temperatures at four cross-sections along Alderson Creek for summer and fall of 2016. See text for explanation.

d. On the basis of visual cues on the landscape, the mainstem branch of Alderson Creek was subdivided into five (5) sub-reaches that aligned with landholdings and property boundaries. Discriminant analysis was performed using multiple biophysical parameters (temperature, pH, conductivity, turbidity) to determine whether these five sub-reaches could also be differentiated according to water quality parameters. In this type of statistical test, the actual parameter values (e.g., pH = 7.2)
are standardized and combined in a way to yield two ‘factors’ or ‘variable groupings’. Each of these factors is an amalgamation of the original parameters with different weighting functions, and the optimal combination is selected by the statistical algorithm so as to determine whether there are natural groupings or clusters in the data. Figure 7 shows that the three sampling stations in Reach 5 (the uppermost property on Alderson Creek above McLeod Road) are quite distinct and separate from the other stations downstream. In addition, the stations in Reach 4 are clearly separated from the other reaches. In contrast, the stations in Reach 1, 2, and 3 appear to cluster together on the diagram, although there is still some degree of separation between Reach 1 and Reach 3. On the basis of the results of this discriminant analysis it is reasonable to conclude that there is some validity to sub-reach differentiation following property boundaries, and that four of the sub-reaches are distinctly different, which is visually apparent on the landscape and also reflected in the water quality parameters.

**Figure 7:** Results from a discriminant analysis on water quality parameters (temperature, pH, conductivity, turbidity) for all 35 stations along Alderson Creek, showing significant clustering according to sub-reaches identified using visual cues on the landscape. The axis values are weighted combinations of the actual water quality parameters reduced to standardized values, labelled as ‘Variable Grouping 1’ and ‘Variable Grouping 2.’
e. Monitoring of vegetation growth at five stations (one in each of the five sub-reaches) along Alderson Creek from spring to winter over the period 2015-2017 using standard plant assays (see Appendix 1 for details) indicates that **there are measurable differences among the five sub-reaches**. Figure 8 shows box-whisker plots representing all the data from the right bank (RB), left bank (LB) and channel centre for each of the five stations, with the solid dot indicating the long-term mean, the central bar indicating the long-term median, the box top and bottom indicating the upper and lower quartiles, respectively, and the whiskers showing the maximum and minimum values. Large box and whiskers indicate a high degree of variation in the percent vegetation coverage, typically due to differences in growth patterns from spring (i.e., small percent cover) through summer (i.e., large percent cover) and fall (i.e., medium percent cover). Each of the box-whisker plots comprises dozens of data points. The plots indicate that Site 5 (an open pasture with livestock grazing and swampy conditions) consistently had the largest percentage cover, both on the banks and in-channel, whereas Site 4 (a mature wetland with large trees and dense overstory) had the smallest percentage cover. This reinforces the important role of large trees in riparian zones for preventing the penetration of sunlight onto the creek, thereby precluding the invasion of aquatic species such as watercress. Sites 1, 2, and 3 are not statistically different but are characterized by a large degree of variation due to the seasonal influence.

![Box-whisker plots showing vegetation density at five locations along Alderson Creek.](image)

**Figure 8**: Results from vegetation assays (2015-2017) from five locations along Alderson Creek. RB refers to the right bank of the creek (facing downstream) and LB refers to the left bank of the creek. See text for explanation.
f. Monitoring of macro-invertebrates (Ephemeroptera (Mayflies), Plecoptera (Stoneflies), Trichoptera (Caddisflies)) at five stations (one in each of the five sub-reaches) along Alderson Creek from spring to winter over the period 2015-2017 using enhanced CABIN protocols (see Appendix 1) indicates that there are measurable differences among the five sub-reaches. Figure 9 shows box-whisker plots representing all the data collected over the three-year period, indicating the number of individuals found in each of the sampling baskets when they were flushed at monthly intervals. The largest numbers of macro-invertebrates on average were found in the lowermost section of Alderson Creek (Reach 1), with regularly large counts. Reach 4 also had large numbers of macro-invertebrates, consistent with the wetland environment. In contrast, only one individual was ever found at Reach 5 in the entire three-year monitoring period.

![Figure 9: Results from macro-invertebrate sampling (2015-2017) from five locations along Alderson Creek.](image)

The biophysical components of the research project indicate that there is large temporal and spatial variability in water quality parameters in Alderson Creek. However, there is some degree of order to the data when accommodations are made for seasonal differences, for example. The trends during summer are different from the trends in spring, fall, and winter, and this is described in more detail in Appendix I. Careful consideration must be given to how average statistics are calculated and interpreted with such highly variable data. More importantly, there appears to be spatial
order in the data, such that what one measures at the top of the system is not necessarily the same as what one measures at the bottom of the system. Conductivity, for example, increases progressively in the downstream direction, on average. **Of special importance to this study, however, is the finding that spatial differentiation at the scale of the small farm is also apparent, particularly so in the vegetation assays and macro-invertebrate counts.** Thus, the conditions on Reach 5 are distinctly different from the conditions on Reach 4, which are different from the conditions on Reach 1, with each of these reaches aligning with a specific land-holding that is subject to different land management practices. The suggestion is that land-management practices appear to make a difference in water quality even very locally, which has both negative and positive implications. On the negative side, poor land stewardship would seem to lead to degraded environmental conditions. On the positive side, implementation of beneficial management practices, such as establishment of a healthy riparian buffer corridor, would likely lead to improved ecological functioning.

### Cost-Benefit Analysis and Ecological Valuation

Social Cost Benefit Analysis (SCBA) aims to measure all the costs and benefits that may impact a population with standing (i.e., those individuals identified as having some stake in the analysis). The approach expressly recognizes that there are often consequences for individuals beyond the immediate participants in a project, all of whom may be impacted as a result of the project. There are a variety of methodologies for measuring these impacts, all of which rest on the presumption that individuals or households have a maximum willingness to pay (WTP) to enjoy or avoid the project impacts, as appropriate to the impact. The ‘revealed preference’ class of methods seeks to measure this WTP by identifying and measuring the amount individuals or households pay for goods that are associated with the impact being valued. For example, how is the price of a house affected by being near a polluted site? The contrasting ‘stated preference’ class of methods is employed when no such surrogate market can be identified. It relies on carefully constructed surveys that build a choice situation that asks the participant to compare a change in the variable of interest, e.g. air quality, and a change in their household disposable income.

Primary research to measure WTP values is costly and time consuming. Consequently, a ‘benefit transfer’ approach has become important in project appraisal. This approach adapts values from existing primary research to alternative situations. It is recognized that each project is unique, and therefore a large aspect of benefit transfer research is determining how to adapt the identified values to the project situation. Adjustments are typically made for project size, project characteristics, and the
impacted population. Benefit transfer is the approach used herein to estimate costs and benefits of the Alderson Creek project. Key steps in the SCBA are set out Table 2.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Alternatives</td>
<td>Three and five meter buffers, relative to status quo of no project.</td>
</tr>
<tr>
<td>Determine Population with Standing</td>
<td>All residents of regional districts of Central Okanagan, North Okanagan and Columbia Shuswap.</td>
</tr>
<tr>
<td>Identify and Quantify Project Impacts</td>
<td>(1) project costs, (2) riparian habitat restoration, (3) aesthetic enhancement, (4) wildlife protection, (5) erosion control, (6) water quality improvement, (7) fish habitat enhancement, and (8) carbon storage.</td>
</tr>
<tr>
<td>Monetize Project Impacts</td>
<td>Values found from literature</td>
</tr>
<tr>
<td>Calculate Net Present Value</td>
<td>Discount and aggregate monetized values for impacts</td>
</tr>
<tr>
<td>Sensitivity Analysis</td>
<td>Calculate NPV with 3% and 5% discount rate, and with and without distance decay of benefit values, using a Monte Carlo simulation.</td>
</tr>
</tbody>
</table>

Table 2: Key steps in the cost-benefit analysis for the Alderson Creek study.

The project alternatives were based on the description of project works recommended through the GEFP process and approved for funding through the Beneficial Management Practices Program. These undertakings were seen as achieving important environmental benefits while not imposing an undue burden on the landowners. The population with standing was chosen to represent a large group of people who may reasonably be seen as having some connection to the north Okanagan. However, it was also recognized that the connection to the study site, and therefore the willingness to pay for the environmental benefits, may not be the same for all individuals in the population with standing. Hence a distance decay adjustment was included as part of the sensitivity analysis.

The project impacts were identified by consulting the project description, through conversations with experts, and by examining the relevant literature. The initial list of impacts was somewhat longer than those listed in Table 2. However, some were deemed small enough to be unimportant in the final analysis, and others were discarded so as to avoid double counting.

Values were drawn from the literature, which proved to be challenging. There were few studies that provided values that could be translated easily into a form that fit with this project. Figure 10 shows the range of willingness to pay values in a usable form that were applied to the benefit categories identified. There is a large diversity of values, with some of them quite imprecise. The small number of studies together with the large range of values led us to conclude that a Monte Carlo simulation was an appropriate way to investigate the distribution of possible project net present values.
Figure 10: Willingness-to-pay values derived from an extensive review of the relevant literature. Values are in 2015 Canadian dollars per household per year.

The project benefits and costs did not all occur at the beginning of the project, which requires discounting and a choice of planning horizon. We chose a twenty-year planning horizon, to reflect the fact that fences don’t last forever. The 3% and 5% discount rates reflect values commonly appearing in the literature.

The important results of our analysis stem from the Monte Carlo analysis and the exploration of how WTP values can decay with distance from the project. To scale the WTP values required locating all of the households with standing in relation to the location of the project. To approximate this, we used Statistics Canada census dissemination areas – blocks with an average of about 650 persons – together with parcel boundary data. The population within each dissemination area was distributed across the residential parcels within that dissemination area. While not providing an exact number of people in each residence, the dissemination areas are small enough that the error is likely small.

With the spatial population distribution, we could scale the WTP for each household based on their distance from the study site. We did so using a simple formula,

\[ w_i = 1 - \left( \frac{d_i}{1 + d_i} \right)^\alpha \]

where \( w_i \) is the weight applied to the WTP for household \( i \), which is located at distance \( d_i \) from the study site. The parameter \( \alpha \) determines the rate at which WTP decreases.
with distance from the study site, which larger values of $\alpha$ corresponding to a slower rate of decay. For demonstration purposes, we set $\alpha = 1$ and also calculated results for all people with standing having equal WTP, equal to that of households located immediately adjacent to the study site. Note that with $\alpha = 1$, the households at one kilometer from the site will value the benefits at half of what those at a distance of zero would, which is a particularly rapid rate of decay. We have no clear empirical basis for choosing the value of $\alpha$, and use this as an anchor case to demonstrate the importance of considering distance decay. Of greater importance is identifying the rate of distance decay in benefits that can result in the project “breaking even” (i.e., no net cost or benefit).

Figure 11 shows the results for 10,000 Monte Carlo simulations, with the three and five meter buffers, the 3% and 5% discount rates, and with and without distance decay scaling. Key results are that a lower discount rate increases the net present value (NPV) of the project, a wider riparian buffer increases the value of the project, and introducing a distance-decay function in the value of project benefits reduces the aggregate NPV of the project.

Figure 11: Summary results from 10,000 Monte Carlo simulations indicating the range of net present value (NPV) of the riparian rehabilitation project undertaken at Alderson Creek. Arrows mark location of average NPV for the distance scaling and no distance scaling cases, with numbers giving the average.
Of particular interest is the rate of decay in benefits that makes the project “break even.” Table 3 shows the value for the parameter $\alpha$ for each combination of discount rate and buffer width for which the project NPV = 0. These results can be used to determine what the average willingness to pay must be for someone at a given distance from the project if the project is to break even. The table reports values for both 75 km and 100 km, with the former the distance from the project to downtown Kelowna. If the value of the benefits to someone located immediately adjacent to the project is equal to a one-time payment of about $10, then the average resident of Kelowna needs to be willing to make a one-time payment of at least $0.67 for this project to generate a positive net present value. Whether or not a resident of Kelowna is willing to pay this amount is of course an empirical question, beyond the immediate scope of this project.

<table>
<thead>
<tr>
<th>Buffer Width</th>
<th>3 meters</th>
<th>5 meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Rate</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Alpha</td>
<td>4.261</td>
<td>6.132</td>
</tr>
<tr>
<td>Distance to 0.01</td>
<td>423.5</td>
<td>609.6</td>
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<tr>
<td>Weight at 75 km</td>
<td>0.055</td>
<td>0.078</td>
</tr>
<tr>
<td>Weight at 100 km</td>
<td>0.042</td>
<td>0.059</td>
</tr>
<tr>
<td>WTP at 0 km</td>
<td>$4.66</td>
<td>$6.07</td>
</tr>
<tr>
<td>WTP at 75 km</td>
<td>$0.26</td>
<td>$0.47</td>
</tr>
<tr>
<td>WTP at 100 km</td>
<td>$0.20</td>
<td>$0.36</td>
</tr>
</tbody>
</table>

Table 3: Distance decay parameter values required for the project to ‘break even’ for the four combinations of discount rate and riparian buffer width, together with implied WTP at 75 km (downtown Kelowna) and 100 km from project.

The Alderson Creek project obtained funding, in part, through monies sourced from both the provincial and federal governments. Additional funding was secured with the assistance of the Splatsin Indian Band, and via material contributions from the Fisheries and Oceans Canada. The approval of the Alderson Creek project works for funding is based on the criteria set out in the Environmental Farm Plan Program and in the Beneficial Management Practices Program, together with the normal flexibility and subjectivity that comes from having individuals and committees participate in the selection process. The existence of the programs that provide these funds is a consequence of senior governments allocating monies to achieve a variety of societal objectives. Our results here highlight two important points.

First, there are benefits generated by environmental rehabilitation projects that are relevant to the broader community. This justifies some level of investment by
society in environmental rehabilitation projects – landowners should not be left to bear the full burden of the costs of providing environmental services to the larger community.

Second, households farther from the restoration projects are likely to value these environmental services less than those near the project, a fact that should be considered in deciding which projects to support. For the Alderson Creek project, it will, on average, break even if households at the distance of downtown Kelowna are willing to make a one-time payment of $0.67 to support the project (noting that this conclusion is specific to this case study and its particular geography and population distribution). Given that residents of the Columbia Valley voted in favour of a $10 annual levy to build up a fund for projects like this, it isn’t unreasonable to expect that Kelowna residents would similarly be willing to support such a levy. If they are, then they are expressing willingness to support about 15 projects like the Alderson Creek rehabilitation each year. Taken together, the Alderson Creek rehabilitation project does generate benefits for the larger community, and given the results of work elsewhere, these benefits are likely more than required to make this particular project break even.

Social Analysis of Barriers and Opportunities to Participation in Climate Change Adaptation Projects

Ecosystem-based adaptation to climate change is a relatively recent approach to the sustainable management of natural ecosystems that focuses on enhancing the resiliency of natural ecosystems as a mechanism to improve the adaptive capacity of human social systems. It is receiving growing recognition because it has the potential to provide significant co-benefits for biodiversity and for society at large, while also reducing the agricultural sector’s vulnerability to a range of climate change impacts. Often it involves some sort of ecosystem rehabilitation effort, as was the case for the Alderson Creek project. However, several issues arise when formulating a government-assisted program that intends to implement ecosystem-based adaptation, and some of these were explored in this research study (see full discussion in Appendix III).

In the following, a key issue or question is stated followed by preliminary study findings.

a) How much do landowners know about climate change and the potential impacts on their farm operations? A questionnaire was designed to illicit responses about participants’ knowledge regarding:

I. climate change in general;
II. the regional consequences of climate change; and
III. current and future implications for the farm operations.
Open-ended questions were included to determine whether landowners were taking action or had plans to take future actions to mitigate the impacts of climate change. Figure 12 shows results from selected questions, and it shows that landowners generally have a strong sense of what climate change means and its global implications (Q1 through Q5 show strong agreement), but that landowners are less certain and have mixed opinions about how climate change might affect Alderson Creek and their farm operations (Q6 through Q10 show a range of responses from disagree to agree to unsure). **The implication is that there is general awareness among landowners that climate change is an urgent and pressing issue for the globe, but that there is uncertainty as to how this global-scale phenomenon will translate to local impacts.** As a consequence, landowners feel no compelling need to take adaptive action in anticipation of future climate-related impacts because they don’t fully appreciate the nature or severity of those impacts. And even if the need is recognized, there is great uncertainty as to what should be done by way of an adaptive strategy that has no guarantee of succeeding.

![Questionnaire Summary](image)

**Figure 12:** Summary scores from questionnaire regarding landowner knowledge about general climate change (Q1 – Q5: showing good agreement) and about local watershed impacts (Q6 – Q10: showing uncertainty).
b) **What is motivating landowners to undertake beneficial management practices that lead to environmental rehabilitation, if not climate change adaptation?** A series of in-depth interviews was conducted to understand knowledge and attitudes to environment as well as the reasons why someone might (not) participate in a collaborative project such as a GEFP. Content analysis of the responses leads to the following tentative conclusions:

1. Farmers and ranchers have a strong land-stewardship ethic that compels them to be environmentally conscious, although they are unlikely to undertake environmental rehabilitation projects unless they can be convinced of the benefits. Those benefits need not be tied directly to improved capacity to generate farm revenues—they can be related to improved water quality or to improved wildlife conditions, for example. However, the costs of the improvements are difficult for the landowner to bear if there is no net return on investment. Producers also have difficulty in paying for the costs of project works up-front (as required by the Beneficial Management Practices Program) and later seeking reimbursement after the project works are completed and approved.

2. Engagement in an environmental restoration project is more likely to occur when expert facilitation is made available, involving someone who is knowledgeable about farming/ranching (i.e., the circumstances of the producer), about environmental science, about the practicalities of implementing beneficial management practices, and about available programs of support. Knowledge is key.

3. Project works on farms and ranches are typically undertaken in response to an immediate challenge such as recurring floods or swampy conditions, invasive weeds, poor soil quality, or some sort of regulatory imposition. Once a decision is made to begin a project (e.g., installation of drainage tiles), it is typically completed in a short time frame so as to resume normal operations as quickly as possible. These actions are not perceived by landowners as ‘adaptive actions’ triggered by climate change, and especially not for the purpose of anticipating future climate change impacts. In most instances, these actions are reactionary rather than anticipatory.

4. Landowners expressed a high degree of frustration with extensive regulatory barriers that prevent rapid completion of project works. Although there is a general sense of appreciation that regulations are needed in civil societies, there is an equally strong sense of ownership and entitlement to do on their
land what is necessary. In the case of project works leading to environmental improvements on agricultural land, with real costs to the landowner, the regulations imposed by government agencies to protect the environment (e.g., short window of time for in-stream works) are seen as antithetical to the motivation of the project, which is to rehabilitate environmental conditions. In this regard, there appears to be a wrongly held perception that ‘government’ is a single entity that should act rationally in the same way that an individual with a specific objective might. Failure to communicate regulatory requirements early in the process leads to frustration, loss of motivation, and failed implementation of beneficial management practices.

(5) Many owners of small land-holdings have additional sources of income and are not completely dependent on farm receipts for their livelihood. Decisions about investments for future ‘market competitiveness’ in a changing fiscal environment are not a priority as they might be for a commercial enterprise. Thus, incentives and knowledge are important to motivate ecosystem-based adaptation to climate change for small land-holdings.

Summary and Conclusions

The project has revealed several things that are important for understanding climate change adaptation in the agricultural sector, including:

1) Natural variability in biophysical parameters (i.e., temperature, conductivity, pH, turbidity) can be quite large. There are daily fluctuations superimposed on seasonal fluctuations as well as an element of random variability associated with the unpredictable nature of weather phenomenon that occurs at timescales of weeks. This makes it very challenging to tease out long-term trends such as an increase in average annual temperature that might be associated with climate change or a decrease in average annual temperature that might be associated with shading of sunlight due to establishment of tree cover in a healthy riparian buffer zone. Moreover, there are distinct spatial trends that appear to be associated with land-management practices, so it matters very much where you decide to take samples. The implication is that long-term monitoring is needed in order to fully demonstrate that any sort of BMP that leads to riparian rehabilitation will have had the desired impact. Critical in this regard is monitoring of macroinvertebrates, vegetation, and ultimately, fish.
2) The cost-benefit components of the study reveal that there is great uncertainty in the value that is attached to a range of environmental conditions, in part because there haven't been many studies reported in the literature that deal with studies at this small scale (i.e., individual farms). Depending on which values one chooses to implement in the model, the outcome can be either positive or negative from the perspective of the net present value that is returned to the original project investment. What is clear is that from the perspective of the individual landowner, there are real costs that outweigh the benefits, so either the landowner needs to have a strong stewardship ethic as well as disposable income to invest in the project or there has to be public investment to provide appropriate incentives.

3) The social components of the study reveal that landowners are well aware of the challenges imposed by climate change in a global sense, but they have difficulty connecting the reality of climate change to their immediate circumstances. Their concerns are "more immediate" having to do with the daily challenges of operating their farm or ranch, and to the extent that project works are initiated, they are done so as a consequence of necessity to remedy specific issues such as persistent swampy conditions, perennial flooding, or the need for irrigation. In part, this is due to knowledge deficits with regard to regional consequences of climate change as well as the general lack of information on what an adaptation strategy might look like (and why it is necessary). Engaging in a collaborative program such as that offered via a GEFP can appreciably raise the level of awareness, but it needs to be coordinated and managed appropriately.
Reflections on Collaborative Project Co-Management for Climate Change Adaptation and Environmental Sustainability

The research findings reported here are specific to the Alderson Creek case study, which is an example of a collaborative project intended to improve the conditions of the land base for agriculture as well as for environmental sustainability in light of climate change impacts. The stimulus for the project arose through the opportunity provided by the Environmental Farm Plan (EFP) Program, which provides expertise and consultation leading to recommendations for on-farm project works that may be eligible for financial assistance through the Beneficial Management Practices (BMP) Program. Similar incentive-based opportunities are often available through other government programs as well as a range of environmental non-government organizations (ENGOs) such as The Nature Conservancy or Ducks Unlimited. Reflections and recommendations arising from this study are intended to be applicable to all manner of environmental projects that involve collaborative efforts regardless of the source of expertise and financing despite making reference to the Alderson Creek example.

Figure 13 is a simplified flow chart which shows the key elements of an on-farm project undertaken by an individual landowner. A connection is made initially between the landowner and the EFP Program, typically through an EFP Planning Advisor (often identified via word-of-mouth) who assesses the landholding and provides a report with recommendations for beneficial management practices. If eligible, the landowner submits an application to the BMP Program for assistance to conduct project works in accordance with the EFP. If funding is available and approved through the BMP Program, a specific budget is allocated to the project works with an expectation of various levels of contributions from the landowner depending on the cost-share funding level of the specific BMP (either cash or in-kind). In this single landowner situation, the responsibility for undertaking the project works lies specifically with the landowner, and this includes project management, securing supplies, machinery and labour, financial accounting, and ensuring that all regulatory requirements are met during the project works. Upon completion of the project, the landowner informs the BMP Program via submission of a budgetary declaration, which may trigger an inspection of the project works. Finally, a reimbursement from the BMP Program is authorized as per the original financial agreement. The lines of communication and responsibilities are clearly apparent in this individual landowner arrangement.
Figure 13: Flow diagram of project works implemented by a single landowner with recommendations from the Environmental Farm Plan (EFP) Program and financial assistance via the Beneficial Management Practices (BMP) Program.

Figure 14 shows a simplified flow chart of the group option of the Environmental Farm Plan (GEFP). It is immediately apparent that the complexity has increased manifold. Multiple landowners must be involved, which implies a high degree of coordination and the need for more effective lines of communication and project management. Again, there is heavy reliance on the Group Plan proponent and/or an EFP Planning Advisor to undertake the assessment and to provide a report on recommended beneficial management practices. But since these recommendations are specific to each landholding, there needs to be communication with multiple individuals as well as with the group as a whole because of the requirement for collaborative co-management.

Since each landowner will have different constraints, challenges, and perspectives on whether the project will be beneficial to them as individuals, there needs to be extended dialogue amongst the group in order to achieve consensus on how to proceed collaboratively. This requires coordination and facilitation, as well as some source of leadership, although it is also an opportunity to share knowledge. In Figure 14, this coordination/facilitation role is indicated by the box with the question marks and red outline, because it is not immediately apparent who will (or should) fill
this important function. It could be one (or a subset) of the landowners who volunteer to act in this capacity, or it could be a lead consultant who receives payment for services provided. This is a critical step in the overall process, and this is where many of the challenges arise in such collaborative projects. **Someone has to assume responsibility for the overall success of the project, otherwise it may languish.**

![Flow diagram of multiple Project Works implemented by multiple landowners participating in a Group Environmental Farm Plan (GEFP). The purple box with question marks refers to a facilitator or lead consultant, who may or may not be included, but who is believed to serve a critical function in the overall success of the project.](image)

**Figure 14:** Flow diagram of multiple Project Works implemented by multiple landowners participating in a Group Environmental Farm Plan (GEFP). The purple box with question marks refers to a facilitator or lead consultant, who may or may not be included, but who is believed to serve a critical function in the overall success of the project.

The project works often have multiple components because beneficial management practices on landholding A may not be required on landholding B, which has a different set of challenges and a different context. Each of these components may be subject to a different set of regulatory requirements that also require coordination and facilitation. The complexity can be increased further if the project works have multiple sources of funding, all of which need to be coordinated because there are often in-kind contributions, requirements for cash contributions, and money that is tied to specific purposes or funder mandates.
The experience from the Alderson Creek projects suggests that the most effective means to ensure project success and positive return on investment is to put in place (and require) a knowledgeable and skilled facilitator who can serve the following functions:

1. provide leadership to the producer group, which involves regular meetings with individuals and the group so as to keep everyone informed about what has transpired and what has yet to take place;
2. liaise with the funding agencies and assist in submitting necessary applications and reports;
3. develop and submit applications for permits to regulatory agencies;
4. liaise with government and agency officials who have oversight responsibility for the project works;
5. liaise with affiliated stakeholder groups, such as First Nations, NGOs, and regional councillors;
6. provide oversight for the implementation of project works; and
7. share knowledge about effective environmental stewardship and serve as a source of inspiration.
APPENDIX 1 – DETAILED REPORT ON BIOPHYSICAL CONDITIONS

Available as separate report from the Farm Adaptation Innovator Program, BC Agriculture & Food Climate Action Initiative or by contacting the authors

Richardson, N., and Bauer, B., 2018. *Assessment of Biophysical Conditions on Alderson Creek, 2015-2017*

APPENDIX 2 – DETAILED REPORT ON COST-BENEFIT ANALYSIS

Available as separate report from the Farm Adaptation Innovator Program, BC Agriculture & Food Climate Action Initiative or by contacting the authors


APPENDIX 3 – DETAILED REPORT ON SOCIAL SURVEY ANALYSIS

Available as separate report from the Farm Adaptation Innovator Program, BC Agriculture & Food Climate Action Initiative or by contacting the authors

APPENDIX 4 – FACT SHEETS

**Fact Sheet 1** – *Land management practices and their effect on stream health on small farms and ranches* (Bauer, Richardson, and Walker)

**Fact Sheet 2** – *Social costs and benefits of a Group Environmental Farm Plan: Alderson Creek, BC* (Janmaat, Picault, and Cebry)

**Fact Sheet 3** – *Climate change adaptation: What does it mean to the small landowner?* (Bauer, Rahimova, Richardson, and Janmaat)

**Fact Sheet 4** – *Barriers and opportunities for riparian rehabilitation via collaborative co-management* (Rahimova, Janmaat, and Bauer)
Land management practices and their effect on stream health on small farms and ranches

Germain Bauer1, Noelle Richardson2 and Justin Walker2

Farm Adaptation Innovator Program
Research Factsheet

Purpose
Stream and creeks flowing through agricultural landscapes are often heavily modified and detrimentally influenced by farming/irrigation activities such as forage crop production and livestock grazing. Riparian rehabilitation and the establishment of buffer zones along stream margins may mitigate these impacts. The purpose of this study was to determine whether a single landowner could improve the health of the aquatic ecosystem on their land independent of the actions of adjacent neighbours. The study was aligned with the Beneficial Management Practices (BMP) Program, which provides government funding to individuals and groups of landowners intending to improve agricultural land by establishing riparian buffer zones, field drainage systems, and nutrient management schemes.

Study Objectives
• Monitor and assess the biophysical conditions in Alston Creek within each of the properties participating in a Group Environmental Farm Plan
• Document the range of natural fluctuations in water quality parameters by selecting and analysing a data set of baseline conditions, prior to implementation of BMPs
• Perform statistical analyses to determine whether land management practices and their influence on stream health can be differentiated from natural ecosystem variation.

Methods
• Three years of flow monitoring (2015–2017) from April to December during the snow-free period. Water quality parameters were measured during bi-monthly visits using handheld probes (pH, conductivity, dissolved oxygen, nitrate, and total phosphorus) and a thermometer. Samples were collected at multiple locations along the creek.
• Macro-invertebrates and vegetation densities were measured at 4 sites along the creek at monthly intervals.
• Cross-section surveys at 34 locations were taken with engineer’s level and rod, with geo-referenced benchmark pins.
• Statistical tests were performed on the data to quantify the depth of temporal and spatial variability and to assess the effect of land management practices.

Key Finding 1
Alston Creek was subdivided into five (5) adjacent segments or sub-reaches based on property boundaries, each of which had different land management practices (e.g. grazing, forage crop production, wetland). Each sub-reach had multiple monitoring stations for water quality measurements.

Key Finding 2
• Macro-invertebrate populations appear to be sensitive to water quality in creeks, which is seemingly influenced by land management practices.

Key Finding 3
• Natural fluctuations in water quality on small streams can be large (Figure 3), where the wettest and driest months can differ greatly (e.g., 49°C in 2015–2017), with the maximum and minimum temperatures set at an average of 6–20°C, which indicates very high variability in both temperature and sunlight.
• Although the average daily temperature is consistently below 20°C, which is considered a typical threshold for fish survival, the warmest period of the day is typically above the threshold, suggesting poor habitat quality during the summer.

Implications for Climate Change Adaptation on Small Farms
• Small creeks typically show great variability in space and time, which means that long-term trends in average conditions aren’t immediately evident, even to those living alongside farm streams—especially in the event of an extreme event or a new trend that is not apparent for the last 30 years.

Definitions
• Morphologic characteristics—physical characteristics of a stream, such as the shape of the channel, the size and shape of the bed, and the amount of sediment.
• Macro-invertebrates—organisms such as insects, crustaceans, and molluscs found in water bodies.
• Aquatic vegetation—plants that grow in or near water bodies, such as algae, mosses, and reeds.
• Stream health—a measure of the overall health of a stream, including water quality, habitat, and biological integrity.
• Riparian rehabilitation—projects that involve restoring or enhancing the condition of riparian areas, such as adding vegetation or improving water quality.

Figure 1. Results from discriminant analysis using biological, flow, temperature, and conductivity data from 2015 to 2017 show significant differences between the five sub-reaches of Alston Creek. The first two discriminant axes explained 95% of the variance. The patterns of the four standardized water quality parameters used in the analysis.
Farm Adaptation Innovator Program
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Social Costs and Benefits of a Group Environmental Farm Plan: Alderson Creek, BC

John Janmar, Julian Piccini, and Alex Cebry

Purpose
Public funds are sometimes available to rural land owners to offset costs for environmental projects. This can be justified if the value society gains from these projects exceeds the cost. The costs are often easy to measure. However, benefits, such as enhanced habitat quality, improved water quality, better drainage during extreme weather events, and aesthetic improvements are more difficult to attach a monetary value too. This project’s purpose is to estimate monetary values for the costs and benefits of the planned works in the Alderson Creek Group Environmental Farm Plan (GEFP).

Geographic Applicability
Alderson Creek drains a small watershed of Armstrong, BC. Specific results apply only to Alderson Creek. Results are applicable in similar situations elsewhere in BC and throughout the world.

Community Reference
Methods and results are applicable to any area where agricultural activities have environmental impacts.

Timeline
2012-2016

Climate Change Adaptation Implications
Stream rehabilitation projects, such as the Alderson Creek project, can mitigate the impacts of extreme weather events, provide some carbon storage and offer habitat, which is necessary as natural species respond to climate change.

The full benefit of such mitigation projects may be much larger than those enjoyed by the participating owners. Accounting for these additional benefits can strengthen the economic case for supporting such projects.

Limitations
The results (Figure 1) are specific to this project, limiting their general application. The lack of many comparable studies results in imprecise NPV estimates.

Some impacts, such as increasing social connections between neighbours and changes in attitudes and knowledge, have not been included in a monetary value. These may be more important.

Definitions
Willingsness to pay (WTP): The maximum amount a person or household would pay for one more unit of a good or service.

Discounting: Expressing future costs and benefits in current (present value) terms, usually as compound interest.

Net Present Value: Sum of the present value of all costs and benefits of the project.

Next steps
Small scale environmental projects, such as those proposed in the Alderson Creek Group EFP, will be critical to climate adaptation efforts in agriculture. There is little current work about how the societal benefits from such projects relate to their spatial distribution. Economic valuation research should address this gap.

Few research results exist to help funders of small environmental projects with climate adaptation strategies for evaluating the economic return from their funding decisions. The usefulness of economic criteria for improving their choices could be enhanced through working with researchers on this topic.

For more information:
More information about the British Columbia Agriculture and Food Climate Action Initiative can be found at this link: [http://www.bcagriclimateaction.org](http://www.bcagriclimateaction.org)

Follow these links for additional information on related topics:
* Economic valuation methods and applications [http://www.ecosystemvaluation.org](http://www.ecosystemvaluation.org)
* Database of economic valuation studies [http://www.eva.net](http://www.eva.net)

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Climate change adaptation: What does it mean to the small landowner?
Bernard Bauer, Nargis Rahemtulla, Hezilkel Richardson, and John Janmaat

Farm Adaptation Innovation Program
Research Factsheet

Purpose
The impacts of climate change (e.g., rising temperatures, severe droughts, intense storms, floods) are being felt across the world, which has led federal and regional governments to recommend and encourage the implementation of adaptation strategies intended to minimize the negative consequences of increasingly variable weather patterns. The purpose of this study was to determine the general awareness among owners/operators of small landholdings about climate change and how it may impact their operations. Without detailed awareness it is unlikely that adaptation strategies can be successfully implemented.

Methods
A 20-item questionnaire was distributed to landowners on the Alderson Creek watershed and adjacent sub-watershed (Blenheim Creek). The questionnaire was specifically designed to reflect the knowledge and experience of the participants' background.

(1) climate change awareness
(2) the regional and local consequences of climate change
(3) the current and future implications for the farm operations

Open-ended questions were included to determine whether landowners were taking action that could affect their future security and mitigate the impact of climate change.

The questionnaire is a small component of a larger project examining the socio-economic and bio-physical effects of climate change, both as an adaptation strategy.

Key Findings
- Landowners have a strong sense of what climate change means and its potential implications.
- On the BC questionnaire, the survey dealt with general knowledge about climate change, awareness of climate change, the effect of climate change, the adaptation to climate change, and the actions and steps taken to mitigate the impact of climate change.

Study Objectives
- Assess state of knowledge about climate change within a community of small landowners on Alderson Creek (Almaating, BC)
- Determine whether adaptation strategies have been or will be undertaken to mitigate future impacts of climate change at the scale of a small farm or ranch
- Identify barriers faced by small landowners in meeting the challenges of climate change (e.g., financial, practical, conceptual)

Implications for Climate Change Adaptation on Small Farms
- There appears to be a disconnect between:
  i. the general awareness among owners/operators that climate change is an urgent and pressing issue globally, and
  ii. an appreciation that there is likely to be regional impacts that may require implementation of adaptation strategies at the scale of the local farm
- Owners/operators of small landholdings often do not understand how global climate change might affect their region and their farm or ranch. This suggests more work needs to be done in down-scaling the results of global climate models so as to reduce the uncertainty about future weather patterns in specific locations.
- Without certain knowledge about future weather patterns (e.g., tendencies toward hotter/cooler or wetter/drier conditions), it is unlikely that any sort of adaptive strategy will seem necessary. Instead, coping mechanisms based on current conditions will dominate near-term planning.
- Many owners/operators of small landholdings have additional sources of income and are not completely dependent on farm receipts. Decisions about investments for future ‘competitiveness’ in a changing market are not a priority relative to immediate challenges that arise from day-to-day operations. Bureaucrat and knowledge are important to motivate adaptation to climate change.

Future Work
The questionnaire should be distributed to a larger, more representative sample of producers so as to get more robust results that can be used to inform government policies.

Funding and support for this project were provided by:

For more information:
regarding agricultural adaptation in BC see:
http://www.bcagriadaptaction.ca/

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Growing Forward 2
Canada
Barriers and opportunities for riparian rehabilitation via collaborative co-management
Nargis Rahimova¹, John Jernimann², and Bernard Bauer³

Farm Adaptation Innovator Program
Research Factsheet

Purpose
Ecosystem-based adaptation encourages sustainable management and restoration of natural ecosystems as a proactive mechanism for mitigating future impacts of climate change. A riparian restoration project in the Alkali Creek watershed near Armstrong, BC was implemented by a group of landowners via the Group Environmental Farm Plan (GEFP) program. The restoration was undertaken to address ongoing water-related issues while also enhancing the health and resilience of the system. The purpose of this study was to identify and examine the barriers and opportunities to collaborative environmental decision-making and collaborative action by small groups of agricultural landowners.

Study Objectives
• To understand what motivated landowners in Alkali Creek to work together on a GEFP.
• To observe how knowledge and attitudes changed, and how their relationship with each other evolved as a consequence of the project.
• To understand the impact of external controls (e.g., regulations) on the successful implementation of the project.

Key Findings
• Landowners are likely to engage in ecological restoration if there is a direct or perceived benefit to each landholder from the restoration effort – benefits can vary in size and nature.
• Potential for involvement and collaboration is greater if the process is facilitated by local (independent) restoration practitioners who are fully engaged and knowledgeable.
• Provision of environmental benefits alone may or may not trigger participation in a restoration effort. However, provision of environmental co-benefits is often required by funding agencies.
• Shared natural resources (such as streams running through several adjacent farms) tend to connect people due to the interdependence of people and their environment.
• Regulatory controls can be essential for triggering action but successful outcomes depend on good will, adequate resourcing, and enforcement.
• Institutional barriers may frustrate efforts and prevent projects from being completed in a timely fashion. Issues resulting from lack of inter-agency coordination, recent changes in regulatory environments, and communication gaps are perceived as impediments by landowners wishing to implement EMIs.
• Landowners are usually interested in pragmatic solutions to immediate issues (e.g., poor drainage, adequate water supply) rather than long-term environmental planning.
• Focused education efforts can help raise awareness about climate change and the role of ecosystem-based adaptation. Education sessions should provide opportunities for sharing experiences from similar collaborative projects to improve the chances for success.

Methods
• Two groups of landowners were involved in the study: (1) six landowners participating in GEFP, and (2) five landowners in the neighboring sub-basin.
• Paper surveys were used to gather and compare (1) knowledge about climate change and local impacts; (2) knowledge about ecosystems services and their role in climate regulation; and (3) environmental attitudes.
• Open-ended interviews with landowners and restoration practitioners were conducted.

Climate Adaptation Implications
• Adaptation is not necessarily triggered by local climate change observations. Adaptation takes place in response to emerging or prominent issues (social, regulatory and ecological) which adapting individuals do not necessarily relate to climate change.
• Lack of awareness might be a potential obstacle to implementing ecosystem-based adaptation approaches unless damage on private lands can be resolved by resolving natural ecosystems. Landowners need to be convinced that restoring natural ecosystems can help resolve problems on their land.

Limitations
The conclusions of this study are based on the results from interviews with the landowners and restoration practitioners involved in the Alkali Creek project. Implementing a similar study with landowners in other sub-basins could broaden the perspectives and enhance the understanding of opportunities and potential barriers.

Next steps
As a part of a knowledge sharing initiative, implement focus group discussions with study participants, restoration practitioners, and representatives from local governments. A study involving respective government agencies and restoration practitioners needs to be conducted to examine potentials for streamlining the administrative burden.

For more information:
Information regarding agricultural adoption in BC may be found at: http://www.bcoepadaptation.ca/

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